Souvenir

International Seminar on Exotic and Underutilized Horticultural Crops: Priorities & Emerging Trends

October 17-19, 2023

ICAR-IIHR, Hesaraghatta Lake Post,
Bengaluru-560089

Supported by:

Organized by

Indian Council of Agricultural Research (ICAR), New Delhi, India
ICAR-Indian Institute of Horticultural Research, Bengaluru, India
Society for Promotion of Horticulture, ICAR-IIHR, Bengaluru, India

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ICAR-Indian Institute of Horticultural Research
Hesaraghatta Lake Post, Bengaluru-560089, Karnataka, India
Tel. No. : +91-80-23086100
E mail : Director.IIHR@icar.gov.in
website : http://www.iihr.res.in

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Director

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M. Sankaran	Rajiv Kumar	S. A. Safeena	Sujatha A. Nair
G. Karunakaran	Raja Shankar	T. H. Singh	C. Kanupriya
Anuradha Sane	B. R. Raghu	Sridhar Gutam	Vivek Hegde
			S. Sujatha

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Dr. S. K. Singh
Director
ICAR- Indian Institute of Horticultural Research
Hessaraghatta Lake (Post), Bengaluru-560 089

Preface

It is with great pleasure and enthusiasm that I extend my warmest greetings to all participants, distinguished guests, and fellow enthusiasts of horticulture. As the Director of ICAR-IIHR, Bengaluru, I am delighted to introduce the **International Seminar on Exotic and Underutilized Horticultural Crops: Priorities and Trends**, scheduled to take place from October 17 to 19, 2023.

Allow me to commence by illuminating the pivotal role of horticulture in our nation's agricultural landscape. India stands as one of the world's foremost producers of fruits, vegetables, and spices. In the 2020-21 fiscal year, India achieved a remarkable total horticultural production of 331 million metric tons, with fruits and vegetables contributing substantially to this impressive figure. These statistics underscore the undeniable significance of horticulture in our country, both in terms of its vast production capacity and its potential for growth.

Horticulture has been a vital component of agriculture, addressing the growing need for nutritious and diversified food sources, contributing to the economic well-being of nations, and promoting a sustainable environment. The potential of horticulture in addressing food security and livelihoods cannot be overstated. However, our field continues to evolve, and we find ourselves in a transformative era where traditional crops are being complemented, and sometimes even replaced, by exotic and underutilized horticultural crops. This shift is driven by changing consumer preferences, the need for crop diversification, and the increasing importance of niche markets.

As horticultural enthusiasts and practitioners, it is imperative that we stay ahead of the curve. The primary inspiration for this international seminar stems from the desire to bring together experts, researchers, and stakeholders to delve into the priorities and emerging trends in the domain of exotic and underutilized horticultural crops. Our aim is to foster dialogue, share knowledge, and forge collaborations that will enable us to harness the full potential of these crops and pave the way for their commercial success and sustainable production. The seminar will provide a platform for in-depth discussions on a wide range of topics, including breeding and cultivation techniques, post-harvest management, marketing strategies, and policy implications. Our distinguished panel of speakers and contributors will share their insights and experiences, providing a comprehensive overview of the current state of exotic and underutilized horticultural crops.

Bengaluru, often referred to as the ‘Garden City of India,’ is a fitting location for this seminar. The city’s rich horticultural heritage and vibrant agricultural research community make it an ideal setting for the exchange of ideas and the exploration of new horticultural frontiers. I look forward to engaging in lively discussions, sharing valuable experiences, and fostering collaboration during this three-day seminar. Let us collectively explore and unlock the immense potential of exotic and underutilized horticultural crops, thereby contributing to global food security, economic prosperity, and environmental sustainability.

I extend my sincere gratitude to all the participants, organizers, sponsors, and partners who have made this event possible. Together, let us embark on a journey towards a more diverse and prosperous horticultural landscape.

(Sanjay Kumar Singh)

ಥಾವರ್‌ಚಂದ್ ಗೆಹ್ಲೋಟ್
थावरचंद गेहलोत
Thaawarchand Gehlot

ರಾಜ್ಯಪಾಲರು, ಕರ್ನಾಟಕ
राज्यपाल, कर्नाटक
Governor of Karnataka

No: GS 357 MSG 2023

MESSAGE

I am happy to know that ICAR-Indian Institute of Horticultural Research, Bengaluru is organizing an International Seminar on "***Exotic and Underutilized Horticultural Crops: Priorities and Emerging Trends***" from 17th to 19th October, 2023 at ICAR-IIHR, Bengaluru and has proposed to bring out a Souvenir to commemorate the said occasion.

I extend my warm and heartfelt greetings to the organizers, participants and the Editorial team a grand success of the event.

14-10-23

(**Thaawarchand Gehlot**)

Sri Sanjay Kumar Singh,
Director,
ICAR Indian Institute of Horticultural Research,
Hesaraghatta Lake Post,
Bengaluru-560089

शोभा करांदलाजे
SHOBHA KARANDLAJE

राज्य मंत्री
कृषि एवं किसान कल्याण
भारत सरकार
Minister of State For
Agriculture & Farmers Welfare
Government of India

D.O. No.................MOS(A&FW)/VIP/2022-23/

MESSAGE

Horticulture, which includes fruits, vegetables, flowers, tuber crops, spices, medicinal and aromatic plants, is a priority area for diversification in Indian Agriculture and improving economic condition of farmers and entrepreneurs. Fighting against poverty has become the overriding priority in the new millennium. Our agricultural scientists and technologists have to work for doubling the productivity of the shrinking available land under cultivation.

It gives me immense pleasure to know that ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru, is organizing 'International Seminar on Exotic and Underutilized Horticultural Crops: Priorities & Emerging Trends' from October 17-19, 2023. I hope the issues pertaining to various aspects of exotic and underutilized horticultural crops and their dissemination will be deliberated and discussed during the Seminar in order to bring specific recommendations for the benefit of the farmers. This seminar will serve as a platform to foster international collaborations and advancements in horticulture research and development especially on the exotic and underutilized horticultural crops.

I hope that the outcome of the seminar will help in developing strategies and an action-oriented road map to promote sustainable and profitable horticulture with special emphasis on exotic and underutilized horticultural crops.

I congratulate the organisers and wish the Seminar a grand success.

Shobhakarandlaje

(Shobha Karandalje)

Delhi Office : Room No. 322, 'A' Wing, Krishi Bhawan, Dr. Rajendra Prasad Road, New Delhi-110 001
Tel. : +91-11-23383975/76 **Fax** : +91-11-23383971, **E-mail** : mos.shobha.agri@gmail.com
Residence : 101, Narmada Apartments, Dr. B. D. Marg, New Delhi-110 001

डॉ. हिमांशु पाठक
Dr. Himanshu Pathak
सचिव (डेयर) एवं महानिदेशक (आईसीएआर)
Secretary (DARE) &
Director General (ICAR)

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली–110 001

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH AND EDUCATION (DARE)
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR)
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
Krishi Bhavan, New Delhi 110 001
Tel: 23382629 / 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

Message

I am happy to know that ICAR-IIHR is organizing the '**International Seminar on Exotic and Underutilized Horticultural Crops: Priorities & Emerging Trends'**, October 17-19, 2023, at ICAR-IIHR, Bengaluru, to highlight the importance of Horticultural Crops for widening the food basket, doubling the farmers' income and enriching nutritional security.

Horticulture is one of the major contributors to the substantial progress made in nutritional security in India. In recent years, horticulture sector has become a driving force for economic growth of the country. This sector can provide an opportunity for the much-needed crop diversification and intensification in 80% of the small and marginal land holdings. Besides there are several underutilized horticultural crops that remain neglected, and are yet to be exploited for their potential. The demand for horticultural produce has increased due to greater health awareness, rising income, export demands and increasing population. Indian Horticulture sector contributes a significant 33% to the agriculture Gross Value Addition (GVA), ensuring nutritional security, providing employment opportunities and enhanced income to farmers. India ranks second in fruits and vegetable production in the world. In 2022-23, India exported fresh fruits and vegetables worth Rs. 13185.30 crores/ USD 1635.95 million. The India Greenhouse Horticulture market is expected to register a growth rate of 4.19% by 2030.The horticulture production must look for sustainable use of the available diversity in the exotic and neglected underutilized horticultural crops. However, the issue of climate change has thrown up uncertainties and risks, imposing constraints on production systems.

I hope the seminar will provide an opportunity to researchers, teachers, students, extension workers, policy makers, traders and entrepreneurs to formulate strategies to achieve nutritional security and better environmental sustainability, and to draw a road map for increasing productivity and profitability under new emerging exotic and underutilized horticultural crops.

I wish International Seminar a grand success.

(Himanshu Pathak)

11th October, 2023
New Delhi

डॉ. तिलक राज शर्मा
उप महानिदेशक (बागवानी विज्ञान)

Dr. T. R. Sharma
FNA, FNAAS, FNASc, FASc, JC Bose National Fellow
Deputy Director General (Horticultural Science)

भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन - II,
पूसा, नई दिल्ली - 110 012
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-II
PUSA, NEW DELHI-110 012(INDIA)

Message

The importance of horticultural crops *viz.*, fruits, vegetables, ornamentals, medicinal crops and mushrooms, in improving the food, nutritional, health and livelihood security and the country's economy cannot be emphasised enough. Growth and development in horticulture and allied sectors has enabled us to achieve self-reliance in food security with a reasonable degree of resilience even in times of natural calamities. Further, the growing population is demanding exotic horticultural commodities. Also, there is a huge scope for mainstreaming of different nutraceutically superior underutilized horticultural crops. These changes demand new strategic planning for growing research, development, extension, value chain, expert promotion, etc.

The scientific and technological inputs have been the major drivers for sustainable growth of horticulture. As a result of innovative research, technological and policy initiatives and inputs, horticulture in India has become a sustainable and viable option for the small and marginal farmers today. Besides, this sector has also started attracting entrepreneurs for commercial ventures. As such, there is immense scope for horticulture sector to grow and flourish.

It is a pleasure to see that Indian Institute of Horticultural Research (IIHR), Bengaluru, a premier institute of the Indian Council of Agricultural Research (ICAR) is organizing the International Seminar on **"Exotic and Underutilized Horticultural Crops: Priorities & Emerging Trends"**, from **17th-19th October, 2023**, for the benefit of growers, horticulturists and other stakeholders.

I wish ICAR-IIHR all success in the conduct of this seminar.

(T.R. Sharma)

ಕರ್ನಾಟಕ ಸರ್ಕಾರ
ತೋಟಗಾರಿಕೆ ಇಲಾಖೆ

Government of Karnataka
Department of Horticulture

ರಮೇಶ್ ಡಿ. ಎಸ್., ಭಾ.ಆ.ಸೇ.
ನಿರ್ದೇಶಕರು

Ramesh D.S., I.A.S.
Director

MESSAGE

Horticulture plays a pivotal role in Karnataka's agricultural sector and it is essential to explore the potential of exotic and underutilized crops to diversify and enhance our horticultural production. Your initiative in bringing together experts, researchers, and stakeholders from across the globe to deliberate on these crops' priorities and trends is commendable. The seminar's thematic focus aligns perfectly with our vision to promote sustainable horticultural practices, improve crop diversity, and address the challenges of food security and climate change.

I am delighted to extend my warmest congratulations to you and your esteemed institution, the Indian Council of Agricultural Research - Indian Institute of Horticultural Research (ICAR-IIHR), for successfully organizing the International Seminar on **Exotic and Underutilized Horticultural Crops: Priorities and Trends** scheduled from 17th to 19th October 2023.

This significant event promises to be a milestone in the field of horticulture research. I am confident that this seminar will foster valuable discussions, lead to innovative solutions, and pave the way for collaborations that will benefit not only Karnataka but also the entire horticultural community. The insights gained from this event will undoubtedly contribute to the growth of our horticultural industry and help us address the evolving needs of our farmers and consumers. I would like to express my appreciation to you and your team for your dedicated efforts in organizing this seminar. I encourage all participants to engage actively in the discussions and make the most of this unique opportunity to share their knowledge and experiences.

Once again, congratulations on this remarkable initiative. I look forward to the fruitful deliberations and outcomes of the International Seminar on Exotic and Underutilized Horticultural Crops.

[RAMESH.D.S] I.A.S.,
Director of Horticulture

ಲಾಲ್‌ಬಾಗ್, ಬೆಂಗಳೂರು-560004.
ದೂ.: 080-26571925
Website: horticulturedir.karnataka.gov.in

Lalbagh, Bengaluru-560004.
Ph. No. 080-26571925
Email: horticulturedirector@gmail.com

Plant a tree, plant a new life...

Dr. J. C. Rana
National Project Coordinator,
UN Environment-GEF Project Management Unit,
Alliance of Bioversity International and CIAT - India Office

MESSAGE

At Bioversity International, we are acutely aware of the importance of exploring and harnessing the potential of exotic and underutilized horticultural crops. These crops often hold hidden treasures of biodiversity that can contribute significantly to food security, nutrition, and sustainable agricultural practices.

The initiative by Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru in convening this international seminar on **Exotic and Underutilized Horticultural Crops: Priorities and Trends**from 17th to 19th October 2023 is a testament to the institute's commitment to advancing the frontiers of horticultural science and promoting biodiversity conservation. It provides an invaluable platform for experts, researchers, and practitioners to come together, exchange ideas, and chart a course for the future of horticultural research. The themes of this seminar are particularly timely, as they address the global challenges of diversifying agricultural production, enhancing resilience, and responding to the changing climate. By facilitating discussions on priorities and trends in this area, ICAR-IIHR is contributing to the broader mission of ensuring a more sustainable and nutritious food system.

I am confident that this event will yield important insights, foster collaborations, and lead to innovative solutions that will benefit not only the Indian horticultural community but also the broader international community. The work being done by ICAR-IIHR aligns closely with the goals and aspirations of organizations like Bioversity International, and I am excited to see the positive outcomes that will emerge from this seminar.

Wishing you a successful and enlightening seminar!

J. C. Rana

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1. Ecology, Agrobiodiversity, Ecosystem Services and Underutilized Crops

N. K. Krishna Kumar
Former Deputy Director General (Horticultural Sciences.)
ICAR, New Delhi - 110012

The increased yield from cultivated land aided in the release of marginal lands out of agricultural production into providing alternative ecosystem services, such as the regeneration of forest cover (Millennium Ecosystem Assessment (2005)). However, the environmental effects of the high input technology have been recognized as a potential threat to the long-term sustainability some of the negative consequences of green revolution technology are high water use, soil degradation, and chemical runoff (Further, the yield trends of all the major crops indicate that the yield growth has slowed down since the mid-1980s. In fact the father of Green Revolution, Dr Norman Borlaug himself warned that research to develop HYV and its corresponding technologies is not the solution to the world's nutrition problem but it has only delayed the crisis for another 30 years (Borlaug, 1971). The edifice of life on earth depends on biodiversity equilibrium; ecosystem services a necessary prerequisite to realize the objectives of sustainable development goal (SDG) in this millennium.

Presently malnutrition, climate change, land degradation and Biodiversity loss are the major challenges and that poor dietary diversity is the number 1 health risk. Global food production is the largest driver of environmental degradation and biodiversity loss. 2 billion people lack key micronutrients and an equal number are obese and nearly 155 million children are stunted. Climate change, land use change, fresh water use, nitrogen cycling, phosphorus cycling and biodiversity loss are some major challenges. Restricting our food basket to 4-8 crops among more than 2000 renders all the others under-utilized. Thus, but for rice, wheat, maize, potato and a few others all other crops are underutilized. Even among these major food crops diversity has shrunk and only selected varieties and hybrids dominate. A classical case is in banana where Grand Naine dominates 60% of its area under cultivation. Diversity is the essence of life and our security to life. Thus, a meeting was organized at the request of The Indian Council of Agricultural Research for understanding the concept of Agrobiodiversity Index & Ecosystem Services and preparing a work plan for initiating studies on it in the Indian context. The meeting was attended by 66 participants representing 10 ICAR and Govt of India institutes, 2 SAUs, besides the Bioversity International staff including four from abroad.

Agriculture biodiversity (ABD) is a key component of biodiversity. ABD is also the foundation of sustainable agriculture. Therefore, measurement of agrobiodiversity is a priority. Productivity increase during the green revolution period was brought about by replacing traditional varieties by high yielding varieties. The diversity of the food basket has reduced to mere 12 crops. However, the traditional varieties were conserved in both in situ and ex situ and now is the time to evaluate them and use their beneficial traits to address some of the problems that have now emerged. He said we have to take stock of what is the genetic resource and what goes up to the market for consumption. He also emphasized the need for giving high priority to crop wild relatives and that its utilization should have clear focus.

Ecosystem encompasses a whole range of layers of soil fauna, flora etc., but data availability is a big issue. He said that we have to keep in mind that ABD is only a subset of biodiversity. Furthermore, while we quantify the contributions of ABD to agriculture, one must include landscape level processes and also consider both direct and indirect role of biodiversity on agrobiodiversity. ABD is important for food and nutritional security but we must first understand ABDI since at the moment the concept is not fully clear. India-centric algorithms must be included in the estimation of ABD and ABDI must be able to differentiate different ecosystems.

ABDI

(i) Must be able to advise/guide/monitor developmental activities such as introduction or population of a new species of food and nutritional value;

(ii) Must be able to measure the sustainability of agricultural ecosystems like Rice-Rice agro-ecosystem;

(iii) Must guide reintroduction of cultivars gone out of cultivation;

(iv) Must be able to guide ongoing efforts by farmers and locals in ABD conservation and use

(v) Be able to advice on the seed system etc.

Further,

- ABDI Measures – Commitment, Action and Status of indicators to promote diversity in Diet, Production, Genetic Resources.
- The development of ABDI involved multiple stake holders viz. investors, private companies, knowledge and data partners, governments and inter-govt, civil society and conservation groups
- The design of ABDI is such that it is evidence based, focused on contribution, transparent, iterative, independent, and responsive.
- It has a wide range of applications like assessment of risk, planning intervention and leverage investment.

But any interpretation is as strong as the data. Database used in the calculation should reflect the actual situation. For the sake of comparison across countries some country specific information is ignored but may be critical to that region or country. Often, Shannon index to calculate the diversity may not be appropriate since it takes only total numbers into consideration and not diversity of species. Diversity should encompass both numerical and functional diversity. In a disturbed ecosystem there may be a need to focus on functional diversity but in the long run it should lead to a balanced equilibrium of numerical diversity that leads to sustainability. In the case of forests, different indicators are used for global studies and different indicators for national level studies. We can explore a similar strategy for ABDI. Dietary diversity is not reflective of the actual situation as in countries like India he variability is humongous. In most cases, pollination data is often not reported. Thus, availability of reliable data is a major concern for wide adoption of ABDI.

Soil Biodiversity and its Relation to Sustainable Agriculture depend on Agriculturally Important Microorganisms. Living Biota encompassed Soil Bacteria, fungi, actinomycetes, cyanobacteria, ants, collembella, termites, root herbivory insects, protozoa, nematodes, mites, lichens and their role in the functional diversity of the soil system is critical. The keystone taxa may be a good index of microbial biodiversity. Similarly, habitat management for exploiting pest regulation through biocontrol is not a numerical but a functional response but also particular traits contributed by various species to ecosystem health and resilience. Insects contribute significantly to vital ecological functions such as pollination, pest control, decomposition etc. But it should be noted that

He said that Agriculture as an enterprise is diverse as well as complex and we must understand ABD and define ABD before it can be used.

We need to clearly define the summations and variables. Of the three “pillars” of ABD, Status deals with “abiotic” factors while actions and commitment reflect “policy” issues. It would be better to separate the pillars dealing on policy from the pillars on status. There is need to give weightage to different indicators and that there should well defined rationale for giving weightage. As regards methodology “variance” should be included in the calculations and the issue of granularity of the spatial data capture, relevance of the diversity indices and whether Avalanche index would be better need discussion.

But ABD must not be considered as the end, but as means to achieve the goal. Consequently, ABDI is not an index of ABD status but an indicator for policy making. ABDI should be consciously kept simple since complexity leads to policy inaction. A simple index triggers policy decision.

The current ABDI developed by BI has the gap by not considering “livelihood” and other uses of ABD and ABDI doesn’t measure ecosystem services per se. India can be a testing point the validity of employing advanced satellite imagery-based data for ABDI.

Action points

1. Need to Bring out a compiled document based on ABD and ESS/LSM meeting
2. A draft proforma to be developed to provide information regarding challenges and opportunities in their target landscapes.
3. One or two landscapes to be selected for piloting ESS/LSM studies in India.
4. A comprehensive list of data sources to be developed for country specific ABDI study.
5. Current list of indicators to be scrutinized and additions if required made.
6. Pilot ABDI estimation for a state/country as a whole.

   The natural resources contained in forests inclusive of trees, natural vegetation, vegetation, medicinal plants, honeybees, rivers, innumerable vertebrates and invertebrates, fishes, parasitoids and predators of insects supporting biological pest regulation, beneficial microbes, pollinators etc., are considered as its “ecological capital”. It is also called as the “natural capital”. Human beings derive benefits directly or indirectly from the ecological capital and these benefits derived are called the ecosystem services. Hence, ecosystem services are defined as those aspects of ecosystems utilized (actively or passively) to produce human well-being.” Some of the benefits include climate regulation, flood mitigation, and landscape amenity, clean air, pollination, pure drinking water etc.

7. The main categories of ecosystem services are provisioning services (nutrition, materials, and energy), regulating services (regulation wastes, flow and physical and biotic environment), cultural services and supporting services. Forest is a natural ecosystem since it maintains equilibrium and sustains it through natural process. So too are the ocean and deserts. Small disturbances do not impact the equilibrium and resilience is inbuilt through natural processes.
8. The InVEST (Integrated Valuation of Ecosystem Services and Trade off) model is being used to quantify some of the ecosystem services from different land use classes. Some of the ecosystem services studied is Sediment Delivery Ratio, Nutrient Delivery Ratio, Biomass, Carbon Sequestration, pollination, natural pest control, dispersal of seeds etc. The quantitative assessment of ecosystem

services would enable designing management strategies which would enable harnessing the natural resources sustainably. It would also enable designing payment for ecosystem services to support the stake holders for their effort in promoting ES.

9. Understanding Biodiversity and ES in a scientific way is critical for effective policy management decisions. Biodiversity can be numerical or functional. Simply stated the mere presence or absence of a species or the numerical strength or their role in stabilizing the ecosystem is critical in taking decisions. For example, while conservations of tigers are of paramount importance (especially as they are at the top of the food chain), one should not forget a million other species which are equally important to maintain the equilibrium. Some of them may be critical in stabilizing the system or may functionally critical.

10. Recently there is a lot of concern on pollination and sustainable development. A major concern has been the use of neo-nicotinoids. Equally indiscriminate deforestation, human intrusion into the forest is responsible especially in the tropics. About 94% of all tropical wild flowering plants are animal pollinated (Ollerton, Winfree, & Tarrant, 2011) and more than 75% of global food crops benefit from (dependence ranging from 1-100% for fruit or seed set) animal pollination(Klein et al., 2007). Wild and crop plants benefit from wild and managed pollinators, and thus are imperative in retention of biodiversity and associated ecosystem services in addition to securing food security. Wild pollinators are heavily dependent on forests for nesting and forage resources. Despite a documented decline in pollinators and negative effects on their role in maintaining biodiversity (directly and indirectly) and food security, little emphasis has been placed on understanding the importance of forest in maintaining wild pollinators. Among pollinators, bees (20,000 species- most are pollinators) are the most frequent flower visitors, followed by flies, butterflies and moths (Winfree, Williams, Dushoff, & Kremen, 2007)Among pollinators, bees (20,000 species- most are pollinators) are the most frequent flower visitors, followed by flies, butterflies and moths. A study conducted in Kodagu coffee landscapes within the Western Ghats biodiversity hotspot reveals that bees contribute to 33% of the total coffee production and wild bees (Apis dorsata) are the main pollinators (58% of the total visitors) of coffee which primarily nest in remnant forests called sacred groves. Forest fragments appear to be necessary for the persistence of Apis dorsata, the main coffee pollinator.

11. Existence of a wide spectrum of habitats, from tropical rainforests, arid to semi-arid vegetation, to coastal wetlands has endowed our country with rich diversity of forms. The varied ecological niches are a treasure trove of crop diversity. In the agrarian context, diversity of forms, species and ecosystems has contributed immensely to the productivity of agriculture, forestry, fisheries and industry. Today, population explosion, monoculture, human interferences leading to ecosystem destruction, lack of greater awareness of genetic wealth and importance of conservation, social changes and changing climate are slowly eroding the diversity of forms in many crops. The varietal cafeteria in various indigenous crops like eggplant, okra, cucumber, melons, bitter gourd, etc. are found to possess a lower genetic variance in comparison to their wild progenitor populations, as they have been developed from a limited number of ancestral populations. Such narrowing of genetic variance limits the potential of cultivars to combat the threat of new pests, pathogens, changing environments and demand of specific quality preferring segments. Addressing these issues could be made easier if the voluminous genetic variation in the crop wild relatives/ progenitor populations become accessible to breeders in a readily transferable form for utilization in their breeding programs. Most CWR are

found in forests and evolve to abiotic and biotic stress through natural selection. Depletion of forests is depletion of valuable CWR which are our future investment for crop improvement and resistance breeding.

12. What is true for CWR is true for medicinal plants. Most of the raw material for traditional medicines have their homes in forests and scattered. Furthermore, ITK associated with the use of these medicinal plants is with the tribal community inhabiting the forest. Shrinking forests robs the next generation of not just the source but the associated knowledge as well.

13. Increased urbanization, shrinking forests and more so the diversity has increased the Man-animal Conflict. The problem is exponentially increasing and there is no silver bullet in mitigation except understanding the ecology through diversification and landscape management. Elephants, monkeys, wild boars, many reptiles, insects, predators, birds etc., are migrating to human habitat in search of food and water. This is a clear indication of declining sustainability. The answer is not just planting more trees but in understanding the food preferences, nesting sites, shade etc. which are so essential for survival of plants and animals in wild.

14. Forests by their very nature are both a source and sink. There is constant destruction of the old and birth of young in a natural equilibrium. Nothing is better manifested better in pest and disease regulation of the vegetation in the wild. Any drastic disturbance in the ecological balance, the spill over is visible in the adjoining agriculture landscape. Today, we are witness the increased incidence of stem borers (Cerambicidae, Buprestidae, Scolytidae etc.,) on coffee, cashew, Sal, sandal, mango, citrus, jack etc.,). One of the primary reasons is the destruction of the natural habitat of these insects. Reduced diversity has contributed to increased incidence on commercial trees.

15. Neglected and underutilized crops species and trees are a source of food, fibber and nutritional security to the marginalize section of the society. Most of these are naturally resistant to abiotic and biotic stress. Many such species have declined, and our food basket has shrunk to select few cereals, vegetables and fruits. Many have therapeutic value. Some are rich in anti-oxidants.

16. In short Biodiversity nourishes life and sustains the planet. Our management practices and policy options to use and safe guard tree biodiversity should lead to attain sustainable global food and nutrition security, reduce poverty, provide livelihood security and above all contribute to mitigate the negative impact of climate change.

Diversity Bugs Pests: An Ecological Perspective

Chemicals Pesticides, once a panacea for pest control, of late are at the receiving end for everything that is environmentally unacceptable. Is solution the problem? The paradox cannot be brushed under the carpet.

Problems of insect pests assuming an economic status is predominantly, a reflection of a disturbed ecosystem. Monoculture replacing crop diversity, indiscriminate application of fertilizer and weedicides eliminating beneficial microarthropods and microorganisms, pesticides eliminating beneficial arthropods, predators, parasitoids, reptiles and birds up the food web has all contributed to pests and diseases assuming alarming proportion. In a way Silent Spring, a book so relevant but forgotten very much today, highlights this paradox and the importance of agrobiodiversity. Short term benefit/Cost ratio, maximising economic returns and much focus in enhancing productivity at any cost without addressing long term soil, plant, and environmental health (Agrobiodiversity) is detrimental to sustainable agriculture especially in the developing world. Self-sustaining ecosystems have fewer problems and agriculture should move in that direction.

It appears that we are in between devil and deep sea. We can neither afford to reduce production and productivity nor food and nutritional security. But robust soil, water and plant health is a function of diversity at its best and is critical for sustainable agriculture. An ecological understanding of the complex interactions among, soil, water, plant, pollinators, pest, and natural enemies shall address our sustainable development goals without seriously compromising productivity. Future hinges more on a scientific understanding of agrobiodiversity to address today's bugs.

Here come the scientific use of under-utilized crops and varieties it is said that the more colourful ones plate is the more it is nutritional. Traditionally, our food habits embraced diversity, taking what nature gives us in each region and season and making the best use for addressing the needs of not just us but as well the domestic animals. The classical cultivation of Ragi and dolichos is a classical case of in this direction. Coarse millets, grain legumes, leafy vegetables, medicinal herbs, spices and condiments, locally available vegetables and tuber crops were part of the plate. Slowly, the world is beginning to see wisdom in this and rapidly beginning to adopt. Paradoxically, while the West seems to appreciate this better, our own citizens are far from it. Underutilized food crops interject that component of stability in soil and water balance, while adding nutrition to our diet. Food and nutrition for a long time has been looked from the perspective of human health and needs but once again we need to have a harmonized way of life where animals are part of the agroecosytem and need not depend on expensive animal feed. Most of our problems today associated with Green Revolution are attributed to mono cropping. To an extent the problems associated with Punjab and adjoining states is traced to large scale cultivation of selected few rice and wheat varieties. How to mainstream the native landraces and crops in agrobiodiversity for the future is dependent on how to reduce our conspicuous consumption of food and fibre. While demographic pressures do exist, a policy framework is needed to address the changing kaleidoscope of demography, income, consumption ecology and environment at large. Nothing can contribute to this more than a science-led policy. Certainly when such a policy is in place the role of underutilized crops will find a special mention.

2. Heirlooms in Horticulture – Fascinating History of Conservation

V. A. Parthasarathy
Formerly Director, ICAR-IISR, Kozhikode, Kerala and
National Project Co-ordinator, UNEP-GEF/TFT Project and COGENT (CGIAR)
Email: vapartha@gmail.com

ABSTRACT

Heirlooms are gaining popularity for their unique flavour and quality, and above all, the historical significance. An heirloom plant, variety, or fruit is an old cultivar that is selected, nurtured, and handed down from one family member to another for many generations and growing as individual plants in several orchards of the mango-growing farmers. It is adapted over time to the climate and soil and gives sufficient insurance against catastrophic loss, propagated over the centuries through grafts and budding. Heirloom varieties are often selected for their productivity, their ability to withstand biotic and abiotic stresses. Some of the cultivars may represent the last (small) populations of endangered varieties. The trend of growing heirloom plants in gardens (preferably apple) has been returning in popularity in North America and Europe in recent decades. Earlier, tomato cultivars were selected and inherited in a family or community, thus earning the name heirloom. Heirloom tomato usually has a shorter shelf life, but is generally more disease resistant than most commercial tomatoes, except for specific disease(s), for which a commercial hybrid was bred to be resistant. Heirloom tomato varieties are open-pollinated and are unique in size, shape and colour. Usually only one or two individuals in a community, maintained significant numbers of heirloom varieties and many communities have lost their heirloom vegetable heritage altogether. Many Indian mango growers are maintaining mango varieties in-situ has been proved as heirloom as it has numerous characters that modern cultivars do not have. The identified desired traits of heirloom can be used successfully in future breeding programmes to boost quality mango production throughout the world.

Introduction

The definition of heirloom varies, and the term itself does not carry precise scientific designations. One of the most typical concepts of an heirloom is its non-hybrid, or open-pollinated nature. Heirlooms can be from cross- or self-pollinated species, but if the crop species is cross-pollinated, then the heirloom is considered open-pollinated. Because of this fact, some heirloom cultivars may be quite variable, and it is therefore apparent why heirlooms may not fit well into modern agricultural systems that place great value on uniformity (Dwivedi et al.2019). The conservation of genetic diversity in crop species is also of immense importance to modern plant breeders. Heirloom and landrace varieties along with their wild relatives account for about 6% of the germplasm lines used to breed modern vegetable varieties – a contribution to global agriculture which is measured in the billions of dollars. In addition, small-scale agriculture which relies upon heirloom or landrace varieties accounts for 15–20% of the world's food supply, providing sustenance and cultural value for about 1.4 billion indigenous and peasant farmers (Tuxill, 1999). Plant breeders are constantly looking for new sources of genes, which confer climate adaptation, resistance to pests and diseases and tolerance to abiotic stresses. The greater the range of genes available in a crop plant species, the more secure the future of that crop. Modern resistant cultivars, but also some old, locally adapted cultivars serve as sources of desirable genes (Gustavssona *et al*., 2013).

It is generally accepted that the flavor quality of many fruits has significantly declined over recent decades. While some of this decline can be linked to selection for certain traits, such as firmness and postharvest shelf life, that run counter to good flavor, a major contributing factor has been the challenge of breeding for such a complex quality trait. The foundation for breeding fruits with improved flavor is the incredible genetic and chemical diversity in the reservoir of materials available to breeders of such crops as tomato, melon and strawberry. Deterioration of flavor quality is a relatively recent event and excellent flavor exists today in many 'heirloom' cultivars of mango, apple or tomato. But these cultivars usually fail miserably in large-scale commercial production compared with modern cultivars, since they lack many of the disease resistances of modern varieties and have relatively poor yields. The idea of transferring complex traits controlled by many genes from a poor-yielding variety with good flavour into a modern, high-yielding cultivar would have been impossible even a few years ago. But the combination of genome and transcriptome sequencing, better understanding of the metabolic pathways, and high-throughput molecular marker screening now makes breeding for flavour much more realistic. Stacking of the multiple, independent genes likely to be needed for flavour quality improvement is now technically feasible. It is simply a matter of identifying the appropriate genes and alleles needed (Klee, 2010).

According to Klee (2010), you can choose one dependable, disease-resistant hybrid variety as a fail-safe and take a greater chance on two or three heirlooms each year. Or you can add one of the new hybrids derived from popular heirlooms into the mix. If you're growing tomatoes in containers, it might be wise to choose a dwarf, determinate hybrid variety. A diversity of choices for the garden is as good a thing as diversity in the gene pool. With their often-unusual appearance, surprising flavors and multifarious culinary uses, heirlooms have become the darlings of the horticultural and foodie sets. They have breathed new life into gardening and cookery, encouraging a whole new generation to take up those noble pursuits.

Heirloom varieties

Heirloom varieties are defined as local or regional varieties, passed down from generation to generation of gardeners/farmers, maintained by asexual means, also include old commercial varieties/antiques, presently not grown on commercial scale and limited to few in orchards. Historically, these are important non-commercial varieties that do not limit or restrict to a particular family or community (Bajpai *et al*., 2016). Typically, heirlooms have adapted over time to the climate and soil they have been grown in. Due to their genetics, they are often resistant to local pests, diseases, and extremes of weather. Heirloom fruits have flavors and nutritional benefits, and a longer picking season with early and late ripening.

Landraces and heirloom cultivars are important as documents of the history of agriculture and form part of our bio-cultural heritage, but a loss of such varieties does not necessarily lead to erosion of the genetic diversity of the crop or to the reduction of the diversity in a region (Wouw *et. al.,* 2009). Pre-occupation of the agricultural research sector, mango growers and market sector, which are mainly concerned with few established commercial varieties might overlook and underestimate the potential of heirloom varieties (Rajan *et al*., 2014).

Votava and Bosland (2002) found that the pepper cultivar 'California Wonder' had substantial amounts of genetic variability compared to a standard modern cultivar. They recommended that this cultivar not be used for genetic analysis because of this variability.

Criteria for an heirloom variety/seeds and historical perspectives

Although the loss of on-farm diversity can be lasting, fruit trees have an advantage over annual crops because these trees can live to remarkably old ages, surviving some fads in consumer demand. Single apple trees have been known to live 150 years or longer. In many areas, it is still possible to find trees of 'heirloom' cultivars once abundant at the beginning of the 20th century. Remnant orchards planted before the modern era of fruit production (Jackson, 2003) hang on tenaciously around abandoned farmsteads and historic orchards. Although farmstead trees often persist without their original names being retained, they represent a snapshot of the diversity of fruit varieties available over a century ago during the peak of fruit tree diversification (Routson *et.al*. 2009).

The term ‘‘heirloom'' refers to cultivars introduced during the 19th century and before as opposed to recent introductions developed through modern fruit breeding programs. Seedling trees would not share the same ‘‘heirloom'' status as named 19th century cultivars but may still possess useful traits or local adaptations (Routson *et.al*. 2009).It's said that a variety of heirloom seeds needs to be at least 50 years old to be considered an heirloom. A very old heirloom in the 1500-Year-Old Cave Bean found in a sealed clay pot in a cave in New Mexico, U.S.A.

The majority of heirloom seeds are open pollinated, meaning that they reproduce themselves from seed. The plants from these seeds grow true to that variety. When they are grown, they will be the same as the parent plant. Heirloom Seeds are grown today to keep people in touch with their ancestry. They offer a wide variety of sizes, tastes, colors and shapes, then the hybridized varieties bred to meet the needs of the commercial growers do.

Taylor's Guide to Heirloom Vegetables defines an heirloom as, 1) being at least 50 years old, 2) being an open-pollinator, and 3) having a history of its own (Watson, 1996). But there are several versions of this heirloom classification. All heirloom aficionados agree that an heirloom plant must be an open-pollinating variety. Open-pollinators are pollinated naturally by the wind, birds, and insects and produce seeds true to type that replicate the parent plant.

In Sweden and Finland, as in some other European countries, conservation of apple genetic resources is directed mainly to so-called heirloom cultivars, i.e., old and presumably indigenous cultivars (Nybom and Garkava Gustavsson, 2009). Many of these cultivars have arisen as open-pollinated seedlings and their origin is often unknown. Furthermore, the choice of cultivars for preservation is seldom based on proper genetic analysis, and no attempts are made to maximize genetic diversity (Gustavssona *et al*., 2013).

Domestication of horticultural varieties

Maintenance of heirloom cultivars is a method of *in-situ* conservation. Means, the purported advantages of *ex situ* conservation are the capability of storing a large number of accessions (entries) in a collection, the ready access of the germplasm for characterization, evaluation and distribution, and the secure conservation conditions and *In situ* conservation, in contrast, is promoted because landraces are an essential component of indigenous cultures, it supposedly allows evolution to proceed, its cost is low, and it is the primary form of conservation for wild crop relatives.

The statement that large numbers of accessions can safely be maintained in ex situ collections has to be tempered with the observation that germplasm collections are generally underfunded, the viability of accessions is threatened by lack of timely regeneration, and their utilization is inadequate because of limited characterization and evaluation. The evolutionary potential of *in situ* conservation is limited by the rapidity and magnitude of anthropogenic impacts on our planet, as outlined earlier. However, farmers can manage their genetic resources not only to maintain high levels of diversity in their fields but also to select for essential traits in their particular environment, often by combining diversity from landraces and cultivars. Plant breeding, with its emphasis on elite x elite crosses in the incessant pursuit of higher performance (Kelly et al., 1998) and close adherence to norms imposed by the market, is a strong force in the reduction in genetic diversity. Furthermore, improved cultivars also lead to a reduction in genetic diversity through displacement of native heirloom or landrace cultivars. Paradoxically, plant breeding has been undermining the very genetic basis on which it rests, leading to an overall phenomenon of de-diversification or genetic erosion. Plant breeders have become aware of this situation and have attempted to rectify this situation by broadening the genetic basis of their cultivar gene pool (Gepts, 2006).

World status of Heirloom varieties (Apple and tomato as examples)

Many apple varieties commonly planted in the United States a century ago can no longer be found in today's orchards and nurseries. Abandoned farmsteads and historic orchards harbour considerable agro-biodiversity, but the extent and location of that diversity is poorly understood. Some gardeners believe strongly that the flavor of heirlooms is so superior that no growing season should be wasted on anything else. Others feel it's their responsibility to grow heirlooms in order to preserve diversity in food crops so that we don't lose valuable genetic variation we might need down the road.

An increasingly popular sector of the produce industry is heirloom and ethnic vegetable crops. Heirloom varieties, particularly tomatoes, were traditionally grown in backyard gardens and are becoming more popular with small commercial growers (Grassbaugh, *et.al*. 2004). The different quality and functional attributes in heirloom tomato cultivars have shown a high variability. Nowadays, all these attributes have a growing importance for the consumer. The diversity found in 553 heirloom tomato cultivars could be a rich source of germplasm for quality and functional attributes, therefore the results obtained could be useful for tomato breeders working on the development of new cultivars (Alonso *et. al*., 2011).

Because tomatoes do not naturally out-cross very often, seeds of a tomato produce plants resembling the parent. Due to this property, earlier tomato cultivars were selected and inherited in a family or community, thus earning the name heirloom. Heirloom tomato varieties are open-pollinated and are unique in size, shape and colour (Watson, 1996). Available in varieties with diverse characteristics, heirloom tomatoes tend to be prized for their distinctive flavours. And some gardeners are determined to taste as many different flavors of tomato as they can in a lifetime. But other gardeners are focused on results. They want what they're used to. They place the highest priority on getting a lot of predictable tomatoes just when they expect them with as few problems as possible

There is tremendous heterogeneity for fruit color, size, shape and chemical composition among old, open-pollinated 'heirloom' varieties of tomato. "Heirloom" (traditional) varieties of tomato possess unique or superior fruit quality characteristics and may be useful for the development of new greenhouse tomato cultivars with improved internal quality. Values obtained for TSS, TA, FI and AA demonstrated that many “heirloom” varieties had better organoleptic and nutritional qualities than modern varieties. As considerable variation was found for most traits, some of the materials studied represent sources of variation of great interest for tomato breeding (Rodr-Guez-Burruezo *et. al*., 2005). Heirloom tomatoes (*Solanum lycopersicum* L.) such as ‘*Cuore di Bue*’ are highly appreciated by consumers for their outstanding quality and flavour. Nowadays, they are often grafted onto vigorous rootstocks in order to overcome several soil-borne diseases. Most of the U.S.A. heirloom sweet potato materials were initially developed in several breeding programs around the country and some are still used as parents in current breeding programs.

One of the interesting research was on the heirloom tomato variety “Yellow Stuffer”. Van der Knaap and Tanksley (2003) examined the genetic basis of the unique phenotype of the heirloom tomato cultivar ‘Yellow Stuffer,’ which looks more like a bell pepper than a traditional tomato. Their analysis was based on a segregating population derived from a cross between Yellow Stuffer and a wild species of tomato. They found three quantitative trait loci (QTL) that influenced fruit shape and seven QTL that influenced fruit mass, many of which had already been identified in other tomato mapping research.

Relevance of Heirloom varieties of mango and their conservation in India

Although, *Mangifera* species have originated in South-East Asia, and this region has experienced enormous economic development, natural and wild plantations of mango have been totally or partially destroyed due to the expansion of agriculture to feed the masses or for harvesting precious hardwood. Hence, this has resulted in irreversible genetic erosion of mango genetic resources (Khan *et al*., 2015). Therefore, suitable efforts should be employed for the long term safeguard and conservation of precious mango genetic resources (as heirloom) by utilizing both *ex-situ* and *in-situ* approaches (Bompard, 1993).

The modern cultivars have undoubtedly replaced many traditional varieties. Under the UNEP-GEF/TFT project recently concluded in India at three sites viz*., Chittoor, Sirsi, Amaravathi, Pusa* and *Malihabad*, many mango seedlings were selected as heirloom. These seedling progenies were observed to be growing in large numbers in the regions. These were located, evaluated and registered. The information gathered from the selected community indicated that farmers are maintaining these varieties for different purposes viz., pickling, table, sucking and dual purposes. These varieties evaluated *in situ*, *ex situ* resulted in indicating the desirable traits, which would help in introgression through breeding.

At Chittoor, Karnataka, BVRR Naati 1 recorded the maximum fruit weight (530.7 g), TSA Naati 4, had highest pulp recovery (82%), RVRR Naati 3 for high total carotenoids contents (26.44 mg/100g). At Pusa, Bihar, Madhukpia seedling and Pusa Mango 2 had maximum fruit weight (510 g); Kishanbhog seedling had highest TSS (22.80°B) and pulp recovery (83%). ‘Sukul seedling’ has keeping quality up to one week at room temperature and highly fibrous quality suited for pickle making and sucking purposes. ‘Sipia seedling’ has excellent eating quality, nil fibres and suited for table purposes (Fig. 1.). At Malihabad, UP ‘Goal Bhadaiya’ had maximum fruit weight (945 g), ‘Nisar Pasand’ had highest TSS (25 ^{0}B) and ‘Mahesh Pasand’ had maximum pulp recovery (up to 90.97%) (Dinesh *et.al*., 2015).

This would not only help the farmers in conservation but also help in deriving benefit out of these in the form of royalty after registration through PPV&FRA. Further making the farmers aware of importance of these and linking those to market would help them in livelihood security.

Conclusion

Heirloom seeds or propagule are links to our ancestors. We honor our ancestors when we plant the seeds/ grafts into mother earth's soil and she repays us with nourishment. Heirloom varieties will be of immense value to a researcher as they can be used in the breeding programme, also they can be used by the farmers for other value-added products and due to their regularity in bearing help the farmer in getting better income when the commercial varieties are not in fruiting. Another important characteristic feature is the bearing season, seedling types may bear early season, mid-season and late season and above all they are rich source of donor genes for imparting resistant against various stresses.

In India, North Eastern Himalayas and Western Ghats can be considered to be home of huge lot of heirloom varieties. Taking cue from Veteto's theory, quoting Whealy (1998), Heirloom seeds are especially prevalent in isolated mountain areas and also among traditional people living in those areas.

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3. Prospects of Exotic Berries in India

V.B. Patel[1], N.V. Singh[2], P.C. Tripathi[1] and A.K. Bhattacharjee[1]
[1]Horticultural Science Division, Indian Council of Agricultural Research, KAB-II, New Delhi 110 012; [2]Division of Fruits and Horticultural Technology, ICAR- Indian Agricultural Research Institute, New Delhi -110 012

Berries are a diverse groups of plants having small fruits borne in groups or bunches. Most of them are rich in vitamins, minerals and other phyto-chemicals. The fruits are gaining popularly due to their nutritional values in recent years and their demand is growing rapidly both domestic and international markets. Some berries such as strawberry, mulberries and indigenous berries are commercially cultivated in India. But the cultivation of exotic berries like blue berry, crane berry and raspberry is very limited and these are imported in the country to meet growing demand of the country. The focusing of government is to promote commercially viable exotic fruit crops in India, including blueberry to meet the increase demand to demand and substitute the import. .

Most of the berries are shrubs or small trees. They belongs to different genera or families. They may have similar in their life span, uses and cultivation practices. According to Migicovsky *et al*., (2022), berry is a tiny, fleshy, edible fruit that is usually sweet. Currants (*Ribes* spp.), huckleberries (*Vaccinium* spp) *Gaylusaccia* spp.), salal berries *(Gaultheria* shallon Pursh), and grapes (*Vitis* spp.) are true berries while Saskatoon berries (*Amelanchier alnifolia*), crab apples (*Malus* spp.) are pome and like strawberries (*Fragaria* spp.), raspberries (*Rubus* spp), and blackberries (*Rubus* spp.) are aggregate fruits. Besides these exotic berries, indigenous berries like mulberry, goose berry, wolf or goji berry, sherbet berry, Indian crane berry, wild blueberry, blueberry etc some of them may be included in berry group through they may not be true berries. The current status and future prospects of exotic berries cultivation namely blueberry, raspberry, cranberry and strawberry in India is discussed in this article.

Blueberry (*Vaccinium corymbosum*)

Blueberry belongs to family Ericaceous. It is native to North America and Europe. Blueberry is rich in flavonoids, tannins, phenolic acids, and anthocyanin and consumed fresh as well as processed. The blue berry has various beneficial health effects and can be used to cure a variety of human illnesses (Martineau *et al.,* 2006; Krikorian *et al*., 2010). According to FAO, according to the report, the global blueberry area has reached 2,35,408 hectares by 2021 with a total production of 1,789,590 metric tons. Global production more than doubled during last 10 year and there are more than 10 countries producing above the 10,000-ton. The United States, Canada, and Chile are the largest producers. Peru is now the world's leading exporter by value. Blueberry cultivation have gained significant popularity in India in recent years. With its suitable climate and vast agricultural landscape, India offers favourable conditions for blueberry cultivation. It is often a popular ingredient in continental desserts. Due to the growing popularity of these sweet berries, there is a push to grow them in the country. In India, it is grown at small scale in Himachal Pradesh, Maharashtra, Uttarakhand, Jammu and Kashmir. India imports most of its Blueberry fruit from USA. Belgium, Peru and Chile and is the second largest importer of Blueberry fruit in the World. There are four types of blueberries, 1) Highbush (*Vaccinium corymbosum* **L**.),2)Lowbush (*Vaccinium angustifolium* **L**.), 3) bilberry or forest blueberry (*Vaccinium myrtillus* **L**.), 4) Rabbiteye (*Vaccinium ashei* **L**.).

Some of the blueberry varieties namely Biloxi, Bluecrop, Misty, Sharpblue, Arlene, Legacy and Reveille were imported from USA to India and planted in H.P. (Singh et al., 2017). India's diverse climate allows for the cultivation of low and high chill varieties of blueberries. Sharp Blue and Sunshine Blue are low chilling varities while O Neal and Misty are high chilling varieties. Sharpblue variety is very suitable in areas with mild winters and moderate cold periods. It has excellent fruit quality and can adapt to many different soil types. Sunshine Blue is known for its compact size and early fruiting. Sunshine Blue is the preferred choice for areas with low chilling periods. It produces sweet and delicious berries. O`Neal is a very cold variety, growing well in areas with cold winters. It produces large, sweet-tasting fruits and is very popular in the market. Misty is another hardy variety that thrives in cooler climates. It is known for its vigorous growth and abundance of delicious berries.

Cranberry (*Vaccinium macrocarpon*)

Cranberries are members of family Ericaceae and have tart edible red fruits. It is consumed in as fresh, dried, and frozen. Cranberries are a good source of several minerals and vitamins. Cranberries from the United States are growing in popularity in India. Demand has increased considerably in recent years as Indian consumers have learned more about the incredible health advantages of this berry. Crane berries usually grow well drained, moist humus rich acidic soil having pH 4.5-5.5. These are grown in areas with cold climate and can thrive upto 1500 m msl. It is a cold hardy but the berries are sensitive to frost. In India Cranberry is found in Tamil Nadu, Kerala, Maharashtra, Karnataka, J&K, Andhra Pradesh, and West Bengal. Cranberry plant stalks are weak and creeping. It flowers in June and berries ripe in September he primary diseases affecting cranberry plants are false-blossom virus and several types of fruit rot.

Strawberry (*Fragaria* × *ananassa*)

Strawberry (*Fragaria* × *ananassa*) is a widely grown hybrid species of the genus *Fragaria*, collectively known as the strawberries, which are cultivated worldwide for their fruit. The fruit is widely appreciated for its characteristic aroma, bright red colour, juicy texture, and sweetness. In 2021, world production of strawberries was 9.2 million tonnes, led by China with 37% of the total and the United States and Turkey as other significant producers. Strawberries contain 91% water, 8% carbohydrates, 1% protein, and is a rich source of vitamin C and manganese. Strawberry is one among the fruits having an immense potential and high economic value. Strawberry is a rich source of Vitamin C and iron and is consumed as fresh fruits, processed products like ice cream, soft drink, confectionary and chewing gum and preserved like jam, jellies, and squashes. Strawberries varieties can be classified in three groups based on flowering habits i.e. short-day, long-day, and day-neutral. Strawberry cultivars vary widely in size, colour, flavour, shape, season of ripening, etc. There is a huge scope of strawberry cultivation in India either in open field condition or under protected structures. Strawberries are grown commercially in Mahabaleshwar (Maharashtra), Himachal Pradesh, Uttar Pradesh, Delhi, Haryana, Punjab, Nainital and Dehradoon (Uttarakhand), Bengaluru(Karnataka), Jammu & Kashmir, Kalimpong (West Bengal), (Ooty)Tamil Nadu, Meghalaya and Nagaland. Strawberry in India is mainly grown in the hilly slopes of Mahabaleshwar, which accounts for about 85 percent of the total strawberry produced in India covering an area of about 3000 acres producing around 30000 metric tonnes of strawberry annually. Mahabaleshwar strawberry obtained the geographical indication (GI) tag in 2010. Strawberries from Mahabaleshwar are exported in large quantities to other countries like France, Belgium, Malaysia, and to the Middle East mainly in frozen form.

Strawberries are grown mild cold to temperate conditions. Some varieties of strawberries thrive well in the subtropical climate. They're sown in the open ground in September and October, harvested between May and June. However, they are now cultivated in greenhouses over the course of the off season because of a large seasonal demand for these fruits. This also allows them to command higher prices which can be used in off-season. Important strawberry varieties cultivated in India are Sweet Charlie, Camarosa, Winter Dawn, Chandler, Tioga, Torrey, Selva, Belrubi, Fern and Pajaro. Other varieties include Premier, Red cost, Local Jeolikot, Dilpasand, Bangalore, Florida 90, Katrain Sweet, Pusa Early Dwarf & Blakemore. Some varieties viz. Olympus, Hood & Shuksan having high flavour and bright red colour are suitable for ice-cream making. Other varieties like Midway, Midland, Cardinal, Hood, Red chief and Beauty are ideal for processing. It can be cultivated in tropical and sub-tropical areas round the year with a optimum day temperature of 22^0 C to 25^0 C and night temperature of 7^0 C to 13^0 C. In cold climate, frost as well as winter injury seriously affects strawberry yield. The Straw berry can be grown on any type of soil but best is sandy loam soil and very light soil with a pH of 5.7 to 6.5. Frequent irrigation is needed for establishment of runners. Berries are harvested when 50 to 75 % skin o. the berry develops colours. For long distance market berries are harvested immediately after reaching full colour.

Raspberry

The raspberries are small plants of temperate origin. The fruits have great market potential as fresh berries and value-added products like jams, jams and desserts . Raspberries belongs to Rosaceae family and are native to temperate parts of the Northern Hemisphere. The genetic diversity of different *Rubus* species is spread out in different centres, like There are more than 400 species of *Rubus* in the world, out of these 57 are native to India. Some of the raspberries species found in India are Himalayan raspberry (*R.ellipticus*) and Mysore raspberry (*Rubus neveus*). These are not cultivated commercially the fruits are collected from forest and sold in the market. Yellow ripe fruits of *R. ellipticus* are eaten, fresh juice is also consumed. The roots are used for making country liquor. The fruits of *R. niveus* are used in processing industry and, squash, preserved, jam pies are prepared. There is need to introduced the improved varieties suitable for Indian conditions. Some of the areas such as Himalayan foothills of HP, Uttarakhand, and J&K, Sikkim, Nilgiris, Kodaikanal in T.N are suitable for cultivation of raspberry.

Raspberry cultivation in India is a great option but it depends on several factors, including climatic conditions, market demand and the availability of suitable land and resources. Apart from local domestic market, there is also potential for raspberry export in high demanding countries like United States, European nations, and the Middle East. Raspberry growing in India is still a work in progress, but there's plenty of room for research and development to make sure different types of raspberries suited to Indian conditions come up with the best methods. Raspberry cultivation in India require careful planning, thorough understanding of local conditions, and investment in infrastructures like greenhouses in tropical and subtropical climates.

Cape gooseberry *(Physalis peruviana*, FamilySolanaceae)

It is of native to Chile and Peru. It is now cultivated or grows wild across the world in temperate and tropical regions. It has been widely introduced into cultivation in tropical, subtropical, and temperate areas such as Australia, China, India, Malaysia, and the Philippines. It thrives well at an annual average temperature from 13 to 18 °C tolerating temperatures as high as 30 °C and annual rainfall of 800–4,300 mm . Well drained soil is preferred and grows vigorously in sandy loam. The plant is readily grown from seeds, which are abundant (100 to 300 per fruit), but with low germination rates, requiring thousands of seeds to sow a hectare. Plants grown from year-old stem cuttings will flower early and yield well, but are less vigorous than those grown from seed.

Mulberry

Mulberry (Genus *Morus*), genus of about 10 species of small to medium-sized trees in the family Moraceae and their sweet edible fruits. Mulberries are native to temperate Asia and North America, and several species are cultivated for their fruits. Mulberries are deciduous and have toothed, sometimes lobed leaves that are alternately arranged along the stems. Individuals can be monoecious (bearing both male and female flowers) or dioecious (bearing only male or female flowers). The minute flowers are borne in tight catkin clusters. Each fruit develops from an entire flower cluster and is formally known as a multiple. The fruits somewhat resemble blackberries and ripen to white, pink, red, or purple.

Goji berry

Goji berry is the sweet fruit of either *Lycium barbarum* or *Lycium chinense*, of family Solanaceae. The *L. barbarum* and *L. chinense* fruits are similar but can be distinguished by differences in taste and sugar content.Both of these species are native to Asia and have been long used in traditional Asian cuisine. The fruit has also been an ingredient in traditional Chinese, Korean, and Japanese medicine since at least the 3rd century AD. Since about 2000, goji berry and derived products have become common in developed countries as health foods or alternative medicine remedies, extending from exaggerated and unproven claims about their health benefits.

Challenges and Future strategies

Exotic berries require specific climatic conditions, which can be challenging to replicate in all regions of India. A number of pests and diseases affect berries production in India. Developing effective strategies to combat pests and diseases that affect berry crops. Addressing issues related to market access and distribution to reach a broader consumer base is another challenge. Continuous investment in R&D to adapt to changing conditions and consumer preferences.

To harness the potential of exotic berries in India, future strategies could include introduction of suitable varieties of exotic berries, standardization of production practise for different regions, expanding the area of exotic berries cultivated in India to cater to a wider market, promoting sustainable cultivation practices, Implementing strict quality control measures to ensure the production of high-quality berries, focusing on exports to capitalize on the growing global demand for exotic berries and encouraging the development of processed products like jams, juices, and dried berries to increase value.

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4. Telangana State Oil palm mission: Policy, challenges and achievements

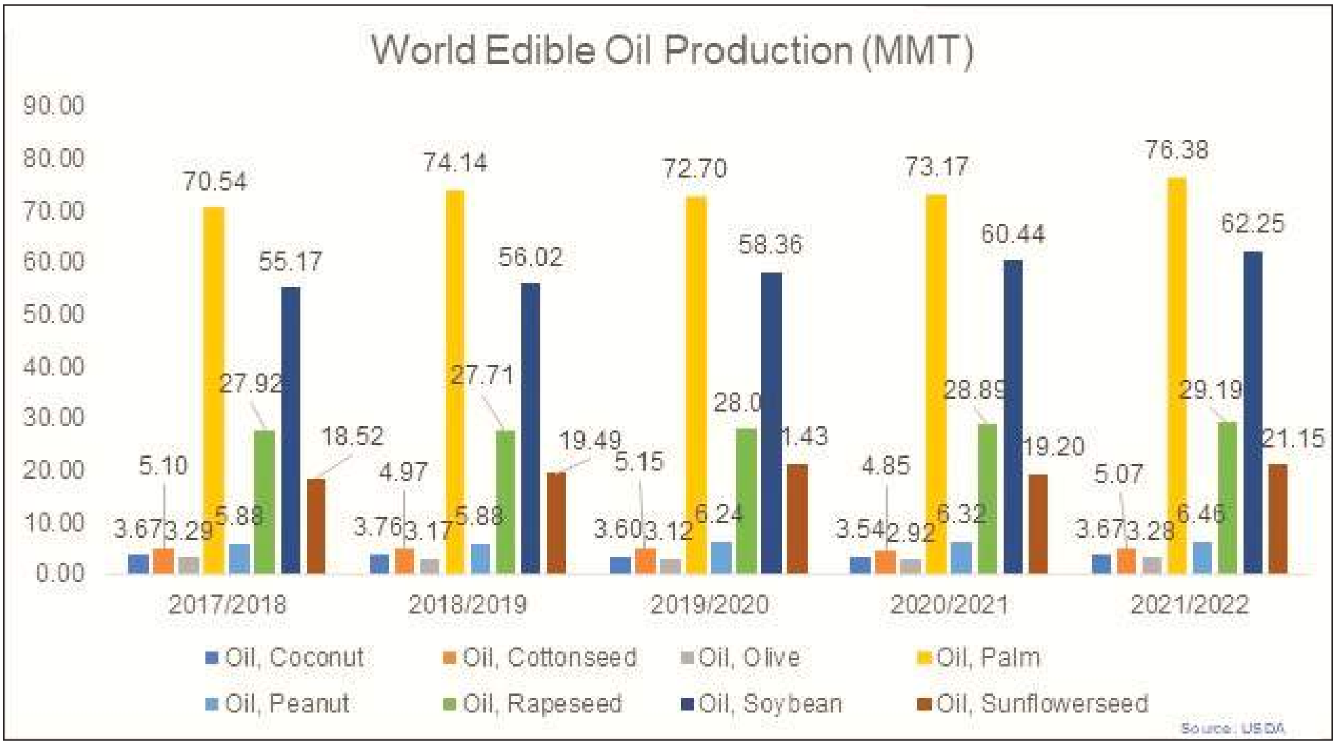
Dr. E. Sreenivasa Rao
Advisor (Horti), Government of Telangana
Email: tshortiadv@gmail.com

Introduction

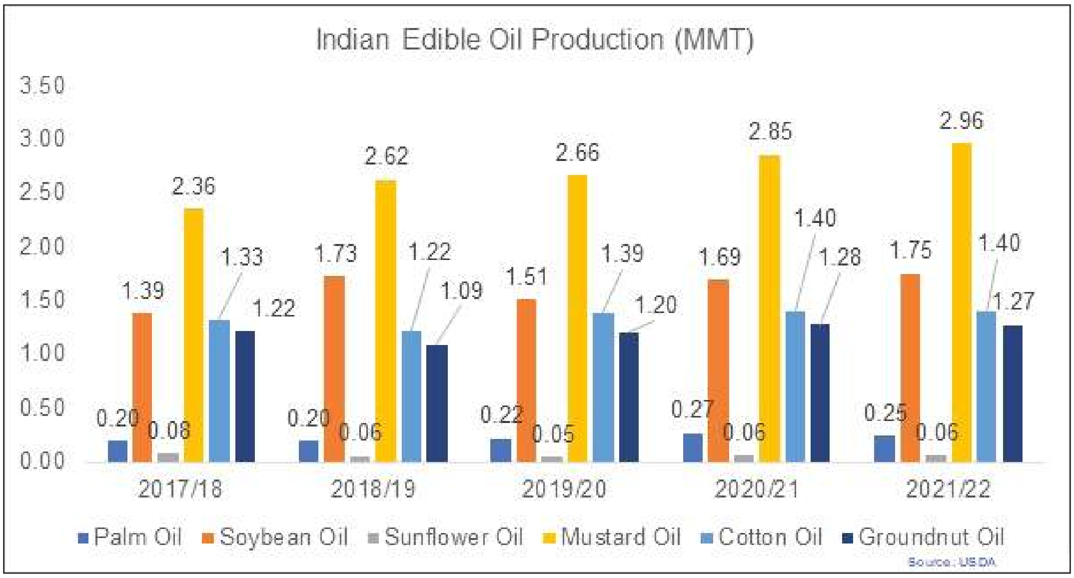
Oil palm is the most cultivated oil crop in the world. Oil palm cultivation in India assumes significance for augmenting the indigenous availability of edible oil as it is the highest oil yielding perennial crop with 4-5 MT of palm oil and 0.4-0.5 MT palm kernel oil (PKO) per Ha. In comparative terms, yield of palm oil is 5 times the yield of edible oil obtained from traditional oilseeds.Nearly 70 percent of palm oil is used in foods and remaining 30 percent used for industrial including the production of bio fuels and cosmetics.

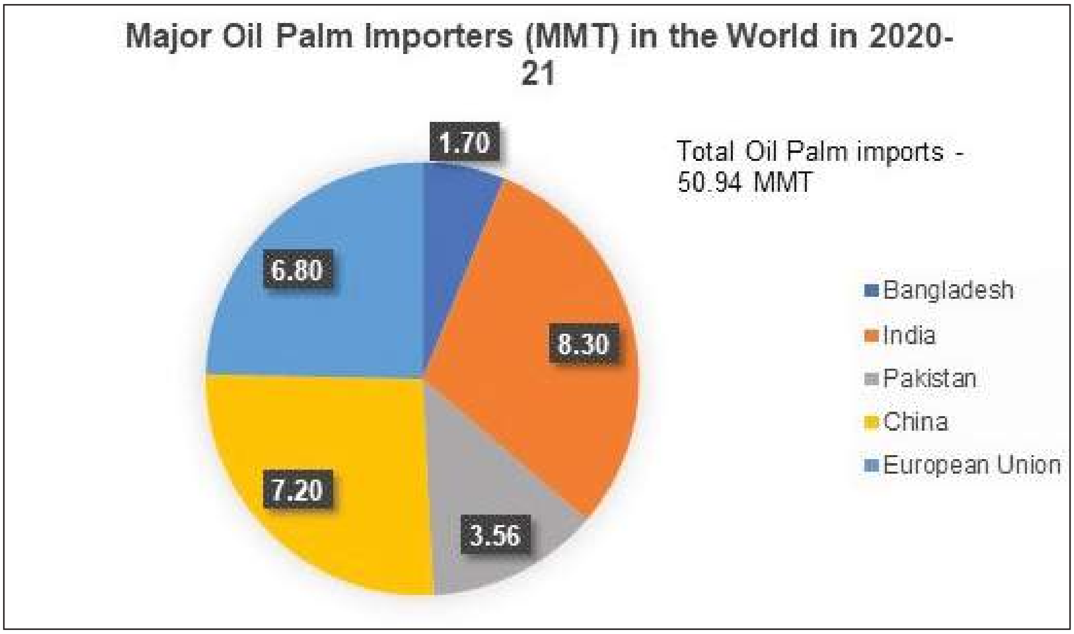
Global and National Scenario

The world edible oil production over last 4 years from 2017-18 to 2021-22 has increased by 8.36 % to 207.45 MMT of which Palm Oil is the major edible oil produced in the world and accounts for 36.81% (76.38 MMT) followed by soybean oil which accounts for 30% (62.25 MMT) of the world edible oil production in 2021-22.



The consumption of edible oil in India is at 23.46 MMT with a per capita consumption of 16 kg/ person, India's edible oil production stands at 8.97 MMT in 2020-21 and it is assumed that the consumption may touch 30 million ton by 2025. The deficit of 14.49 MMT of edible oil is being met through imports from Indonesia, Malaysia, Singapore and Thailand (ITC Trade map) spending huge foreign exchange. Out of the total imports, Palm oil accounts for 58.03% i.e., 8.45 MMT of the total imports of 14.49 MMT in 2020-21.





The major Palm Oil importing countries are India, China, European Union, Pakistan, USA & Bangladesh and India is the major palm oil importing country @ 16.29% of world share (USDA).

Oil palm was introduced to India at National Royal Botanical Gardens, Kolkata during the year 1886. Oil palm, as a small holders' crop under irrigated conditions grown under varied Agro-climatic conditions, is totally new to India.

In the last two decades, down trend is observed in consumption of edible oils like mustard, ground nut and other vegetable oils whereas the consumption of palm Oil is increased by 6.99%

Oil palm has been established as a successful crop in a number of states in the country and at present, the area under oil palm cultivation is 8.85lakh ac., with Crude Palm Oil production of 2.82 lakh MTs against the requirement of 87.55 lakh MT. About of 90 to 100 lakh MTs worth Rs.80,000 crores of Crude Palm Oil and Olein is being imported from other countries. To attain self-sufficiency under Oil palm in India, an additional area of 70 lakh acres is required. The total potential area of Reassessment Committee 2020 is about 70 lakh acres.

To bridge this gap, the Government of India is promoting Oil Palm Development since 1992 under various programmes to augment the domestic edible oil requirement. The major oil palm producing states in India are Andhra Pradesh, Telangana, Karnataka, Tamil Nadu, Gujarat, Chhattisgarh, Mizoram, Assam and Orissa. Andhra Pradesh ranks 1st in Area and Production of Oil Palm in the country. Telangana stands 2nd in production of Fresh Fruit Bunches, in Oil Palm area, and 1st in Oil Extraction Rate (OER) with 19.22 % in the country.

Telangana, a separate state formed on June 2, 2014, carved out as the 29th Indian state for most neglected areas such as Neellu, Nidhulu, Niyaamakaalu (water, funds and jobs).

Agriculture Since the formation of the State, the Government has prioritised the growth of the Agriculture sector through various initiatives such as the Rythu Bandhu scheme (investment support), the construction of new major and medium irrigation projects, 24x7 free power to Agriculture, Mission Kakatiya, promotion of livestock and fisheries, sheep distribution scheme, etc. These initiatives have led to an increase in the share of Agriculture and Allied sectors in the total current-price GSVA of the state – from 16.3% in 2014-15 to 18.2% in 2022-23. Between 2014-15 and 2022-23, the state's contribution to India's nominal GDP increased from 4.1% to 4.9. Assured irrigation is the main input for the crops as it protects the farmers in poor monsoons and leads to an increase in the production and productivity of the crops.

Due to this considerable investment by the Government, the Gross Irrigated Area (GIA) has significantly increased by 117% (from 62.48 lakh acres in 2014-15 to 135 lakh acres in 2021-22). This impressive growth in irrigated area has resulted in an increase in paddy production by 342% between 2015-16 and 2021-22 (from 45.71 lakh MTs to 202 lakh MTs) and the State has emerged as the second largest supplier of Paddy to the Food Corporation of India (FCI).

From 2021-22, the National Mission on Edible Oils-Oilpalm (NMEO-OP) has been launched with the funding pattern of 60:40 ratio between Central and State governments and notified an additional target of 8.24 lakh acres in 25 districts of Telangana.

Owing to scope and advantages of oil palm crop, the Telangana government intends to cover an area of 8 lakh Ha., (20 lakh acres) under oil palm in a mission mode as a part of crop diversification with the following main objectives:

i. To augment the availability of vegetable oils in the state.

ii. To cut down the import of edible oils by increasing domestic production and productivity of Oil palm.

iii. To meet the partial requirement of nations vegetable oil demand.

iv. To promote crop diversification form less demanded crops to Oil Palm which can give remunerative yields for as long as 25-30 with additional benefits of water saving / power saving / improving soil health / environmental benefit / assured income with main crop / regular income from inter crops and border crops.

Policy and implementation

Oil palm cultivation and processing is regulated through The Telangana Oil Palm (Regulation of Productions and Processing) Act 1993.

Before 2014, the Oil palm cultivation was confined to two districts i.e. erstwhile Khammam & erstwhile Nalgonda districts. Now the Govt. of Telangana is taking up Oil palm cultivation in all the districts (except Medchal & Hyderabad) with a target of 20.0 lakh Ac.

To achieve the target, (14) Oil palm Processing companies are permitted to support Oil palm cultivation in (31) districts. These companies have established (38) nurseries with a capacity to raise 2.88 Cr seedlings per annum.

The companies are importing seed spouts from FGV- Malaysia, Sime Derby seeds -Malaysia, Palm Elit - France, Univanich Palm oil public company - Thailand and, ASD- Costa Rica.

The act mandates all harvest to be mandatorily procured by allotted companies in the zone at prices determined by state government. The Oil palm Companies have to invariably establish the Processing Mill to process the Fresh Fruit Bunches (FFBs) produced in their factory zone. The present capacity of (2) Oil palm processing mills in the Telangana state is 90 MTPH and (5) Processing Mills by other companies is under progress.

Under this scheme, assistance will be provided for taking up new area Expansion, maintenance of oil palm gardens & inter-cropping for the initial (4) years, Nursery establishment, Custom Hiring Centers, Capacity building for farmers & Department Officials, Farm Mechanization, etc. The subsidy will be paid directly into the accounts of the farmers under the DBT mode.

Government of India offers subsidy support to farmers under National Food Security Mission in the Centre (60%) State (40%) ratio. i.e Rs.36,000 per acre. (Rs 21600 and Rs 14400 respectively). But Telangana Government is supporting Rs 50916/- per acre by providing additional amount of Rs. 14916/- towards micro irrigation.

Developed a mobile app and online web portal to bring all stakeholders on to a single platform. It facilitates monitoring seed import consignments, seedling availability in primary & secondary nurseries, beneficiary registration, field inspections, issue of plants to farmers, generation of sanction orders for subsidy disbursement. In due course it will be developed further to monitor farmer wise FFB production and payments. The objective of this App and Portal is to simplify the process and to digitize all the activities from registration of farmer to release of assistance to end user in a transparent manner.

Anticipated returns

The promotion of Oil Palm in an extent of 20 lakh acres over the next three years is expected to yield the following returns

- Reducing dependency on import of edible oils.
- Assured income to the farmers for 25 years.
- Employment generation through establishment of processing mills and oil palm nurseries

- Reduce the burden on paddy procurement by an estimated 25 lakh MTs
- Reduce annual electricity subsidy burden by an estimated Rs 1500 Crore per annum since Oil palm cultivation requires only 25% water compared to paddy.
- Increase the state's agriculture GVA (gross value addition) by 10%,
- Increase the annual incomes of an estimated 4 to 5 lakh households by at least 4 times, generate annual SGST revenues of Rs 2,000 Cr, generate rural employment for 30,000 personnel (direct) and farm level employment for 200,000 personnel.
- Effective Carbon sink like Forest & Highest bio mass production.

Constraints in oil palm cultivation:

- Oil palm has a long gestation period and restricts income flow to farmers for at least 4-5 years.
- Small holdings of farmers with limited resources.
- Fluctuation in prices of CPO in the international market.
- Erratic monsoon leading to shortage of water.
- Competition from other economically viable crops such as rubber, arecanut, sugarcane, banana, coconut etc.
- Variation in import duty on edible oils.

Future requirements to support the programme:

- Establish Oil palm seed gardens in the state to meet the in-house demand of Telangana.
- The Viability Price (VP) of Fresh Fruit Bunches (FFBs) is based on last 5 year oil price which not remunerative and required to adopt MSP on par with other crops.
- Establishment of AICRP centre for Oil palm in the state of Telangana to work out agronomy for imported varieties being cultivated

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Primary Nursery of Oil Palm

Secondary Nursery of Oil Palm

Intercroping in Oil Palm with Cotton

Intercroping in Oil Palm with Cotton

Juvenile crop of Oil Palm

Juvenile crop of Oil Palm

Bearing Oil Palm plant

Fresh fruit bunch of Oil Palm

5. Underutilized palms: Progress and prospects of tapping for sap and processing for value added products

K.B. Hebbar* and S. V. Ramesh

* Dirctor, ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala.

Palms are extensively cultivated species native to tropical and subtropical regions of the world. Palm species cultivated or native to India are coconut (*Cocos nucifera* L), palmyra (*Borassus flabellifer*), arecanut (*Areca catechu*), date palm (*Phoenix dactylifera*), fish tail (kithul) palm (*Caryota urens*), pejibaye (*Bactris gasipaes*), sago palm (*Cycas revolute*), royal palm (*Roystonea regia*), oil palm (*Elaeis guineensis*), fox tail palm (*Wodyetia bifurcate*), doum palm (*Hyphaene thebaica*), arenga palm (*Arenga pinnata*). Generally palms have been extensively used by humans for variety of purposes since ancient times. One of the economic applications of palms involves appropriate tapping technique to extract sugary phloem sap characterized with high nutritive value. Palms like coconut, palmyra, and kithul inflorescence is tapped to obtain the sap whereas in date palm stem is tapped while in oil palm both the inflorescence as well as stem are tapped. In general, inflorescence tapping for phloem sap is non-injurious whereas stem tapping causes severe mechanical injury to the palms and at times it may cause death of the palms too. The underlying rationale for tapping palms for sap or sugar production is that sugar in the phloem sap is intercepted and processed externally before it is diverted for production of uneconomic parts such as husk, fibres so that energy use efficiency is achieved.

In coconut, the sap is tapped from unopened spadix. The phloem sap is rich in sugars, proteins, amino acids, minerals, vitamins, and phenolics with immense antioxidant potential etc., and hence offers a healthy alternative for plant juices. In a year coconut produces not less than 10 to 14 spadix and each of which can produce 2 L sap/day thus a conservative estimate suggest that the potential sap yield of a coconut palm is 400L/year. Unfermented sap is consumed directly as a healthy beverage and alternatively could be concentrated to produce syrup, jaggery, sugar and other second line of products based on sap-based sugar (Hebbar et al., 2022). However, traditional method of collection of sap leads to rapid fermentation of the sap leading to the formation of toddy making it neither fit for consumption as a healthy non-alcoholic beverage nor it could be utilized as raw material in the production of sugar and products.

The advent of coco-sap chiller (Hebbar and Augustine 2021), a device to collect unfermented neera or inflorescence sap in its original form, is considered a game changer in post-harvest processing of palms. This technique allows for collection of coconut inflorescence sap devoid of any alcohol content. Tapping, processing and marketing license are being issued either to individual entrepreneurs or farmer in states like Goa or to farmer producer organizations (CPC- Coconut Producer Company or CPF - coconut producer federation) in states like Karnataka, Kerala, Tamil Nadu, and Telengana. It has led to the development of new breed of entrepreneurs who produce coconut sugar from the collected coconut inflorescence sap as commercial ventures.

The biochemical attributes of neera or inflorescence sap reveal it has a high nutritive value and low glycaemic index, and hence the product, palm sugar, fetches a premium price in international and domestic markets. Tapping of palms ensures employment generation for rural youth as it entails tappers, technicians and personnel involved in marketing. Currently, South East Asian countries such as Philippines, Indonesia and Sri Lanka are the major producers of palm sugar and from where the product is exported to countries in North America or Europe. "Palm Sugar Market: Global Industry Analysis (2012–2016) and Forecast (2017–2025)", reveals that palm sugar market is anticipated to reach US$ 2205.8 million in the year 2025. In addition, commodity trading in palm sugars and the income has grown at a CAGR of 3.4% during the period 2017–2025.

Coconut sap tapping

Palm sap from coconut is traditionally collected in rural areas by slicing the head of the inflorescence. Swelling at the base of inflorescence is considered a visual marker for identifying appropriate stage for tapping. Traditional tools like bones/wooden sticks are used to beat the inflorescence uniformly during morning or evening hours for 7 days to stimulate the sap flow. Then spadix is tied all over its body to avoid the bursting or opening of inflorescence. It is followed by slicing or removal of distal portion of inflorescence (around 10 cm) using sickle and is inserted in earthen pot for collection of sap. In order to prevent the rapid fermentation of sap the collection pitcher is coated with lime or some botanicals are also added. However collection of hygienic and unfermented palm sap requires a container that completely arrests the process of fermentation. Hence the technological intervention of ICAR-CPCRI developed a coco sap chiller, a double jacketed box with polyurethane foam based insulation (Hebbar and Augustine 2021) for the collection of unfermented sap. Coco sap chiller has provision for connecting the box on tree top and ensures collection of sap under low temperature using cold ice so that the sap collected is quite distinct from traditionally collected neera. It is golden brown in colour, free of insects, debris, or extraneous materials. Accordingly the sap collected is called as "*Kalparasa*" (Kalparasa has been granted 'Trade Mark' by Intellectual Property India: Trade Mark No. 2813919 dated: 22-09-2014).

Kalparasa, in addition to sugar, contains nutrient such as amino acids, vitamins (ascorbic acid, niacin) antioxidant potential rich polyphenols, flavonoids, in a higher quantity than observed in traditional neera (Hebbar et al., 2020). Kalparasa is also rich in vitamins including ascorbic acid and niacin (Hebbar et al., 2020). The derivatives of Kalparasa namely sap concentrate (honey), sugar are also rich in antioxidant conferring molecules (Hebbar et al., 2020)

Other underutilized palms-for tapping

Besides coconut other palms also have huge potential for tapping and production of palm sugar. *Arenga pinnata* or sugar palm is considered to be the initial source of palm sugar consumed by humans. Palm sugar from *Borassus flabellifer* was used in India even during the fourth century BC. Similarly, in Sri Lanka, use of palm jaggery prepared from the sap of *Caryota urens* is common since antiquity (Table 1)

Table 1. List of potential palm species suitable for palm sap tapping and sugar production

Sl. No	Palm species	Common name	Geographic distribution	Sap characteristics and products	References
1	*Arenga pinnata*	Sugar palm Gomuti	South and South East Asia India,Bangladesh, Sri Lanka	Yields sap 3-6 L/day; starch 75 kg/tree Granulated palm sugar, wine, alcohol are products of sap	Mogea *et al.* 1991

2	*Borassus flabellifer,* *B. aethiopum*	Palmyrah palm	South and South East Asia Tropical dry Forest of Africa	Yields sap 11-20 L/day; sugar, wine, toddy, vinegar	Davis and Johnson 1987
3	*Caryota urens*	Fish tail palm	South and South East Asia Tropical rain forest	Yields sap 20-25 L/day; starch 100-150 kg/tree sugar, wine, toddy, vinegar	De Zoysa 1992
4	*Raphia* spp.	raffia	Tropical rain forest of W. Africa	Tapped for sap	Tuley 1994
5	*Corypha umbraculifera* *C. utan*	Talipot buri	South and South East Asia Tropical rain forest	Yields sap 20 L/day Sugar, wine, alcohol, vinegar	Madulid 1991
6	*Phoenix sylvestris*	Wild date	S. Asia Tropical rain forest to dry forest	Sugar yield 40 kg/tree/year Sugar, wine, alcohol, vinegar	Davis 1972
		Thakil	India and Nepal	Sap for beverage and sugar	Madulid 1981
7	*Hyphaene* spp.	Doum	Deserts of Africa	wine and alcohol	Tuley 1994
8	*Nypa fruticans*	nipa	South and South East AsiaTropical rain forestbrackish water	sugar, alcohol Sugar yield 3000 kg/ha/year	Hamilton and Murphy 1988
		Golpata	India, Sri Lanka, Bangladesh	Sap for beverage and sugar	Bonde *et al*. 1990

Arenga pinnata

Arenga pinnata is a palm that has multipurpose utilities as the core trunk of the palm is rich in starch, root extract is consumed as a cure for bladder stones and fruit is consumed directly as dessert. The inflorescence sap of the palm is prone to microbial fermentation by *Saccharomyces cerevisiae* hence the sap is preserved by adding lime or bark of jack fruit tree. The sugar content of sap varies from 10-20 % which is ideal for the production of palm sugar (Kurniawan et al., 2018). Sap from female inflorescence is of inferior quality and hence male inflorescence is tapped and also tapping of Arenga palm is a labour intensive activity.

Nypa fructicans

Nipah palm is generally found grown in swampy regions of estuaries. The fruit of nipah is physically similar to oil palm and found in Indonesia along with mangroves. The sap production of nipah varies from 0.4 to 1.0 L/day/palm with a sugar content of 15-20%. Palms are taped for 40-70 days in a season for 2 or three seasons in a year so that on an average 80-180 days of tapping could be performed. However, studies have shown that the nipah could be tapped for 100 days in a year yielding a sap of around 1.3 L/day/palm continuously for a period of 50 years. As performed in coconut, the palm stalks are stoked for 15-20 days prior to tapping. The stalks are cut at an angle of 30-45 °C so as to avoid direct exposure of the sap to sunlight. The sap is converted in to granulated sugar for consumption.

Palmyrah palm (*Borassus flabellifer*)

Another potentially important palm is palmyrah which is traditionally tapped for the production of toddy and granulated sugar, jaggery from the inflorescence sap. Besides the genetic characteristics of the palm, other features such as growing conditions, environmental factors, collection time and anthropogenic characteristics such as personal and equipment hygiene determine the quantity and quality of sap collection.

Oil palm (*Elaeis guineensis*)

Oil palm though mainly cultivated for edible oil is an important source of inflorescence sap. Pressing of oil palm frond (OPF) yields sap which is rich in sugars (glucose: 71%; sucrose 27%; and fructose 2%). Besides the production of sugar from the sap obtained from OPF, conversion of sucrose or glucose in to alcohol is another viable option for expanding the economic utility of oil palm. In addition, the trunk of oil palm is tapped for palm sap which could be converted in to sugar. In general the palms that were fallen during the process of oil palm replantation are utilized for the production of palm sugar.

Caryota urens

In *Caryota urens* the inflorescence of appropriate stage is bound into a "candle" form and the end of the candle is sliced off for tapping. The method of bruising the inflorescence, by beating and crushing, and extraction of sap is performed. It is similar to the method followed for tapping *Borassus flabellifer.* The common methods followed to prevent the fermentation of sap are liming, and use of barks of *Vateria copallifera* and *Careya arborea* or the leaves of *Achronychia laurifolia* in the collection chamber.

Besides these palms others such as *Hyphaene coriacea, Hyphaene thebaica*, *Jubaea spectabilis*, *Mauritia flexuosa, Raphia hookeri* are also tapped for sap in different parts of the world. Palms such as *Elaeis guineensis*, *Nypa fruticans*, *Phoenix sylvestris*, *Raphia hookeri* are ready for sap tapping at early stage (4-7 years) whereas palms *Caryota urens* (10 to 15), *Borassus flabellifer* (15 to 30) such as are amenable for tapping at later stages. Palms such as *Arenga* and *Caryota* could be tapped for very long years. The duration of effective tapping stage varies with palms as follows: *Elaeis guineensis* (10 to 15 years), *Cocos nucifera* (> 20 years) *Nypa fruticans* and *Phoenix sylvestris* (50 years) and *Borassus flabellifer* (30 to 100 years). Also some palms namely *Arenga pinnata*, *Cocos nucifera*, *Elaeis guineensis* and *Nypa fruticans* produce sap throughout the year whereas some other like *Borassus flabellifer* and *Phoenixsylvestris* exhibit seasonal behaviour in sap production. In *Borassus flabellifer* female palms produce more sap than males.

The sugar prepared from palm sap in a traditional method comprises many antioxidant properties and is a healthier alternative for white sugar obtained from sugarcane. The method of palm sap tapping is a critical determinant of sugar quality since sap is highly prone to microbial fermentation. Hence, adoption of techniques such as coco sap chiller for tapping and extraction of palm sap followed by preparation of sugar using double walled cooker and use of the sugar for preparation of second line of products including health drink, bean to bite chocolate etc has been established as a value chain that would fetch more remuneration for palm based agripreneurs.

Constraints

- Palm sap production and consequently sugar production varies greatly with genotypes, environmental and geographic factors
- There exists a wide variation in the sugar production processes depending upon local knowledge and traditional practices
- Palm-based sugars are considered a high value product and hence adulteration of sugar-rich products with cheaper sources is a major constraint
- Additives added while producing palm sugar to prevent over-boiling or formation of foam have became a menace and hence appropriate technological advancements and compatible additives are to be identified

Prospects

- High value, nutrient rich products aimed at super markets and health conscious consumers
- Low glycaemic Index products
- Most palms are grown under traditional cultivation methods under organic management practices and hence the product is also organic
- Economic activity and livelihood of farmers, tappers, workers, tapping technicians are bound to witness an improvement
- Besides huge domestic market, there exists a huge demand for coconut sugar in North America, Latin America, Western Europe, Eastern Europe, Asia Pacific, Japan and the Middle East and Africa (MEA).

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6. Underutilised horticultural crops of arid region: A glance at diversity and opportunities for enhancing rural income

Jagadish Rane*, Kamlesh Kumar and Kishan Lal Kumawat
*Dirctor, ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan

There are more than 400000 plants that exist on this earth and about 4000 of them can be considered as suitable for human consumption. A small number of them are being cultivated, while only three crops viz., rice, wheat and maize dominate the scenario with nearly 60% share in food consumed by humankind. However, these crops have relatively higher contributions in accumulation of GHGs as compared to most of the other plants. In this context, the diversity of crops that can contribute to the human diet plays a vital role in shaping the sustainability of agriculture in the years ahead.

The agriculture and sustainability of food production policies often ignore the fact that there is a vast diversity of plants that can be consumed by humans, but a relatively small number of crops dominate our diets. This concentration on a few staple crops like rice, wheat, and maize has several implications for sustainability. These staple crops often have higher contributions to greenhouse gas emissions and other environmental issues. Monoculture farming of these crops, with heavy use of synthetic fertilizers and pesticides, can lead to soil degradation, water pollution, and increased greenhouse gas emissions. Relying heavily on a few crop varieties makes our food supply vulnerable to pests, diseases, and changing environmental conditions particularly in the context of climate change. Crop diversity is essential for developing new varieties that can withstand these challenges and adapt to changing climates. While rice, wheat, and maize are staple foods for many people, they don't provide all the necessary nutrients for a balanced diet. Diversifying our food sources with a wider range of plant species can help address nutritional deficiencies. Over-reliance on a few crops can also affect the economic sustainability of farming communities. Price fluctuations in these crops can lead to income instability for farmers. Thus the adverse environmental impact, lack of nutritional diversity and economic fragility underscore the need to encourage crop diversity that can bolster small-scale and local agricultural systems. This is more crucial for arid agro ecosystems that are challenged by a plethora of abiotic stresses. As we strive to double both fruit and vegetable production by 2047 to meet projected demand, it is imperative to address the pressing question of how much arid zone horticulture can contribute to this ambitious goal. Furthermore, it is also essential to review the prospects of those native crops which are highly adapted to vagaries of arid-agro ecologies and that can contribute to livelihood of local farmers. In this context, underutilized crops of arid regions take on tremendous significance, as they hold the potential to offer climate-resilient and financially rewarding alternatives for sustaining rural incomes in resource-poor and abiotic stress prone arid areas.

Challenges, risks and uncertainties of arid regions

Arid regions that prevail in the western Rajasthan are featured by abiotic stresses originating from atmospheric, edaphic and water associated factors. Extremes of high (March-October) and low (December-January) temperature conditions together with associated abiotic factors in the arid areas limit the choice of crops and their genotypes and quality of produce.Productivity and crop selection in this region are significantly impacted by a range of environmental factors:

- **Ambient temperature Extremes:** The area is subject to extreme temperature fluctuations, with daytime temperatures ranging from 35 to 42 degrees Celsius. But formidable challenge is posed by prolonged (21-28 days), extremes of ambient temperature to an extent of 45 to 50^{o}C during the days and 31–35^{o}C in the night.These temperature extremes can stress crops and limit their growth.
- **Prolonged dry spells:** The region frequently encounters extended periods of drought, characterized by a limited number of heavy rains. Out of 21 rainy days in a year, only 1 to 5 may bring substantial rainfall, leading to prolonged dry spells.
- **Low temperature and frost:** Winter is dry and minimum temperature fluctuates around 4 -100^{O}C during December–January and some-times it is prolonged to February. Most of the years, low temperature situations dips-down below freezing (-1 to -60^{O}C) and occurrence of frost is frequent in hot arid zone.Occasional frost events can further damage crops, particularly during colder seasons.
- **Hot and cold winds:** The presence of hot, dry winds in combination with cold winds can exacerbate the challenges faced by crops and affect their health and yield.The damage to crop plants by high wind velocity can occur due to both the direct damage by sand particle and also by totally covering the annual crop plants further, in summer, there effects of heat stress are manifested by severe burning symptoms not only due to high ambient temperature but also due to high temperatures of surface soil.
- **Soil and water quality:** The quality of both soil and water resources in the region plays a critical role in determining crop suitability and productivity. Soil composition and water availability are essential considerations for successful farming practices. However, the arid region in the west Rajasthan is featured by typical desert constraints such as the coarse texture of sandy soil, poor nutrient and water retention capacity, strong winds that carries away fertile top-soil. Underground water of the region is highly saline.

Given these environmental challenges, it is essential for farmers and agricultural practitioners in this region to adopt resilient farming techniques, select crop varieties that are well-suited to the prevailing conditions, and implement integrated and efficient soil and water management practices to mitigate the impact of drought and to optimize agricultural productivity.

Underutilised crops of the region

While the several field and horticultural crops have been chosen to support rural food security and livelihood in the arid regions, the locally adapted crops of high nutritional and functional values promise to provide unique opportunities for establishing nature positive, entrepreneur positive and climate change negative agricultural products. These deserts adapted crops have remarkable resilience to abiotic stresses that prevail in the region. Some of the under-utilised crops are ker (*Cappari deciduosa*), phog (*Calligonum polygonoides*), lasoda (*Cordia myxa*), halophytes that yield saji (soda ash) and pilu (*Salvadora persica*), which offer great potential for value added products and hence enhanced income for famers through secondary agriculture.

While ker is known for its use in pickles and for nutraceutical properties. Immature tender green as well as pink/ red ripe fruits of ker are used in various ways. Immature, tender fruits can be used in two ways after harvesting either as fresh for making vegetable or dehydrated for pickle making. Ker pickle premium priced in the market @ Rs. 800-1200 per kg during fruiting season while dehydraded/processed ker fruits fetches Rs. 500-600 per kg during off-season making it an ingredient of Panchkuta. Mainly fruits are processed for making good quality pickle and as main ingredient in Panchkuta, a traditional delicious vegetable in the region of Rajasthan. Mature unripe fruit contain high level of glucosinolates and can only be used at limited scale after proper processing. Similarly, highly favoured quality pickle made from lasoda is gaining popularity in arid region during market glut and sold @ Rs. 400-500 per kg; dehydrated lasoda is sold @ Rs. 200-300 per kg during off season i.e utilized as vegetable or as one of the ingredient of Panchkuta. Flower of phog is one of the costliest ingredients of butter milk preparations which are said to be remedy for stress experienced during high ambient temperature events particularly in summer. The soda ash (Saji or barilla) is obtained after air drying the foliage of chenopod shrubs like Haloxylon, Salsola and Suaeda which thrive in extremely saline soils in the desert. When used as an ingredient, the "saji" improves organoleptic qualities of products like papad and make it crispy. The Saji produced from Khara lana (*Haloxylon recurvum*) is of the best quality, whereas Saji produced from Pichkilana or luni (*Suaeda fruticosa*) is of medium quality, and that produced from lani (*Salsola baryosma*) is of inferior quality [Vineet et al, 2020 in DOI: 10.5772/intechopen.93841].

Saline conditions creating deleterious effects on plant basic physiology and metabolism in form of ion toxicity, osmotic and oxidative stress in arid region where salt affected patches prevailed (Joshi et al. 2023). Some Halophytes also found growing naturally, flourishing well in extreme saline conditions and yielding economic product of mankind. Halophytes are not only sustained but also proliferate in such saline environments by implementing distinct adaptive mechanisms. Salinity tolerance is varied plant species to species and attributed by plant habitat, form of plant grow, special xerophytic specialized features like salt gland, salt bladder and Kranz anatomy etc. Saji is an example of one of halophytes. Saji (*Suaeda fruticosa, Haloxylon recurvum*) belongs to family Amaranthaceae. It is an important perennial cash crop of salt affected areas of Indian desert. It is found growing naturally in areas having high saline patches and mostly in Thar Desert and some parts of Pakistan. Saji is a perennial shrub with smooth or glabrous stem, oblong or elliptical leaves, black seed and can grow up to a height of 0.5-3.0 meter. It has nutritional, medicinal and economic importance (Joshi et al. 2023).

Saji is a product from an efflorescent ash obtained from alkaline deposits in the soil by burning of *Suaeda fruticosa* and *Haloxylon recurvum*. The product fetches premium price in the market. It is sold @ Rs. 1000 to 2000 per kg according to fineness/grade/quality of saji. It is utilized in bhujia, papad industry at large scale for making confectionary items tasty and crunchy. The product is locally known as "Khar" source of crude salts with sodium carbonate- Sajji khar improves dough rolling properties and frying quality. However, the cultivation of crop is yet to reach commercial scale due to lack of appropriate techniques for raising planting material and simulations of conditions for growth.

A view of naturally grown saji in salt patches at Lunakaransar, Bikaner (Rajasthan)

A view of saji collection for establishing artificially at ICAR-CIAH, Bikaner for research and demonstration purpose

Another promising option for desert agriculture is the cactus pear, a member of the Cactaceae family, is a versatile plant that can be either a creeping or upright shrub, reaching heights of 3-5 meters. It is garnering increasing global interest, particularly for its unique characteristics that confer resilience to harsh ecological conditions. Cactus pear can thrive in areas where other crops struggle to grow and can be a valuable tool for restoring degraded land. It stands as a dependable resource when all else fails. The cactus plant, its flat stem segments (cladodes), and its fruits are known by various names, including prickly pear, cactus pear, Indian fig Opuntia, Barbary fig, spineless cactus, and nopal cactus, among others. The young cladode is referred to as "nopal," and the fruit is known as "tuna". Nopal cactus is especially known for its culinary exploitation of cladodes in the form of vegetable, salad, pickle *etc* (Kumar *et al.,* 2018).

While crops with well-optimized planting material production methods are rapidly gaining ground in arid regions, the cultivation of locally valuable crops has yet to gain traction. Therefore, it is crucial to refine propagation techniques for many of these desert crops. For the first time at ICAR-CIAH, Bikaner; multiplication technique and plant standards of ker (ICAR-CIAH, Annual Report, 2020) and pilu (ICAR-CIAH, Annual Report, 2021) have been successfully standardized and recently a block of ker has been established for research and demonstration purpose. Experiments carried out at the institute have shown that High-quality planting material for the Ker plant can be successfully produced by utilizing semi-hardwood stem cuttings measuring 30-35 cm in length. This method is most effective when carried out during the month of September, and it requires the use of potting media that includes either (i) sand or (ii) a three-layered mixture of clay, vermiculite, and clay. Further, it was also demonstrated that planting should be done under mist chamber/ greenhouse condition for better and early sprouting. It is crucial to provide proper care and attention to these sprouted cuttings for the next six months to ensure the healthy development of both roots and shoots. This extended care period is essential for establishing strong and vigorous plants. Methods have been optimised to raise seed rootstock and plant standards have been developed for lasoda crop (Kumar *et al.,* 2022) for commercial orchards. A mother block of ‘Thar Bold’ variety of lasoda has been established at CIAH-Bikaner.

Functional and nutraceutical values and need for enhanced awareness

It is widely recognized that plants, when exposed to abiotic stresses, have the capacity to produce secondary metabolites that can play a significant role as functional foods and nutraceuticals. This phenomenon has been extensively demonstrated in various arid fruit crops. The traditional knowledge and practices surrounding the use of underutilized crops have often limited their consumption to local or regional levels. To expand the consumer base for these crops, a comprehensive campaign is needed. The objective of commercializing these crops for benefit of farmers can be achieved through following campaigns involving following activities.

1. **Raise Awareness:** It is necessary to educate consumers about the nutritional and health benefits of these underutilized crops and tohighlight how the secondary metabolites produced under abiotic stress can be beneficial for health.

2. **Promote Accessibility:** Ensure that these crops are readily available in local markets and supermarkets, making them easily accessible to a wider audience.

3. **Diversify Products:** The development of a variety of products, including processed foods, beverages, and supplements, that incorporate these underutilized crops. This can make them more appealing to consumers who may not be familiar with their traditional forms.

4. **Collaborate with Farmers:** The industries/startups should work closely with local farmers to promote the cultivation of these crops. Offer training and incentives to encourage their production, which can help meet the increased demand.

5. **Highlight Sustainability:** It is necessary to emphasize the sustainable and eco-friendly aspects of cultivating and consuming these crops, as they often thrive in arid regions with limited water resources.

6. **Engage in Research:** Institute should be supported to continue with scientific research to better understand the potential health benefits and applications of secondary metabolites from these crops. This can further validate their nutraceutical potential.

7. **Cultural Integration:** By actively endorsing the integration of these underutilized arid crops into local culinary traditions and cultural customs, it becomes feasible to broaden their consumption beyond their customary confines.

In summary, the development of production and crop protection technologies aimed at optimizing high-quality yields from above mentioned underutilised crops for commercial cultivation is still in its infancy. This necessitates systematic experimentation with locally adapted underutilized crops, including halophytes that provide high value products. At the same time, there should be a comprehensive and large-scale campaign to raise awareness among potential consumers about the functional and nutraceutical properties of the products derived from these crops.

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7. Strategic approaches for climate resilience and sustainable production of lesser-known fruits

[1]M. Kavino, [2]G. Karunakaran, [2]Sakthivel, T., [2]Arivalagan, M., [2]Ruchitha, T. and [2]K. Abhilash
[1]Tamil Nadu Agricultural University, Coimbatore-641 003.
[2]ICAR-Indian Institute of Horticultural Research, Bengaluru-560 089.

ABSTRACT

Of late, there is a huge demand for nutrient-dense fruits to promote health status of human beings. The production of commercial fruit crops is becoming progressively input-dependent to cope up with the losses caused by biotic and abiotic stresses. A wide variety of lesser-known fruit crops, which are neither commercially cultivated nor traded on a large scale, are mainly grown and consumed locally. These less known fruits have many advantages in terms of ease to grow, hardiness and resilience to climate changes compared to the major commercially grown fruit crops. Consumption of minor fruits helps to meet the nutritional needs of rural populations, such as those living in arid and semi-arid regions around the world. In addition, local people are well aware of the nutritional and medicinal properties of this less known fruit crops like dragon fruit, ber, phalsa, pummelo, bael, wood apple, aonla, karonda, barbados cherry, pilu, Kair and khejri etc. These fruit crops are not only rich in nutrients but are also a probable alternative to mitigate the loss due to changing climate. Reinforcement of their domestication through standardization of cultivation practices, facilitation for supply of planting material and re-governance of the market chain by exploring their uses, creation of awareness among consumers and establishing a good distribution network are also crucial for attaining sustainability in the context of climate change.

Introduction

The burgeoning global population together with the ongoing loss of arable lands and climate change led to an increasing demand for climate resilient crop production. To cope with these changing and challenging circumstances, horticulture production systems of the future need to be shaped sustainably. In developing countries like India, agriculture including horticulture is an important contributing factor to economic growth and poverty alleviation, particularly via providing food and employment opportunities besides ensuring nutritional securities. In India, major fruit crops such as mango, banana, citrus, guava and apple, account for more than 72% of the total area under fruit crops, while indigenous (native) or less known fruit crops contribute only 6.56% of the area (0.437 mha) with quite high productivity (11.47 tons/ha) (NHB, 2019) even though there is lots of scope for cultivation due to its diverse agro-climate. In general, those fruits which have less acreage and are available in low quantity in the market are generally called as minor or underutilized or less known fruits.

Climate change favors fluctuation in temperature, radiation frequency; extreme events such as drought and flood especially in arid or semi-arid areas, can result in an intensification of the negative impact of salinity, mineral deficiency/toxicity and insect-pest attacks on crops (Mumivand *et al*., 2022; Sanwal *et al*., 2022). Consequently, climate change is a key threat in achieving the sustainable cultivation of important commercial fruits. Under such environmental conditions, the fulfillment of the consumers' choice and nutritional and food security at an affordable and sustainable level is a major concern for the researchers, policy makers as well as the growers. The indigenous fruit crops are not only proven to be superior in terms of wider adaptability to environmental conditions but are also known for their nutritional value (Berwal *et al*., 2021). However, a limited research has been carried out for the development of production protocols and utilization of these less known fruit species. Moreover, the limited number of identified varieties, the low availability of quality planting materials and the inadequate availability of suitable cultural and post-harvest management practices are still major limitations challenging the systematic cultivation of these less known fruit crops. These fruits are not very popular and are sold at very low prices in the local markets because of the lack of (a) people's awareness of their nutritive values (b) consumption habits (c) limited research and (d) developmental policies by the government agencies for their potential exploitation.

The scenario of climate change not only affects our environment but also affect the physiology of crop that we use for our consumption. Most of the cereal and pulse crops that we consume as food are annual crops which are not directly affected that much as compared to that of the fruit crops which are mostly perennial. For example, in mango, high temperature during floral bud differentiation led to poor sex ratio of flowers in the current season. Rising temperature prevents desirable fruit coloration in coloured guava and reduces quality grape productions that eventually decrease the area of cultivation and market demands also (Rajan, 2008). Similarly, temperature also determines the quantity and sex ratio of flowers. This directly impacts the fruiting potential for the crop for the season. These are some examples but the actual scenario is much larger and if proper measures are not taken situation may get worsen. The probable alternative to ensure nutritional security intact through fruits availability is by selection of climate smart fruit crops. These fruit crops are believed to be much more tolerant to heat stress and moisture stress. The fruit crops like dragon fruit, phalsa, pumello, bael, wood apple, aonla, karonda, Barbados cherry, pilu, kair, khejri and lasora are believed to be having a less moisture demand and have lesser transpiration rate. Besides, that these fruit crops are believed to withstand effects of climate change.

Scope for less known fruits production

Utilization of fallow land

There is a vast scope for less known fruit cultivation in our country because total area under horticultural crop is very small and it is about 9% of total cropped area and fruit occupy 29% of total horticultural area. Area under fallow land is more. So, we can utilize this untapped fallow and degraded land for cultivation of lesser known fruit crops.

Hardy nature of plants

Less known or minor fruit crops are found in numerous agricultural ecosystems and often survive mainly in marginal areas. These crops are hardy in nature (tolerant to adverse soil and climate) and they are free from diseases and pests.

Nutritional security

The majority of the Indian population resides in village areas and they suffer from malnutrition. In order to overcome malnutrition problems of arid, hilly and tribal people, it is necessary to enhance the production of minor fruits, which can be done by increasing production and area under fruit crops. Nutritional content of some minor fruits is shown in Table 1.

High medicinal importance

Apart from nutritive value, less known fruits have medicinal value. Some examples are: aonla is the main ingredient of 'chyavanprash' which is famous for its therapeutic value in the Ayurvedic system of medicine; unripe bael fruit can cure diarrhea, constipation and dysentery with certainty; jamun fruits are helpful in curing diabetes. Thereby the expanding demand for herbal remedies, both internationally and in situations where modern pharmaceuticals are unavailable or too expensive for local populations.

Value addition

With the advancement of postharvest technologies, installation of agro-industries, storage and transport facilities, there is great demand for less known fruits throughout the year as most of the fruits are used for preparation of value-added products. Different processed products of minor crops are shown in Table 2.

Market opportunities

The high standard of living in industrialized countries generates demands for more natural food and environmentally-friendly products, a demand which can also be met by underutilized species.

Improving socio-economic condition of tribal people

Most of the tribal population resides in remote, hilly, forest and degraded areas. Adaptation of suitable minor fruits cultivation region-wise helps to earn money, fuel and their engagement which create a socio-economic impact for their sustainability.

Less known fruits for different climatic zones of India

Broadly the country can be divided into tropical, subtropical and temperate regions. Within each broad category there are differences due to rainfall, humidity, altitude, etc. Considering these aspects six different horticultural zones have been identified so that appropriate choice of the crops can be made and development is planned. According to these zones less known fruit crops are classified below:

Temperate climate zone

Less known fruits like crabapple, chestnut, wild apricot, blackberry, seabuckthorn, etc., can be grown in this climatic condition.

Southern tropical climate zone

In this climate, less known fruits like ber, custard apple, aonla, bael, karonda, jamun, wood apple, Barbados cherry, bilimbi, hog plum, kokam butter tree, rose apple, star apple, star gooseberry, Surinam cherry, white sapota, kodampulli, etc. can be grown successfully.

North-eastern subtropical zone

The parts are Bihar, Assam, Meghalaya, Manipur, parts of West Bengal, Uttar Pradesh, etc. The crops are mahua,karonda, passion fruit.

North-western subtropical region

This includes parts of Jammu and Kashmir, Himachal Pradesh, hills of Utter Pradesh, South of Punjab and Haryana. The crops are phalsa, date palm, ber, custard apple, tamarind, loquat, amlok, behmi, kaliphal, wild apricot, pecan, lasoda, ker, etc.

Central tropical zone

South Madhya Pradesh, Chattisgarh, Gujarat, Maharashtra, Orissa and West Bengal. Under this zone crops are fig, mahua, phalsa, khirni.

Coastal tropical humid fruit zone

Kerala, Goa, Diu Daman, Tripura, coastal parts of Maharastra, Andhra Pradesh, West Bengal, Tamil Nadu, Orissa, Karnataka. Under this zone the minor fruit crops are bilimbi, breadfruit, hog plum, lanson, tamarind and kokum butter tree.

Importance of less known fruit crops

1. Easier to grow and hardy in nature, producing a crop even under adverse soil and climatic conditions and requires low input.
2. Provides variety of products that include food, fodder, fuel wood, gums, resins, fibre, medicine etc.
3. Most of them are very rich sources of vitamins, minerals, and other nutrients such as carbohydrates, proteins, fats and nutraceuticals.
4. Vital source of genes against biotic and abiotic stresses.
5. Produce higher biomass than field crops per unit area resulting in efficient utilization of natural resources.
6. Can help achieving ecological security through improvement of wastelands by preventing soil erosion, improving fertility of soil and promoting biodiversity

Constraints in less known fruit crops cultivation

1. Poor awareness about the nutritional and medicinal value of underutilized fruit crops.
2. Less emphasis in researches for exploitation of potential underutilized fruits.
3. Lack of standardized propagation techniques in many such fruits and non- availability of quality planting materials (seed and vegetative parts).
4. Limited application of modern cultivation practices e.g. negligible use of innovative and novel technologies such as biotechnology, plasticulture for enhancement of productivity.
5. Lack of proper transportation facilities for an efficient supply of production inputs and timely disposal of produced in the market.
6. Lack of knowledge about suitable postharvest management practices. Under-developed marketing channels and infrastructure like storage facilities.
7. Non-competitive prices of produce of underutilized fruits.
8. Inadequate extension services for promotion of cultivation underutilized fruits.
9. Negligible set up of agro-industrial units.

Strategies for the promotion and cultivation of less known fruit crops

1. Creation of awareness about the nutritional importance of unexploited fruits through organization of special awareness camps/ campaigns, exhibition, etc., at micro and macro level, use of mass media like radio, TV, newspaper and distribution of other printed literature.
2. Emphasis on sustainable collection and use of various fruits from forests and domestication of potential wild species for avoiding overexploitation from natural sources.
3. More crop-specific systematic research and development efforts entailing conservation of genetics resources, improvement, production technology advancement, postharvest management, value addition etc., keeping in view the agro-climatic suitability of the region.
4. Independent tailor-made research for crops important for subsistence farming and those exhibiting potential to become commodity crops. Development of trait-specific varieties from the available gene pool to cater the intended demand.
5. Mass multiplication of planting materials and their distribution.
6. Expansion of infrastructure facilities with priority on market development, transport and communication.

Thus, it can be concluded that more attention is needed on exploitation of genetic resources of less known fruits. There is a tremendous scope of less known fruits cultivation in water scarce areas of the country. Under drought conditions, using lesser known plants in horti-pasture and agro horticultural system are suitable to fulfill the local demand of food, fodder and fuel besides several products of economic uses. The genetic resources may be utilized for crop improvement as a source of resistance, hardiness and vigour. The post harvest management of underutilized fruits is essential for value addition.

Characteristics and potential uses of less known fruit crops

Arid and semi-arid regions are considered as the hotspot for abiotic stresses, such as extreme temperatures, intense solar radiation, salinity, drought and nutrient deficiency, where the commercial fruit crops either fail to grow or struggle to express their potential performance. Under such climatic conditions, the integration of arid-zone less known fruit crops can be a better strategy to sustain the crop productivity under stress due to their typical morphological, physiological, anatomical and biochemical xerophytic characteristics that allow them to perform optimally under harsh climates. Therefore, adaptive traits such as those that increase the overall resilience and resistance to suboptimal environmental conditions do not necessarily result in a yield penalty. It is generally assumed that adaptive traits ensure yield stability in specific conditions, being fitness typically measured in terms of fertility, fruits and seeds. For instance, these traits include phenology shifts (flowering/ripening in a specific period of the year) and/ or morphological characteristics (root/shoot ratio, leaf macro and/or micro-morphological traits, etc.) that allow specific genotypes to escape environmental stresses (not necessarily involving an active and metabolically costly response to stress). This can result in the capacity of these genotypes to have fruits reaching ripening compared to those that did not have any adaptive trait. In order to cope with abiotic stresses, the arid-zone underutilized fruit crops, such as ber (*Zizyphus* spp.), aonla (*Emblica officinalis*), bael (*Aegle marmelo*s), jamun (*Syzigium* spp.) and wood apple (*Feronia limonia*), have modified and/or developed their organs to assure vital morpho-physiological functions (i.e., strong deep root system, a high root-to-shoot ratio for reaching into deeper moist soil layers and uptake more water and nutrients). Similarly, crops such asber, bael, lasora (*Cordia mixa*) and pilu (*Salvadora persica*) have round, thick and barked stems for easier water storage and reduced cuticle transpiration. Some crops such as kair (*Capparis decidua*), lasora, aonla and pilu have synchronized flowering and fast fruit development during the season characterized by larger moisture availability. Crops such as ber, phalsa and bael exhibit leaf shedding/ dormancy for reducing water loss in summer and for protecting the plants from frost in winter. Similarly, other underutilized crops possess numerous morphological characters, such as spines instead of leaves (ber), scanty foliage (kair), spiny cladodes (prickly pear), mucilaginous sap for reduced transpiration loss (kair, lasora, pilu, bael, etc.), small-sized and thick leaves, fur/hairiness and waxy coating on the leaf surface and sunken and deep stomata, for water saving through the reduction in transpiration rate and heat shocks (ber, phalsa, lasora, fig), and selective or reduced absorption of cation (Na+) and anions (Cl−, SO4 2−). These characteristics are also associated with the accumulation of osmolytes, compatible organic and inorganic solutes (proline, phenolics, flavonoids, soluble sugars, glycine, betaine, etc.), and biosynthesis of enzymatic and non-enzymatic antioxidants, heat shock proteins and drought-responsive genes to maintain cell turgor, allowing better survival under the adverse conditions of arid and semi-arid environments. In addition, the genetic basis of the adaptive traits deserves to be studied because this information could be used in future breeding programs that may also involve novel tools, such as genome editing. These lesser known fruit crops may represent the next generation of futuristic crops, which could enhance the farmer’s income through sustainable production systems even under a climate-change scenario.

Less known / climate smart fruit crops

The fruit crop like dragon fruit, kair, phalsa, pumello, bael, wood apple, aonla, karonda, barbados cherry and pomegranate are believed to be having a less moisture demand and have lesser transpiration rate. Hence, these crops can be the next generation climate smart fruit crop.

Dragon fruit/Pitaya (*Hylocereus undatus*)

This is a new emerging fruit of tropics and subtropics particularly in peri-urban and urban areas. The fruit belongs to the family cactaceae and have a high drought tolerance. In this succulent plant, leaves are modified to spine. Hence, the fruit crop has high drought tolerance. The fruit is borne in the junction of cladode when it reaches a certain height. In dragon fruit, the temperature and light intensity may affect the blooming. Dragon fruit can be grown at a high temperature up to 45^{O}C. Besides that, it can grow in rainfed conditions as well. It can be grown in rainfall up to 100-2000mm rainfall, with alternate dry and wet period (Swamy *et al*., 2004).

Phalsa (*Grewia subinaequalis*)

Phalsa is one of the most hardy fruit plant, drought resistant and thus requires little care with low inputs. It can be grown almost in all parts of north India except at higher elevations. It is mainly grown in the states of U.P., Bihar, Rajasthan, Haryana, Punjab, Gujarat, Maharashtra, Andhra Pradesh and Madhya Pradesh. Phalsa being very vigorous in growth can be an ideal plant for plugging gullies and ravines and for contours to protect bunds. The plants are deciduous and normally shed leaves on the onset of winter season and go on dormancy. But in warmer region plant does not shed leaves and there is no dormancy.

It can grow at temperature ranging from 3^o C to 45^oC. Plant can tolerate light frost. However, it requires protection from the very low temperatures.

Fruits are perishable and keeping quality is very less. Recently, variety 'Thar Pragati' has been identified for cultivation by ICAR-CIAH, Bikaner. It is dwarf, early precocious bearer (bearing in 3rd year), drought tolerant and suitable for high density planting. It is suitable for table and processing purpose. The fruits are highly perishable and are used in preparation of squash and juice.

Pummelo (*C. grandis / C maxima*)

The pummelo is tropical or near-tropical and flourishes naturally at low altitudes close to the sea. Pummelo can be grown successfully in semi-arid and hot sub-tropical regions as well. This can be attributed to the fact that among all other citrus species, it is having minimum water requirement. Beside that the flowering does not require critical or exact temperature requirement. It has a high heat requirement and can tolerate drought and heat waves. Pummelo is known to give sufficient fruiting even at 45 ^{O}C. The best thing with this citrus species is its extensive disease and pest resistance and it can be successfully grown in high temperature zones with scares rainfall.

Wood Apple [*Feronia limonia* (L.) Swingle]

Wood apple (*Feronia limonia* Linn. Swingle), syn. *Limonia acidissima* L. *Feronia elephantum* Correa, *Schinus limonia* L. belongs to family Rutaceae. The wood apple is native to India and common in the wild form in dry plains of India and Sri Lanka. In India, the fruit was traditionally a "Poor man's food" until processing techniques were developed in the mid-1950's. Systematic block plantation in the form of orchards of wood apple is uncommon. The wood apple is a small-to-moderate size, glabrous, deciduous tree with thorny branches, rough and spiny bark and it is able to grow on saline, poor and neglected lands normally unsuitable for fruit cultivation. It is the only species of the Citrus family that can tolerate both drought and salinity stress. Wood apple have the basic potential to withstand severe drought stress and can survive in dry soil as well. Wood apple is known to tolerate temperature as high as 45^OC. The fruit is processed as powder, preserve, squash, sherbet, beverage, jam, cream, leather, wine, toffee, candy, RTS, pickle and capsules.

Custard Apple (*Annona squamosa* L.)

Custard apple is one of the drought-hardy fruit plants belonging to the family Annonaceae, which is commercially cultivated in a limited area of the Indian Deccan plateau region. The light, gravel and small pebbles soil is also suitable for its cultivation. Its flower is borne mostly in new flushes after the shedding of old leaves commencing from March to August with a peak in April–May. The fruit is climacteric, it may be symmetrically heart-shaped, lopsided or irregular, and the interspaces between the protuberances become yellow at full maturity. The demand of custard apple fruit is increasing in domestic and international markets. Custard apple fruit contains vitamins A, B, C, E, and K1, essential minerals, antioxidants and polyunsaturated fatty acids. They are antimalarial, immunosuppressive, cytotoxic, diterpenes and are used to treat HIV. Moreover, a range of cosmetic products using custard apple is available in the market, such as perfumery, soaps, pimple creams, essential oils, hair lotions, etc.

Ber/Indian Jujube (*Ziziphus mauritiana* Lamk; Rhamnaceae)

The Indian jujube (ber) is one of the most ancient cultivated fruit trees in north Indian plains. It grows even on marginal lands or inferior soils where most other fruit trees either fail to grow or give very poor performance. It is regarded as the king of arid zone fruits and also as poor man's apple. There are three main species found in the country. The *Z. mauritiana* is the main species of commercial importance with its several varieties. *Z. nummularia* is prized for its leaves (rich in protein) which provide fodder (Pala) for livestock. The third one, *Z. rotundifolia* also bears edible fruits but of smaller size. It is used as rootstock for commercial Indian jujube. Jujube fruits contain fairly high amount of vitamin C, besides vitamin A, B, protein, calcium and phosphorus.

The ber tree is extremely drought-hardy due to the deep taproot system and xerophytic characteristics, such as (a) dormancy (leaf shedding) during the peak period of hot summer preventing transpiration, (b) waxy and hairy leaves, (c) thick bark. Ber fruit is mostly consumed as fresh within 4–5 days after harvest due to the short shelf life. Thus, it is necessary to develop a value-added product at a farmer-field or industry level, and there is the need to work on the diversification and popularization of jujube products.

Aonla/Indian Gooseberry (*Emblica officinalis* Gaertn.; Euphorbiaceae)

The aonla is being cultivated in India since Vedic Era. As a result of intensive research and development, it has attained commercial status and also proved to be potential fruit crop for arid ecosystem. It is hardy, prolific bearer and highly remunerative even without much care and can be grown in variable agro-climatic and soil conditions. Due to pure deciduous nature and hard physiology, the tree can withstand long dry spell. The leaves are having minimum surface area because of which the moisture loss due to transpiration is also low. Aonla can successfully tolerate frost and can be grown successfully even at temperature nearing 50^0C (Chaubey, 2000). The medicinal and therapeutic properties of aonla are considered as 'amritphal' or a wonder fruit for health. The aonla fruit is 3 and 160-times richer in protein and vitamin C compared to apples, respectively. It is the richest source of Vitamin C (500–1800 mg/100 g) among the fruits after Barbedos cherry, and the content in leucoanthocyanins, polyphenols, pectin, iron, calcium and phosphorus makes its fruit largely used in Ayurvedic medicines for making "Triphala" and "Chyavanprash". Aonla fruit is generally used to prepare a number of delicious, processed food products such as preserve, candy, jelly, toffee, pickle, leather, squash, juice, etc., and ayurvedic tonics such as Chayvanprash, Triphala, Amrit Kalash and Amol Ki Rasaya.

Kair [*Capparis decidua* (Forsk.)]

Capparis decidua Forsk belongs to the Capparidaceae family, and it is locally known as Kair, Ker, Karil Teent, Della, and Neptiin. It is an indigenous, multipurpose small woody perennial much-branched, leafless bushy shrub widely grown without much care on farm boundaries, orans, gochars and wastelands tracts of arid and semi-arid regions. Its xerophytic characteristics, such as deep root system, scanty foliage, mucilaginous sap and tough conical spine, make it an ideal plant for stabilizing sand dunes and controlling soil erosion by wind during the hot desiccating summer in the Thar desert of western Rajasthan. However, it easily survives in desert conditions characterized by temperatures ranging from −8 to +48^{o}C or more, drought, saline and poor nutrients soil ecological conditions. The kair fruit is used as a vegetable, pickles and condiments. Dried fruit is an important ingredient of a traditional vegetable of Rajasthan known as '**Panchkutta'**. Its fruit is rich in proteins, carbohydrates, fiber and minerals (Ca, P and Fe). It is used in medicine for sedation, anticonvulsant asthma, inflammation and cough.

Karonda (*Carissa carandas* L.; Apocynaceae)

Karonda is an evergreen spiny shrub or a small tree up to 3 m height and suitable for arid tropics and sub-tropics. It grows successfully on marginal and wastelands and locally known as Christ's thorn. Karonda can withstand temperature as high as 45^{O}C. The natural ability of the plant to withstand dry spell is remarkable. The tree can survive temperature extremities without any loss in reproductive vigor in upcoming season. It yields a heavy crop of attractive berry like fruits which are edible and rich in vitamin C and minerals especially iron, calcium, magnesium and phosphorus. Mature fruit contains high amount of pectin and, therefore, besides being suitable for making pickle, it can be exploited for making jelly, jam, squash, syrup and chutney, which are of great demand in the international market.

Karonda fruit is considered the richest source of iron (39 mg per 100 g), contains a fair amount of vitamin C and is used to cure of anemia and scurvy. In addition, they are a good source of calcium, magnesium and phosphorus and have high antioxidant activity. The mature fruit is suitable for making pickles and jellies due to the high content of pectin. They can also be exploited for making jams, squashes, syrups and chutneys, which have high market demand.

Bael [*Aegle marmelos* L. (Correa)]

Bael is the only species of the genus Aegle, which belongs to the family Rutaceae; it is one of the oldest indigenous fruits known by various names in different parts of India, such as billi, Bengal quince, stone apple, etc. Bael has a wide distribution in various ranges of edaphic-climatic conditions due to its ability to withstand heat, drought and low-temperature poor-nutrient soil. Natural thorny nature of the tree enables it to survive even in the harshest of climate. It is found growing vigorously in temperature well above 40^{O}C in dry areas. It is deciduous, medium-sized, slender, gum bearing with a cauliflorous fruiting habit, deep taproot system, bold thorny branches and trifoliate leaves. The bael fruit is a rich source of riboflavin used to cure beriberi, and unripe fruit is suggested to treat diarrhea and dysentery, whereas the marmelosin in fruit has therapeutic properties being a good remedy for stomach ailments. However, all plant parts of bael contain various compounds with medicinal values, e.g., coumarins, alkaloids, sterols and essential oils, that have analgesic, antipyretic, anti-inflammatory, anti-antifungal, microfilaria, hypoglycemic, anti dyslipidemic, antiproliferative, wound healing, insecticidal and anti-fertility abilities. Bael fruit is consumed only in processed products, such as powder, preserve, nectar, toffee. These products have had high market demand during the COVID-19 pandemic period due to its ayurvedic medicinal values.

Lasora (*Cordia myxa* L.)

Cordia, locally known as Gonda belongs to the Boraginaceae family and is grown across India except for the high hills and the temperate climates. It is known as Indian cherry, lehsua or goonda. Lasora leaves have sunken stomata and other characters of drought tolerance. Plants are deciduous in nature. Cordia is a fast-growing tree with a beautiful inverted dome/umbrella crown, utilized as an avenue tree and ornamental furniture; ovate, alternate and stalked leaves used as fodder during hot summer when green grasses are not available and also used as rearing lac insect. It is mostly used as green fresh vegetables and pickles, especially in the lean period when the availability of conventional vegetables is limited. The fruit is considered as a naturally rich source of antioxidants, i.e., carotenoids, ascorbic acid, phenols, and minerals, crude fiber, protein, ascorbic acid, ash and vitamins, which represent essential nutrients for human health and for curing certain human ailments (improve digestion, birdlime, anti-tumor, anti-helmentic, diuretic, demulcent and expectorant; improve hair growth).

Tamarind (*Tamarindus indica* L.)

Tamarindus indica is a dicotyledonous, monotypic, long-lived, semi-evergreen fruit plant belonging to the family Leguminosae. It has a wide range of adaptability, and it is an ideal tree for avenue plantation as a roadside, backyard and agro forestry systems. It bears terminal and lateral drooping bisexual flowers in May–June and forms fruit as pendulous pods ten months after fruit set. Tamarind fruit pulp and seeds contain tartaric acid, reducing sugar, tannin, pectin, cellulose, fiber, potassium, calcium phosphorous and other minerals, such as sodium, iron and zinc. The fruit pulp is the chief source for souring sauces, curries, chutneys, beverages, food colorants and it is considered a great delicacy. All its parts are valuable for food, fodder, timber, fuel, textile, nutritional and pharmaceutical industries, such as fluoride remover. Tamarind trees are planted as roadside avenue trees in the Banaras Hindu University, Varanasi, the largest university campus of India.

Jamun (*Syzygium cumunii* Skeels; Myrtaceae)

Jamun is an Indigenous evergreen hardy fruit tree that naturally grows in neglected and marshy areas. Deep loamy, well-drained soils and dry weather during the flowering and fruiting period are ideal conditions for its cultivation. Jamun is rich in biochemical compounds, e.g., anthocyanins, myrecetin, ellagic acid, isoquercetin, glucoside, kaemferol, and it is used for its anti-inflammatory, neuropsycho, anti-microbial, anti-HIV, nitric oxide or free radical scavenging, anti-fertility and antiulcerogenic activities. Glycosides in the seed, jambolin or antimellin, are considered to have anti-diabetic properties by halting the conversion of starch into sugar. Ripe jamun fruit is used to prepare many products, such as squashes, juices, jam, jelly, pickles and wines. In Goa and the Philippines, the fermented fruit of jambolans is used to produce Brandy and a distilled liquor called ‘jambava’ .

Mahua [*Madhuca longifolia* (Koenig)]

Mahua is an indigenous deciduous tree belonging to the family Sapotaceae and is characterized by medium-to-large-sized canopy, grey-black cracked bark, milky and short trunk and many-branched. It is a multipurpose tree, which fulfills the three basic requirements of tribal people (food, fodder and fuel). Mahua flowers are edible and highly nutritive, being a good source of sugars, vitamins, proteins, minerals and fats, and they are used as a sweetener to prepare numerous traditional dishes. Mahua dry flowers are also fermented to produce wine, brandy, ethanol, acetone and lactic acids. Mahua is also used in medicine for its hepatoprotective, antiburn, anti-skin disease and wound healing, emollient, bone healing, swelling gum, anti-ulcer and anti-snake bite.

Khejri [*Prosopis cineraria* (Druce.) L.]

Khejri or Jand/shami belongs to the Leguminosae family and is considered as the wonder tree, nature's gift, the king of desert and the golden tree. Khejri is an evergreen, slow-growing tree with exfoliated bark, rounded canopy, small and mucilaginous leaves and a strong deep taproot system that can reach extraordinary depths (up to 53 m or more). It was reported to be drought and salinity tolerant (10.0 to 25.0 EC dSm^{-1}). It is native to Arabia and the Indian Thar desert. It is a multipurpose tree as it provides a vegetable pod, flour, cattle fodder, fuel, timber, gum, resin and medicine. It is also used as fencing/ windbreak, avenue tree, on farm boundaries in water deficit areas, topiary, bonsai and screening trees in home gardening, and forest restoration in arid landscapes. It is a high litter accumulating tree and improves soil fertility through fixing atmospheric nitrogen, and these effects result in the increase in the soil content of organic matter, soluble calcium and available phosphorus and in a reduction in soil pH. Moreover, the Khejri tree is considered a productivity booster in inter-cropping and companion cropping systems thus it is highly suitable for agroforestry systems in arid and semi-arid regions.

Mulberry (*Morus* spp.)

Mulberry is grown throughout India but more extensive in Karnataka particularly Mysore especially for sericulture. In India, there are many species, of which *Morus alba* and *M. indica* are fully domesticated. All three mulberry species (*M. alba*, *M. rubra* and *M. nigra*) are deciduous trees of varying sizes. White mulberries can grow to 24 m and are the most variable in form, including drooping and pyramidal shapes. In the South on rich soils the red mulberry can reach 20 m in height. The ripe fruit of mulberry is highly appreciated for its delicious taste which is consumed fresh or after extraction of juice. Immature fruits are used for chutney preparation. Mulberry fruit is used to treat weakness, dizziness, tinnitus, fatigue, anemia, and incontinence (Krishna and Chauhan, 2015).

Chironji (*Buchana nialanzan;* Anacardiaceae)

Chironji is originated from the Indian subcontinent and has no specific requirements in terms of soil and climate. It is naturally found in the arid and semi-arid forests of Jharkhand, Chhattisgarh, Madhya Pradesh, Rajasthan, Gujarat and Uttar Pradesh. Chironji is a medium-sized, sub deciduous/evergreen plant with a straight trunk and coriaceous leaves. It is a deciduous tree which produces edible seeds. The fruit can be eaten both raw and roasted. It has the potential capacity to cure various diseases, such as snakebite, dysentery, diarrhea, asthma, burning sensation of body, fever, ulcers, cold and Alzheimer's, and it has anti-diabetic and anti-hyperlipidemic activity.

Manila Tamarind [*Pithecellobium dulce* (Roxb.) Benth.]

Manila tamarind is commonly known as Madras thorn Monkey pod and Jungle jalebi and belongs to the Fabaceae family. It is a multipurpose, fast-growing, medium-sized thorny tree used as live fencing, animal fodder, hardwood timber, windbreak and a potential source of lac culture. Its fruit has a sweet acidic taste and high content of dietary fiber, proteins, Ca, Fe, P, unsaturated fatty acids and antioxidants. Manila fruit is used to treat toothaches, mouth ulcers, sore gums, dysentery, chronic diarrhea, stress, aging symptoms and dark skin spots.

Khirni (*Manilkara hexendra* L.)

Khirni/rayan belongs to the Sapotaceae family, and it is a native to India, evergreen, medium-sized, slow-growing fruit plant with a spreading canopy. It is a wild plant found in the arid and semi-arid to tropical climate as an avenue tree and can be used as bonsai due to the evergreen, dense foliage and dwarf habit. It bears flowers in February–March, whereas fruit ripen in May–June, and it is commercially used as rootstock for sapota to exploit its tolerance to salinity and drought. Its bark, seeds and fruit are rich sources of tannins, oil and vitamin A, respectively. Khirni fruit and bark are used for numerous medicinal purposes, such as curing fever, flatulence, stomach disorder, leprosy, ulcers, opacity of the cornea, dyspepsia, urethrorrhea and bronchitis.

Table 1: Nutrient content of different minor crops (100 g $^{-1}$ fruit).

Different nutrient	Sources
Vit – A (retinol)	Persimmon (2710 IU), cape goose berry (1000-5000 IU), loquat (1528 IU), jackfruit (175-540 IU), tree tomato (150-500 IU), phalsa (419 IU), bael (55 mg)
Vit – B_{12} (riboflavin)	Bael (1.19 mg), Wood apple, ber
Niacin	Bael (1.1 mg), custard apple, wood apple
Vit – C (ascorbic acid)	Barbados cherry (1000-4000 mg), seabuckthorn (40-2500 mg), aonla (600 mg), Indian ber (50-150 mg), carambola, custard apple (37 mg), jamun (18 mg), phalsa (39 mg)
Calcium	Tamarind (0.74%). Karonda (0.16%). Wood apple (0.13%), bael (0.09%), aonla (50 mg), wood apple (130 mg), phalsa (129 mg), ber (30 mg), and date palm (0.3 g)
Phosphrous	Wood apple (110 mg), date palm (0.1 g), aonla (20 mg), karonda (600 mg), custard apple (23.5%) and tamarind
Iron	Karonda (39.1%), date palm (10.6%), ber (300 mg), sapota (2 mg), aonla (1.2 mg), phalsa (3.1 mg) and custard apple (1.9 g)
Organic acid	Aonla, jamun, tamarind
Protein	Wood apple (7.3 g), tamarind (3.1 g), custard apple (1.6 g), chironji and bael (1.8 g)
Carbohydrates	Dry karonda (67.1%), date palm (67.8%). Bael (31.8 g). Custard apple (23.5 g), jamun, phalsa (14.7 g), wood apple (15.5 g), ber (12.8 g) and tamarind (70.8 g)

Source: Das and Das (2006)

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Source: Das and Das (2006)

Conclusion

Global climate changes are likely to exert pressure on the fruit production system and may constrain in the attainment of future fruit production targets. These changes are natural but its control in our hand through several mitigation measures which reduce the concentrated gases in the atmosphere that are responsible for climate change and fruit crops have a great role in the mitigation of these gases through carbon sequestration by photosynthesis. At present, available adaptation, strategies can help to reduce negative impact in the short term but to a limited extent. Though minor fruits are popularly known as 'lesser known fruits' these fruits have great values both in nutritional and medicinal properties. However, in spite of rich germplasm existing in India, development of standard varieties is limited. Having a wide degree of adaptability with high degree of tolerance, they can thrive well under adverse climatic and edaphic conditions. These fruits also serve a potentiality in sustainable agriculture. Hence, research and development work, farmers awareness and feasibility for cultivation of these less known fruits are to be given due consideration.

Future thrust

Development of stable genotypes, which can perform across different environments within the region. Development of location specific rootstocks that can tolerate abiotic and biotic stresses induced by temperature regimes is needed. Adoption of improved agro-techniques like mulching and cover crops in orchards will help in bringing down the orchard temperature. It is feasible to grow cover crops of economic importance, which will also add to the income from the orchard. Use of precision farming methods like high- density planting and drip irrigation would help in providing microclimate with proved to be suitable against climate change.

Besides,

(i). Quantification of sensitive stages and sensitivity in fruit crops to weather aberrations.

(iii). Quantification of carbon sequestration potential of the fruit cropping system.

(iv). Monitoring the phenology of fruit crops under changing climate situation and location-specific weather forecast based on eco-friendly horti advisory and real-time for fruit crop monitoring is to be done in adhoc mode to address the issues related to climate change.

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8. Strategies for Enhancing the Use of Germplasm Collections in Crop Improvement

Hari D Upadhyaya[1]*, M Vetriventhan[2] and Andrew H Paterson[1]
[1]Plant Genome Mapping Laboratory, University of Georgia, Athens, GA 30605, USA
[2]International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, 502324, Telangana, India
*Email: hari.upadhyaya@uga.edu

ABSTRACT

Agriculture is vulnerable to global warming and depletion of natural resources. Global warming causes loss of agrobiodiversity, increased incidence of droughts and floods, and changes in pest dynamics, potentially reducing food quality and increasing the risk of food contamination (mycotoxins). South Asia and sub-Saharan Africa are particularly vulnerable to climate change and variability effects. The risk absorbing capacity of the farmers in these regions is low, and developing high-yielding climate-resilient cultivars with a broad genetic base together with judicious management of natural resources is an important way to address global food and nutritional security. Germplasm diversity contributes to developing improved crop cultivars aimed at increasing crop productivity. Globally, 7.4 million accessions are conserved in more than 1,750 genebanks. However, scant use (<1%) of assembled germplasm in breeding programs is a major concern, leading to narrow genetic bases of crop gene pools. The germplasm collections without sufficient information on traits of importance limit their utilization in crop improvement. Moreover, it is a time and resource-consuming task to evaluate a large germplasm collection for traits of interest. The use of appropriate strategies for tapping the potential of germplasm can enhance their utilization for sustainable agricultural productivity and nutrition. The development of germplasm diversity subsets such as core and mini core collections, focused identification of germplasm for a specific trait from the ex-situ collection using existing evaluation and climate data, and use of genomic tools for allele mining are some potential strategies for enhancing the use of diverse collections in crop improvement and for broadening the genetic base of crop cultivars.

Introduction

Germplasm is the total gene pool of a species consisting of landraces, advanced breeding lines, elite cultivars, and wild and weedy relatives. It forms the raw material for any crop improvement program and plays an important role in developing cultivars with the intrinsic genetic potential to mitigate the adverse effects of climate change on global agriculture. Plant genetic resources (PGR) contribute significantly to multiple sustainable development goals of the United Nations, towards achieving food, feed, nutritional and environmental security. Nikolai Ivanovich Vavilov was an early and exemplary advocate of the importance of genetic diversity for crop improvement and organized extensive germplasm collections of various crops from their 'centers of origin' and distribution for conservation. Since then, the germplasm collections of major crop plants continued to grow in number and size. Globally about 7.4 million germplasm accessions are conserved in 1750 genebanks (FAO, 2010). The international collections of plant genetic resources for food and agriculture (PGRFA) hosted by 11 CGIAR centers are important components of the United Nations Food and Agriculture Organization's global systems of conservation and use of PGRFA. By 2021, the 11 CGIAR institutions conserved over 739,000 accessions of crop, tree, and forage germplasm and are available under the Plant Treaty's multilateral system (https://www.genebanks.org/resources/annual-reports/). The diverse landraces, exotics and wild relatives hold a wealth of genes/alleles which, if included in breeding programs, can help raise the yield as well as enhance the stress resilience of agronomically superior cultivars. However, scant use (<1-5%) of assembled germplasm in breeding programs is a major concern, leading to narrow genetic bases of crop gene pools. Genetically uniform modern varieties are often closely related and planted in large areas, making them vulnerable to new pests, diseases, climatic conditions, and changes in market needs. This is mainly due to the availability of very limited information on traits of importance. Moreover, it is a time and resource-consuming task to evaluate a large collection for traits of interest. Thus, the use of appropriate strategies for tapping the potential of germplasm can enhance their utilization for sustainable agricultural productivity and nutrition.

Strategies for enhancing the use of germplasm collections

Several approaches are available for tapping the genetic potential of PGR. These include developing representative subsets of germplasm diversity such as core and mini core collections, and use of genomic tools such as genome-wide association study (GWAS), Eco-tilling, and genomic selection. These approaches maximize the probability of identifying appropriate germplasm and their utilization in crop improvement.

Core and mini-core collections

Among the 7.4 million germplasm accessions in genebanks, only limited use is reported in many crop breeding programs globally (Upadhyaya et al., 2006a). The elite cultivars of many major crops trace to very few founder genotypes – for example, 50% of wheat cultivars trace to 9 genotypes; 75% of potato to 4, and 50% of soybean to 6 (World Conservation Monitoring Centre, 1992). Similarly, in chickpea, 41% of cultivars from hybridization have Pb7 as a parent; in pigeonpea 41% have T1 and T190; in urdbean 64% have T9 and in mung bean 35% have T1. Limited numbers of germplasm lines were used in chickpea breeding programs including those of ICRISAT and ICARDA. At ICRISAT, only 91 germplasm lines were used to develop 3,548 advanced varieties from 1978-2004. L-550 (909 times) and K 850 (851 times) were the most widely used accessions (Upadhyaya *et al.*, 2006a). The main reasons for the low use of germplasm include the large size of collections and limited availability of reliable data on traits of economic importance, which show high genotype × environment interaction (Upadhyaya et al., 2013a). To overcome these problems, (Frankel, 1984) proposed the concept of core collections (10% of entire collection) that can be evaluated more extensively to identify promising germplasm. Ironically, a long-standing obstacle to the use of germplasm collections has been their size -- even the size of core collections is unwieldy for replicated multilocational evaluation to identify sources of variation for traits which show genotype ×environment interaction, as the large field areas required to evaluate thousands of lines inherently added to environmental variation. To overcome this, (Upadhyaya and Ortiz, 2001) proposed the concept of mini-core collections (10% of the core or 1% of the entire collection).

Developing core and mini-core collections

Upadhyaya and Ortiz (2001) proposed a two-stage strategy for developing mini-core collections, as follows:

1. Development of a core collection (~10%) from the entire collection;
2. Evaluation of the core collection for various morphological, agronomic and quality traits or need-specific characters and selecting a further subset of about 10% of accessions that sample phenotypic diversity.

At both stages, standard clustering procedures are used to identify groups of similar accessions (Fig. 1), to guide the sampling of diversity from the entire collection in the core or mini-core entries. The core and mini-core collections developed at the ICRISAT genebank are presented in Table 1. The core collection must be dynamic, thus a periodic review and modification of the core collection considering the increased size of and information about the collection, to add new diversity.

Table 1. Core and mini-core collections developed at the ICRISAT Genebank

Crop	Accessions	Traits	Core/mini core	Accessions	Reference
Chickpea	16,991	13	Core	1,956	(Upadhyaya *et al*., 2001)
	1956	22	Mini core	211	(Upadhyaya and Ortiz, 2001)
Groundnut	14,310	14	Core	1,704	(Upadhyaya *et al*., 2003)
	1704	47	Mini core	184	(Upadhyaya *et al*., 2002)
Pigeonpea	12,153	14	Core	1,290	(Reddy *et al*., 2005)
	1,290	33	Mini core	146	(Upadhyaya *et al*., 2006c)
Sorghum	22,473	20	Core	2,247	(Grenier *et al*., 2001)
	2,247	21	Mini core	242	(Upadhyaya *et al*., 2009b)
Pearl millet	20,766	12	Core augmented	2094	(Upadhyaya *et al*., 2009a)
	2,094	18	Mini core	238	(Upadhyaya *et al*., 2011c)
Finger millet	5,940	14	Core	622	(Upadhyaya *et al*., 2006b)
	622	20	Mini core	80	(Upadhyaya et al., 2010)
Foxtail millet	1,474	23	Core	155	(Upadhyaya *et al*., 2009c)
	155	21	Mini core	35	(Upadhyaya *et al*., 2011a)
Proso millet	833	20	Core	106	(Upadhyaya *et al*., 2011b)
Barnyard millet	736	21	Core	89	(Upadhyaya *et al*., 2014a)
Little millet	460	20	Core	56	(Upadhyaya *et al*., 2014a)
Kodo millet	656	20	Core	75	(Upadhyaya et al., 2014a)

Core and mini core collections developed using phenotypic traits vs those based on molecular markers

In early 2000, when the first author (Hari Upadhyaya) started developing core and mini core collections of the ICRISAT mandate crops and presented outcomes in international conferences and discussions, scientists often asked about the efficacy of phenotypic traits vis-à-vis molecular markers in sampling diversity to form the core and mini core collection. Our collaborative work at ICRISAT with the Generation Challenge Program helped us to genotype a large number of germplasm accessions of chickpea, sorghum (both 3000 accessions), groundnut, pigeonpea, pearl millet and finger millet (1000 accessions each), and foxtail millet (500) with 20-50 simple sequence repeats (SSR). The aim was to study genetic diversity, population structure and to establish reference sets of 200-400 genetically diverse accessions. To cite an example, the genetic structure, diversity and allelic richness in a world composite collection of chickpea (3000 accessions), using 48 SSR markers, was assessed and a reference set of 300 accessions was established at ICRISAT (Upadhyaya et al. 2008). The 48 SSR markers detected 1683 alleles in 2915 accessions, of which 935 were considered rare, 720 common and 28 most frequent. The composite collections were also characterized for qualitative and quantitative traits at ICRISAT Center, Patancheru, India. Reference sets based on SSR markers, qualitative traits, quantitative traits and their combinations were formed and compared for allelic richness and diversity. In chickpea, for example 48 SSR based reference set captured 78.1% of 1683 alleles in the composite collection compared to 73.5% of alleles in the reference set based on seven qualitative traits. The reference sets based on SSR and qualitative traits captured 80.5% (1354) of alleles in the composite collection. Similarly, in groundnut the SSR-based reference set captured 95.1% (466) of alleles in the composite collection (490) compared to 93.3% (457) of alleles in the reference set based on 14 qualitative traits. The reference sets based on SSR and qualitative traits captured 95.9% (470) of alleles in the composite collection. In pigeonpea, a reference set based on SSR data and consisting of 300 most diverse accessions, captured 187 (95%) of the 197 alleles in the composite collection. Another reference set based on qualitative traits captured 87% of the alleles in the composite set. This demonstrated that SSR and qualitative traits were similarly efficient in capturing the allelic richness of composite collections, and thus mini cores that were selected using phenotypic traits were as good as those based on SSRs.

A mini core collection as a source of diversity for crop improvement

Once the core and/or mini-core collection is available, researchers would have a manageable number of accessions to evaluate extensively and identify new variability and trait combinations. For example, the evaluation of 242 accessions of a sorghum mini core resulted in the identification of promising germplasm sources resistant to biotic stress (70 accessions), abiotic stress (12 accessions), and other traits such as bioenergy (13 accessions) and nutritional traits (27 accessions) (Upadhyaya *et al*., 2019). Similarly, in the groundnut mini core collection (184 accessions), 28 accessions were identified as resistant to abiotic stress and 30 to biotic stress (Upadhyaya *et al*., 2014b); and in the chickpea mini core collection, 40 accessions were reported as resistant to abiotic stress and 31 to biotic stress (Upadhyaya *et al*., 2013b). When an additional or new source of variability is required for a given trait, researchers can refer to the clusters from which the core collection accession came to select large numbers of accessions from the entire collection that are likely to have similar properties. This approach can increase the probability of identifying trait-specific sources from a large *ex-situ* collection. Mini core collections often meet the needs of plant breeders for variation in multiple traits. The use of diverse germplasm lines identified from a groundnut mini core resulted in developing exceptionally high oil (up to 63%, compared to ~48% in a control cultivar) and high-yielding breeding lines, indicating that new germplasm sources contribute to enhancing genetic gains.

Mining the ex-situ collection using genomic approaches

Advances in whole-genome sequencing and the availability of high-resolution and cost-effective genotyping platforms enabled large-scale genotyping of germplasm collections at low cost, time, and resources. Allele mining is the identification of allelic variation of relevant traits within genetic resources. It will help to trace the evolution of alleles, identification of new haplotypes and development of allele-specific markers for use in marker-assisted selection. Allele mining can be achieved through Genome-wide association mapping (GWAS), Eco-TILLING and genomic selection.

GWAS is a tool to link genetic markers to phenotypic variables in the population and further discover genes and alleles for traits of interest. It is possible to simultaneously screen many accessions for genetic variation underlying complete traits using the GWAS approach. The long history of recombination events captured in large germplasm collection, when combined with dense marker coverage, permits increased genetic resolution, sometimes to a level that allows causative sequence variant identification (Korte and Farlow, 2013; Ogura and Busch, 2015). Diversity subsets are the ideal genome-wide association mapping panel. Many researchers used either core or mini-core collection as an association mapping panel for the genetic dissection of complex traits in different crops. The ICRISAT sorghum mini core collection consisting of 242 accessions has been extensively used as an association mapping panel to identify marker-trait associations for anthracnose (Upadhyaya *et al*., 2013d), leaf rust, and grain mould resistance (Upadhyaya *et al*., 2013c), germinability and seedling vigour under low temperature (Upadhyaya et al., 2016) and biomass and sugar yield (Upadhyaya et al 2022). Genome-wide and candidate gene-sequencing-based association mapping approaches were used in chickpea to understand the genetics of drought and heat stresses (Thudi *et al*., 2014). A total of 312 significant marker-trait associations (MTAs) were identified and 18 SNPs from 5 genes were significantly associated with different traits related to drought and heat stresses (Thudi *et al*., 2014).

EcoTILLING is a reverse genetics approach, used to detect polymorphisms in pre-determined target genes in natural populations. It facilitates the screening of genebank collections for desirable traits. Isolation of natural sequence allelic variants in targeted candidate genes has been successfully demonstrated through EcoTILLING in many plants such as *Arabidopsis*, banana, *Populus*, field bean, mung bean, barley, potato, *Cucumis* spp, tomato, Sugar beet, chickpea and rice. For example, in rice, the EcoTILLING approach was used by targeting several genes known to be involved in salt stress signal transduction (OsCPK17) or tolerance mechanisms (*SalT*), finding a total of 15 SNPs and 23 InDels in OsCPK17 and SalT genes, respectively (Negrão *et al*., 2011). Allele mining for a panel of drought-related candidate genes in a set of 96 barley genotypes was performed using the EcoTILLING approach and identified 185 SNPs and 46 INDELs, organized into 94 haplotypes (Cseri *et al*., 2011). Based on overlapping haplotype sequences, markers were developed for four candidate genes (HvARH1, HvSRG6, HvDRF1, HVA1), which allowed distinguishing between the main haplotypes showing either differences in amino acid sequence or which have larger INDELs in the promoter region (Cseri *et al*., 2011). In Chickpea, a pool-based EcoTILLING approach together with agarose gel detection was used to discover SNP allelic variants from diverse coding and regulatory sequence components of 1133 transcription factor (TF) genes by genotyping in 192 diverse desi and kabuli chickpea accessions of a seed weight association panel, identifying eight SNP alleles in the eight TF genes regulating seed weight (Bajaj *et al*., 2016).

Genomic selection (GS) has the potential to enhance the use of desirable genetic variation in germplasm collections. Individual genetic material(s) that have been genotyped and phenotyped comprise the training population. The prediction model is then applied to a set of selected candidates that have been genotyped but not evaluated phenotypically (validation population). Following this approach, large germplasm collections may be efficiently mined for desirable traits to unlock the potential of plant genetic resources. Many researchers have used this approach to identify desirable traits from germplasm collections. For example, rust resistance (Muleta *et al.,* 2017), mineral contents (Manickavelu *et al.*, 2017), heat and drought stress adaptation (Crossa *et al.,* 2016) and seed morphometric traits (Kehel *et al.*, 2020) have been identified in wheat. The potential of GS depends on the accuracy of predicting genomic estimated breeding values (GEBVs). Prediction accuracy, measured as a correlation between the GEBVs and the observed phenotypes of the validation population, is affected by several factors, including the presence of strong population structure, the genetic relationship between training and validation populations, size of the training population, and marker density. (Muleta *et al.,* 2017).

Use of crop wild relatives

Wild relatives of crops continue to play a key role in crop improvement, contributing genes for adaptation to varied climate conditions, and biotic and abiotic stresses. For example, a recent study revealed the contribution of one wild species accession, *Arachis cardenasii* GKP 10017 originating from Bolivia, to the development of groundnut cultivars resistant to foliar fungal disease. The ICRISAT genebank obtained the GKP 10017 accession from USDA-ARS, registered as ICG 8216. From ICRISAT it spread globally and contributed to developing groundnut cultivars resistant to late leaf spot and rust in Africa, Asia, Oceania, and the Americas, providing widespread improvement of food security as well as environmental and economic benefits (Bertioli *et al.,* 2021). In groundnut, TXAG 6, an amphiploid, has been successfully used to enhance 100-seed weight (up to 87 g, cultivated parent ~ 40g), pod yield (up to 27% more than cultivated) and traits related to drought tolerance such as specific leaf area and SPAD chlorophyll meter reading. In pearl millet, there are continuous efforts to introgress disease resistance genes from crop wild relatives in the development of high-yielding and disease-resistant cultivars (Sharma *et al.*, 2020). Pennisetum wild species also contributed significantly to improving forage yield and quality. Interspecific hybridization between *P. glaucum* and *P. purpureum* has led to the development of forage hybrids with high biomass and better quality. The genetic potential of wild relatives of sorghum, particularly as sources of resistance to pests and diseases, is well documented (Kamala *et al.*, 2002, 2009, 2012). The sorghum wild species *S. propinquum* was used as a pollen parent for the development of perennial types of introgression lines at ICRISAT. Recombinant inbred lines of *S. bicolor* x *S. propinquum* (Kong *et al*, 2013) were crossed as pollen parents with four cultivars, Teshale, Macia, Lata and BTx623. The resulting F_1s showed rich variation for important traits. Hybrids flowered earlier and 15 of them yielded more (up to 22%) than the highest yielding parent (BTx623). The RIL 234, which has 75% of *S. bicolor* and 25% of *S. propinquum* alleles, increased seed yield in F_1 combinations with all four cultivars. This was not an artefact of the poor yield of the RIL itself, as the RIL 234 was among the highest-yielding RILs. Overall, the deep understanding of the wild species genetic resources and prioritization of traits for their utilization, trait discovery using high throughput phenotyping and molecular tools, the introgression of traits with minimal linkage drag, and the continuous supply of the new and diverse genetic variability derived from CWRs has much to offer to the breeding pipeline for further deployment in breeding programs.

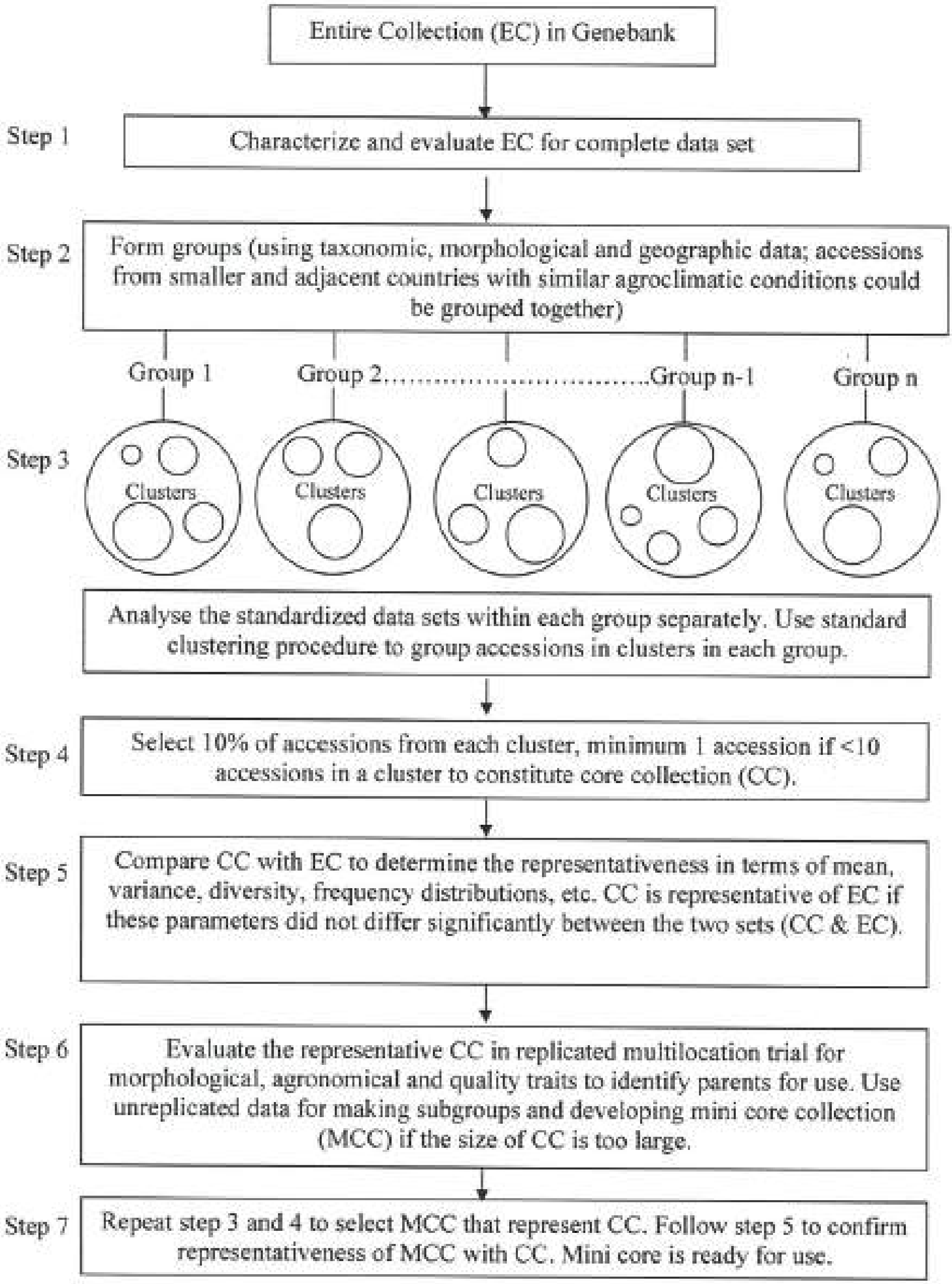

Fig. 1: Flow diagram to establish core and mini core collections in a crop species (adapted from (Upadhyaya et al., 2009)

Conclusion

To meet unprecedented challenges to global agriculture in the 21st century, new genetic variation for developing climate-resilient crops is required. Globally considerable numbers of germplasm accessions are conserved in genebanks. Genebank accessions harbour a pool of genetic variations for various traits. The use of appropriate strategies to develop germplasm subsets, high throughput phenotypic evaluation and genotyping can facilitate allele mining of germplasm for climate adaptation traits and yield and quality traits. The concept and process of forming mini core collections, which was recognized as an International Public Good, is very useful in identifying promising sources. Utilization of new diversity in crop improvement is required to broaden the genetic base of crop cultivars for sustainable agriculture.

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9. Genetic resources and sustainable production of underutilized fruit crops

Dandin S.B.
Senior Advisor, CIFOR-ICRAF, New Delhi
Formerly Consultant, Bioversity International Rome &
Former and Founder Vice Chancellor UHS, Bagalkot
Email: dandinbnm@gmail.com

Introduction

A total of 30,000 species were known to be used for food, fibre, fodder and various industrial purpose to meet the day-to-day requirements of humankind. As agriculture progressed, people started cultivating few crops in a larger area resulting in the narrowing of the crop biodiversity. Thus, only 30 crops are providing 90% of the world's food and energy. Three cereals namely; Rice, Maize and Wheat coupled with five animal species provide 60% of the food and energy. Shrinking of the diversity in commercial cultivation and in food baskets has resulted in the suffering of people on a large scale due to vitamin and mineral deficiency, micronutrient deficiency namely; Iron, Zinc, Iodine etc., along with Vit-A, B12 and D has become rampant, especially among women and children in underdeveloped and developing countries. Further, the situation is aggravated due to climate change effects where monoculture cropping has become more vulnerable. In view of the above, broadening the biodiversity base in general and fruit and vegetables in particular is imperative to overcome the challenges.

Fruits, the cheapest, natural and major source of nutritious food and health-supporting compounds including minerals and vitamins and constitute significant part of human nutrition and are highly recommended for a healthy and vitamin-rich diet (WHO,2004). As per the report of FAO (2016), overall per capita consumption of fruits and vegetables is lower than the recommended level of 400 g, as a result, a sizable population is reported to suffering from different health disorders. More than 600 million tonnes of fruits are produced all over the world each year and top six countries producing fruits are China, India, Brazil, USA, Italy and Mexico. Fruit crops are found distributed all over the world covering the tropics, subtropics and temperate climatic regions right from humid tropics to cold arid zones. Because of their better adaptability over a wider range of soil and climatic conditions, they have been contributing to food baskets in the regions of their distribution. Besides being a good source of food, they also yield other products like; gums, resigns, beverages, fiber, etc., which are of high economic value. Local people have recognized the role of this important component of biodiversity as the basis of their nutrition and livelihood. Because of the aesthetic and religious values of fruits, they have become part and partial of local religious functions and rituals (Pareek and Sharma, 2009). Other than the few major fruits which have been commercialized, large proportion of underutilized and neglected fruit species form the major components of biodiversity and provide immense support to ecosystem services. Local people especially tribals have contributed great deal of information and knowledge on multipurpose uses of wild fruits even as vegetables and pickles. Wine and local drinks are prepared after fermentation. Good number of the fruit species are also used for medicinal purposes to cure several chronic and serious health ailments. Traditional and ethnic food recipes developed for the preparation of several food products are becoming very popular in the present-day world. Fruit trees serve as an excellent source of pollen and nectar for honeybees and contribute immensely to honey as well as pollination services.

Vietmeyer (1990) and West Wood (1993) have reported that nearly 3000 tropical and 2400 temperate fruits and nut species are growing on this planet and hardly 30 are exploited commercially. Despite the large amount of fruit diversity found all over the world, hardly 28 species (7 tropical, 7 subtropical and 14 temperate) are only commercially exploited and more than 95% remain less known and underutilized (Pareek and Sharma 2009). Distribution of underutilized edible fruits and nuts is given for the 12 regions of diversity of cultivated plants by Zeven and de Wet (1982) and the same is shown in Table 1. Pareek *et.al.* (1998) listed 1750 species of underutilized fruits and nuts occurring in the 12 Vavilovian centres of diversity. Pareek and Sharma (2009) reported that, Asia and Pacific, Tropical Africa, Central and South America as the major regions of distribution of tropical fruit whereas the Himalayan region of South Asia, East and West Asia, Europe, Siberia, The Mediterranean, North Africa and North America for temperate fruits. Nagy and Shaw (1980) reported about 600 tropical and subtropical fruits in their respective areas of diversity.

Arora (1985) has reported 337 fruit and nut species belonging to 124 genera of 53 families occurring in tropical, subtropical and temperate regions of Asia. India, a rich biodiversity resource country has as many as 84 species of underutilized fruit species belonging to 34 families and 56 genera (Arora 2014). Arora and Ramanatha Rao (1998), Pareek *et.al.* (1998), Bose *et.al*. (2002), Bhagmal (2007) Vishal Nath *et.al*. (2008 & 2009), Chadha and Pareek (2009) and Pareek and Sharma, (2009) have dealt in detail regarding the minor fruits especially of tropical and subtropical region. Eyzaguirre *et.al.* (1999), William and Haq (2000) and Padulosi *et.al.* (2013) have suggested criteria for bringing them to the mainstream for commercial exploitation and livelihoods of smallholder farm families. CFF of Bioversity International and ICUC have drawn worldwide programmes to highlight the importance of Neglected and Underutilized (NUS) and several programmes have been initiated both at regional and national levels. The underutilized crops are being considered as 'crops of the future' because of their climate resilience, nutritional and health benefits and also income for small and marginal farmers.

Table 1: Underutilized edible fruits and nuts in different centers of diversity

Region	Species enumerated (No.)
Chinese-Japanese	222
Indochinese-Indonesia	226
Australian	57
Hindustani-Indian	344
Central Asian and Near Eastern	38
Mediterranean	30
African	131
European-Siberian	62
South American	263
Central American and Mexican	122
North American	255

Source: Zeven and de Wet (1982) in O.P Pareek, Suneel Sharma and R.K. Arora (1998) (eds).

Why do they remain neglected?

Among all the underutilized and neglected species (NUS), fruits occupy the second prominent place because of their abundant occurrence, wider distribution and larger number besides their importance as a granary of nutrients. These crops are being cultivated in a limited area by small and marginal farmers and tribals in local areas and some of them are still found in semi-domesticated conditions. Further, because of the large-scale popularization of very few fruit crops, NUS remained an orphan and did not attract the attention of researchers, extension agencies, policymakers and donor organizations. Cultivation of these crops became rear because of the following reasons:

- Under estimation of their potential use and non-availability of their botanical description.
- Low yield and poor income made them economically not viable for commercial cultivation.
- Restricted distribution to a small geographical area, especially in and around their center of origin.
- Consumed by a very small population, especially by tribals/local inhabitants.
- Inadequate research on improvement, multiplication, cultivation, nutritional potential etc.
- Deprived of modern processing and post-harvest technical know-how for value-added products.
- Promotion and popularization of very few fruit crops viz., Mango, Orange Apple, Grapes, etc for large-scale consumption.
- Continuous disturbance of ecosystem and habitat destruction has resulted in the disappearance of interspecific and intraspecific variability and in turn species themselves.
- Lack of marketing and policy support for popularization of these crops.
- Stigma attached as “foods of the poor”.

Why they are important now

- They are found harbouring nutritionally important elements.
- Due to increased food and nutritional insecurity.
- Their climate-resilient nature.
- Hardy crops adaptable to wider and harsh ecological conditions.
- Amenable for cultivation under different and integrated farming systems.
- Rich in nutraceutical values.
- Some of them are reported as a good source of medicine for curing important ailments.

International initiatives

Considering the importance of these minor fruits, Bioversity International has been working on the management of fruit tree Bioversity for the last 10 years and initiated good number of programs in temperate regions of Central Asia (Uzbekistan, Tajikistan, Kazakhstan, Kyrgyzstan, Turkmenistan and China), on tropical fruit tree conservation in South and South-East Asia (India, Indonesia, Malaysia and Thailand), in Latin America and In West and Central Asia.

The important programmes are

1. TFT UNEP-GEF Project (2009-2014). "Conservation and sustainable use of cultivated and wild tropical fruit diversity: promoting sustainable livelihoods, food security and ecosystem services".
2. Community Biodiversity Management (CBM).
3. IFAD-NUS Project in 4 Phases from 2001 to 2016. "Reinforcing the resilience of poor rural communities in the face of food insecurity, poverty and climate change through on-farm conservation of local agrobiodiversity".
4. BFN -UNEP-GEF Project (2012-2017). "Mainstreaming biodiversity for nutrition and health".
5. India UNEP Project 2016-2021: Mainstreaming agricultural biodiversity conservation and utilization in the agricultural sector to ensure ecosystem services and reduce vulnerability
6. Big idea on NUS-Fruit tree diversity for nutrition and food: A new proposal.
7. Neglected plants- food for the future.

Since, tropical and sub-tropical fruit crops are difficult to conserve as a seed, due to the inherent defects of seed production and viability, *in-situ* / on-farm conservation supported by *ex-situ* conservation in gene bank as backup is necessary. Further, challenges faced by large number of small holder farmers who are involved in on farm conservation need to be addressed. Accordingly, a programme on exploration, collection, conservation and characterization of the genetic diversity of the minor fruits of tropical and subtropical regions for sustainable use has been carriedout between 2014 and 2019 at its Bengaluru Project office. Exploration and collection of underutilized fruit species has been completed covering 26 districts of 7 states. 62 custodian farmers, 18 nurseries and 24 institutions have been visited for the study and collection of the material. Required onsite information is collected for the purpose of preparing the passport data and catalog

***Ex-situ* genetic diversity park**

An *ex-situ* genetic diversity park at its Bengaluru centre for conservation, characterization, food value analysis, mainstreaming, multiplication and distribution of these neglected and underutilized species of tropical and sub-tropical region. At the end of the year 2019, 220 varieties belonging to 100 species, 55 genera and 33 families of fruits have been collected and maintained in the genetic diversity park. (Table 4). Among them, family Anacardiaceae with five genera, five species and 20 varieties; Annonaceae with seven species and 24 varieties; Moraceae with three genera 11 species and 42 varieties; Myrtaceae with four genera 14 species and 34 varieties; Sapotaceae with three genera, five species and 13 varieties; Rutaceae with three genera, seven species and 14 varieties and Clusiaceae with one genera, six species and eight varieties are the dominant ones. Many of these species/varieties are yet to be studied for their multipurpose benefits as they are reported to possess high nutritional values and are potential source of vitamins, minerals, antioxidants etc. Some of the species are reported to possess medicinal properties and found useful in mitigating specific health disorders. Some of these species are still found in semi domesticated / wild condition. However due to ethnobotanical and medicinal properties, they have been grown traditionally in the kitchen gardens, backyards of houses and near water sources of the farm land. Jack, Clustered apple, *Garcinia*, Java plum (Jamun), Tamarind, Java apple (Rose apple), Drumstick, Ber, Lemons etc., are found commonly grown around the dwelling houses mainly because of their multipurpose use. Species belonging to the genus Garcinia, Morus, etc., have been used to extract industrial products. In the Annonaceae family, about five species are found cultivated in backyards or in kitchen gardens and serve as a rich source of seasonal edible fruits, *Annona muricata* which is exploited as a source of medicine used for curing cancer. For all the species maintained in the diversity park, the following information has been collected and furnished as per the details given below;

Information compiled for each collection

1. Botanical name.
2. Common name and vernacular (local) name(s).
3. Habit.
4. Origin and geographical distribution.
5. Flowering and fruiting period.
6. Mode of propagation.
7. Recognized varieties/landraces/farmer's varieties if any.
8. Source of germplasm material maintained.
9. Food/nutritional value composition.
10. Uses-as food, medicine, culinary, industrial, etc.

Nutritional composition and dietary value

The nutritional composition of these minor fruit crops has been analysed and reported by several workers to emphasize the importance of these crops. This information has been consolidated by Pareek et al. (1998). However, for several of these crops complete information is not available and for few, the information is totally lacking. Hence, information on nutritional composition needs to be accomplished as per the USDA National Nutrient database for standard reference, SR-15 (Table-2).

Table 2 : Components to be analysed for nutritional value (per 100 g edible portion)

Proximate principles	Mineral content	Nutritional vitamins
Energy (Cal)	Calcium (mg)	Vit. A (IU)
Water (%)	Iron (mg)	Thiamine Vit. B1 (mg)
Protein (g)	Magnesium (mg)	Riboflavin Vit. B2 (mg)
Total Fat (g)	Phosphorus (mg)	Pyridoxine Vit. B6 (mg)
Carbohydrates (g)	Potassium (mg)	Vit. C (mg)
Fiber (g)	Sodium (mg)	Vit. E (mg)
-	Selenium (mcg)	Niacin (mg)
-	-	Total Folate (mcg)
		Biotin (mg)

(Source: USDA National Nutrient Database for Standard Reference, SR-15

On-farm/ *insitu* Conservation needs involving custodian farmers

As per the interaction with farmers during exploration trips, the following aspects need to be considered for the empowerment of custodian farmers for effective On-farm/*In situ* conservation;

1. On-farm conservation is reported to be the cheapest and most effective method for sustainable use of this fruit diversity.
2. Documentation of farmer's practices along with associated traditional knowledge and their validation is imperative.
3. Need for capacity building and promotional opportunities.
4. Better publicity and recognition of custodian farmer's efforts/activities.
5. Long-term arrangements for the establishment of mother plot orchard, multiplication and supply of quality seed/planting material to harness this wealth.
6. Establishment of value chain and marketing facilities for sustainable income.
7. Networking of all custodian farmers with
    a. Other stakeholder farmers/Self - Help groups
    b. Nurserymen/Seed banks
    c. Marketing agencies
    d. Food industry

Since, the role of custodian farmers is imperative in sustainable production, commercialization and conservation, they need to be supported for better economic returns. Further, the minor fruit species needs to compete with popularly and commercially exploited species which enjoy maximum support in the form of subsidies, minimum support price, and post-harvest processing incentives etc., a level playing ground is essential for the popularization of these minor fruits to fetch good return to the farmer on par with other major fruit crops. Hence, it is imperative to extend the available policy support to these minor fruit crops. In addition to *in situ* conservation there is a need to establish *ex situ* genetic diversity in different regions of the country as source material to enhance research activities

Mainstreaming of potential crops

The ultimate objective of the study is to identify the potential fruit species and popularize them for inclusion in the daily food basket to improve the nutrition and health of the people. Eyzaguirre et al (1999), William and Haq (2000) and Padulosi et.al. (2013) have suggested criteria for mainstreaming the neglected and underutilized species. As per the suggested criteria, the important aspects to be considered are 1. Nutritional dance with good food and nutritional composition 2. Local adaptability for large-scale cultivation and yield potential 3. Market potential 4. Local acceptance both for cultivation and consumption and 5. The broad genetic base for climate resilience.

Based on the preliminary studies of all the species and varieties collected and maintained at the College of Horticulture, of UHS Bagalkot Bengaluru, in the first phase six species namely Jack. Custard apple, Ber, Jamun (Java plum) Tamarind and Drum stick have been identified as potential crops for mainstreaming (Table-3 and Fig.1). In-depth studies have been initiated on the characterization of all the available genetic variability along with landraces & wild relatives; Associated ethnobotanical and traditional knowledge;

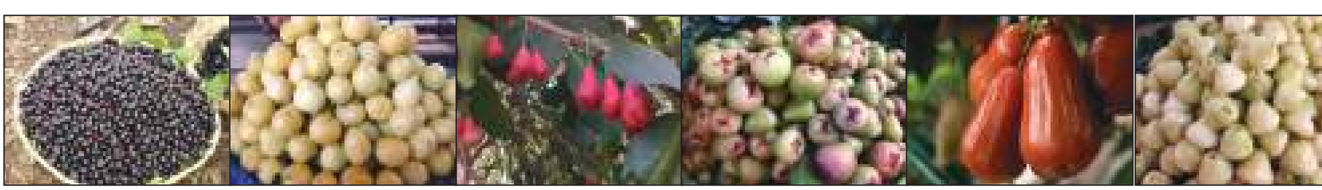
food and nutritional composition (Table 4), local food preparations and recipes; information of custodian farmers who are maintaining the germplasm of these species and good cultivation practices besides, the propagation protocols etc., has also been compiled.

Table 3. Potential underutilized fruits for mainstreaming

Crops	Species	Varieties
Jack - *Artocarpus* Species	6	32
Custard Apple - *Annona* Species	7	24
Ber - *Ziziphus* Species	3	08
Jewish Plum - *Syzygium* Species	9	17
Drumstick - *Moringa oleifera*	1	05
Tamarind - *Tamarindus indica*	1	05

Artocarpus altilis ***A. heterophyllus*** ***A. lacucha*** ***A. integer*** ***A. hirsutus***

Annona squamosa ***A. reticulata*** ***A. muricata*** ***A. cherimola*** ***A. galbra*** ***A. atemoya***



Syzygium cumini ***S. jambos*** ***S. malaccense*** ***S. malaccense*** ***S. malaccense*** ***S. malaccense***

Zizuphus mauritiana ***Moringa oleifera*** ***Tamarindus indica***

Fig. 1 Variability in few potential underutilized species

Table 4. Food and nutrition value of selected potential underutilized species

Food components	Jackfruit	Custard apple	Jamun	Tamarind	Ber	Drumstick
Water (g)	72-94	69-75	83.7-85.8	17.8-35.8	81-83	69.9
Calories (Kcal)	72-98	88-96	62.00	-	63.00	-
Protein (g)	1.3-2.0	1.53-2.38	0.7	2.0-3.0	0.8-1.8	2.5
Fat (g)	0.1-0.4	0.26-1.10	0.15-0.3	0.6	0.07	0.1
Carbohydrates(g)	16.0-25.4	19-25	14.0-16.0	41.1-61.4	14.17	3.7-8.5
Fibre (g)	1.0-1.5	1.14-2.50	0.3-0.9	2.9	0.6	4.8
Calcium (mg)	20-37	19.4-44.7	8.0-15.0	34.0-94.0	25.6	30.0
Phosphorus (mg)	18-38	23.6-55.3	15.0-16.2	34.0-78.0	26.8	110.0
Iron (mg)	0.5-1.1	0.28-1.34	1.2-1.62	0.2-0.9	0.8-1.8	5.3
Vitamin-A (IU)	152-540	5.0-7.0	80.0	-	34.0-35.0	184.0
Thiamine (mg)	0.03-0.09	0.1-0.13	0.01-0.03	0.33	0.02	0.05
Riboflavin (mg)	0.03-0.05	0.11-0.17	0.01	0.10	0.02-0.04	0.07
Niacin (mg)	0.4-4.0	0.65-0.93	0.2-0.29	1.00	0.7-0.9	0.2
Ascorbic acid (mg)	8.0-10.0	34.0-42.0	5.7-18.0	44.00	65.0-76.0	120.0

Cultivation practices

For popularization and commercial exploitation of these underutilized crops, identification and main streaming alone is not sufficient. For the identified potential crops, easy and quick method of propagation and multiplication, the region-based package of cultivation practices right from selection of site, variety and planting material to the harvesting of fruits, post-harvesting processing and development of value-added products are also equally important. All the icar institutions and fruit division of state horticulture and agriculture universities have developed propagation and cultivation practices for the major fruit crops. However similar information for the potential underutilized is not available and this aspect remains as a major bottleneck in the popularization of these crops. Except for the concentrated efforts of Narendra Deb University, Faizabad, CAHRI, Bikaner and its nested unit, IIHR, Bengaluru and UHS, Bagalkot where some attempts have been made to develop propagation protocol and postharvest processing., and cultivation practices, However, these attempts are limited to only few crops and there is a need to initiate large-scale activities in this aspect. ICAR, crop-based institutions ICAR, Horticulture Universities in the country, the National Horticulture Board and also State Department of Horticulture in major fruit-producing states must take the lead in this direction. The following aspects appear to have a place in future programs

1. Identification and short listing of suitable fruit crops and varieties to different agroclimatic regions of the country
2. Development of cost-effective propagation/multiplication protocol for each identified species
3. Establishment of a mother plant orchard of recommended crops and varieties

4. Starting large-scale nurseries either through private or government agencies or through the partnership in PPP mode
5. Development of a cultivation package for each crop to suit the identified local regin and which may include the recommendation starting from planting to harvesting of fruits
6. Post-harvest handling till marketing of the produce as most of these fruits are perishable with short storage qualities
7. To ensure their availability throughout the year to the consumer, the development of value-added products is also imperative
8. To improve production and strengthen the marketing network establishment of FPOs also may be considered

Way forward

Several organizations and researchers associated with biodiversity conservation for future prospectus are thinking loudly about broadening the biodiversity base of crops to mitigate the dual problem of health and nutrition insecurity and the adverse effects of climate change and also to support the livelihood of smallholder farmers. Hence, neglected and underutilized species (NUS) are assuming vital importance and being recognized as "Future Smart Foods (FSF). International Centre for Underutilized Crops (ICUC); Global Facilitation Unit (GFU), Bioversity International, Rome and FAO have started a large number of consultations and discussions both at Regional and International level for improvement and mainstreaming of these potential species. Thus, the following publications namely; Proceedings of International Consultation entitled "Enlarging the basis of Food Security - Role of Underutilized Species" held at MSSRF, Chennai, India (1999); Global Research on Underutilized Crops - An Assessment of Current Activities and Proposals for enhanced Cooperation by Williams and Haq. (2000) of ICUC; Neglected and Underutilized Plant Species: Strategic Action Plan of the International Plant Genetic Resources Institute, Rome, Italy IPGRI. (2002); Fighting Poverty, Hunger and Malnutrition with Neglected and Underutilized Species by Padulosi et al. (2013) of Bioversity International, and IPGRI/GFU/MSSRF. (2005); Meeting the Millennium Development Goals with Agricultural Biodiversity jointly initiated by International Plant Genetic Resources Institute; Global Facilitation Unit for Underutilized Species, Rome, Italy and M.S. Swaminathan Research Foundation Chennai, India, assume greater importance. This is mainly because of the fast erosion of biodiversity due to habitat destruction and imbalance in ecosystems all over the globe. In the recent publication entitled "Diversity in Underutilized Plant Species-an Asia-Pacific Perspective" (Arora, 2014) has given a good insight into the need for a global network in conservation and utilization of these crops.

The importance of underutilized plant species in general and fruits in particular to mitigate multiple problems namely climate change effects, health and nutrition insecurity, ecosystem services, small farmer's livelihood etc. is well documented. Now there is an urgent need for the worldwide network programme to address these issues as emphasised by Williams and Haq (2000), MDGs/SDGs goals, of UNO (2018) Padulosi et al. (2013) and several others. Bioversity International is making an all-round effort through a special "Big idea" programme of "Moving from orphan to high potential crops" (Un-Published Note No. EE/PO 1.2.1 of Bioversity International). This program is mainly aimed at Conservation, evaluation and mainstreaming some of these potential crops and making them more popular to substitute or supplement the major food crops covering Africa, Latin America, and Asia through active participation of custodian farmers and networking them. All the organizations/ institutions working worldwide on the subjects related to this vital aspect need to be networked and given responsibility to work in the local areas towards generating the needed information. Many of the CGIAR institutions, APAARI members and other NARS institutions need to be involved in this global program. Following are the few issues that need attention both at the global and regional levels and definite action needs to be drawn at the national level:

R and D issues

- Prioritizing the potential fruit crops country/region wise to address commonly accepted researchable issues.
- Documentation of available worldwide information on ethnobotanical aspects and traditional knowledge and exchanging the same among researchers working on underutilized fruit crops.
- Promoting the concept of on-farm/*in-situ* conservation of fruit biodiversity through custodian farmers and involving farmer-cum-nursery men for the production and distribution of quality planting material.
- Establishment of *ex-situ* genetic conservation parks in the different diversity-rich regions as a backup for future research and development needs.
- Concept of a virtual gene bank could be considered as a viable link between *in-situ* and *Ex-situ* conservation approaches.
- Initiating worldwide investigations on food composition and nutrition value and also analysis of special molecules available in these individual fruit crops and their varieties including their health-beneficial properties through a biomedical approach.
- Capacity building of custodian farmers in general and women in particular for consumption, cultivation, and conservation of these crops.
- Networking all the stakeholders in the value chain for better coordination and building organic linkages.

Policy issues

- Creation of a common global level platform for consolidation, sharing and exchanging of the available information on the status of the NUS of fruits.
- Developing an acceptable model of benefit sharing for better rewards to all the stakeholders.
- Developing a food value chain for better availability to consumers and good returns to the growers/ producers.
- Creating a level playing ground on par with other major crops by providing production incentives, minimum support price etc. which will enhance the visibility and availability of these crops.
- Convincing policy-making bodies to include some of these nutrient-rich underutilized crops in common/social food security programs such as public distribution systems, mid-day meals, hospital menus, grains for work etc.
- Attracting the attention of donors for liberal funding on research programs aiming at improvement, popularizing and mainstreaming these crops.
- By establishing a single global level body for initiating a long-term network programme for overall development and promotion of these crops as “Fruit crops of the future” or “Future Smart food”.

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10. Underutilized tropical and subtropical fruits of Asia

Sisir Mitra
Former Dean, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741 252, Nadia, West Bengal.
Email : sisirm55@gmail.com

subtropical fruit crops grown commercially in Asia are mango, banana, citrus, guava, grape, pineapple, papaya, and litchi which comprise more than 75 per cent of total area under fruit cultivation. There are quite a large number of underutilized fruit crops, which are being used by the local inhabitants. In fact for people living in villages, these underutilized fruits are the only source of protective food, to meet their vitamins and minerals requirements, in their poor diet. Because of their medicinal properties, these fruits have been used in Ayurvedic and Unani medicines since time immemorial. Apart from their nutritive and medicinal values quite a few of these underutilized fruits have excellent flavour and very attractive colour. In spite of these quality attributes most have not undergone any conscious phase of domestication and human selection. Their cultivation is very restricted and they grow mainly wild. Being tolerant to biotic and abiotic stresses, these fruit species are considered suitable for growing in the disaster- and drought-prone areas. In view of global warming, some of these crops could be the crops for the future.

Although some fruits have already been recommended for commercial planting, it is apparent that there are a lot more fruit types that await future exploitation. The more familiar one includes: jackfruit (*Artocarpus heterophyllus*), bael (*Aegle marmelos*), longan (*Dimocarpus longan*), dragon fruit (*Selenicerus* spp.), rambutan (*Nephelium lappaccum*), jamun (*Syzygium cuminii*), ber (*Ziziphus muritiana*), durian (*Durio zibethinus*), carambola (*Averhoa carambola*), aonla (*Emblica officinalis*), karonda (*Carissa congesta*) and phalsa (*Grewia asiatica*).

Introduction

Plant biodiversity represents the primary source for food, feed, shelter, medicines and many other products and means that make life on earth possible and enjoyable (WCMC, 1992; UNEP 1995). The number of plant species used by humans around the world is only one third of the number of species which generations of diverse cultures used around the world to meet specific needs. The centres of diversification of most common cultivated species are known today (Zeven and de Wet, 1982), but for many other species of local importance, the knowledge on the distribution of their genetic diversity and use patterns are still largely limited. Increased reliance on major food crops has been accompanied by a shrinking of the food basket which humankind has been relying upon for generations (Prescott-Allen and Prescott-Allen, 1990). This nutritional paradox has its roots in the agricultural "simplification", a process that favoured some crops instead of others on the basis of their comparative advantages for growing in a wider range of habitats, their simple cultivation requirements, easier processing and storability, nutritional properties, taste, etc.

Around 10 plant species meet the food (calorie) requirements out of nearly 600 species of major and minor crop plants at present being utilized (Paroda and Bhag Mal, 1993). The short list of most commonly used food plants is even smaller, including a mere 20 crops (Wilkes, 1984). The other, underutilized crops could also have an important role to play as new promising crops due to their consistent use in lesser common farming situations and subsistence agriculture practiced by poor farming households

(Mitra *et.al.,* 2020). If the 20th Century witnessed the undertaking of systematic collecting to rescue the genetic resources of staple crops (Pistorius, 1997), the 21st Century has started with the awareness on the need to rescue and improve the use of those crops left aside by research, technology, marketing systems as well as conservation efforts. These underutilized crops (referred to also by other terms such as minor, orphan, neglected, underutilized, underexploited, underdeveloped, lost, new, novel, promising, alternative, local, traditional, niche crops) have been included in world-wide plans of action after having successfully raised the interest of decision makers. Leading international research organisations such as Food and Agricultural Organization (FAO), International Centre for Underutilized Crops (ICUC), International Tropical Fruits Network (TFNet), the Consultative Group on International Agricultural Research (CGIAR) (Swaminathan, 1999), and others are taking a keen interest in strengthening the work on these species.

The countries in Southeast Asia and their neighbours, endowed with a climate conducive to many tropical and subtropical plants, are the centers of origin of many fruits trees. India is the home of world's most useful plants thriving in her diverse agro-ecological zones and altitudes – in the monsoon tropics of the south to temperate and alpine north–western Himalayas, from the extremely arid and semi-arid north-western plains to the humid tropics of the east. The several less-known fruit species which have the potential for commercial exploitation are yet to be utilized to their potential (Pareek and Sharma, 1993). Most of these species have wide adaptability as well as high degree of tolerance and hence can thrive even under most adverse situations. These fruits are the only source of protective food for people living in villages to meet their requirements of vitamins and minerals. Because of their curative properties, these fruits have been used in Indian traditional system of medicine such as Ayurvedic and Unani. Apart from their nutritive and medicinal values (Mitra and Rajendran, 2018), quite a few of these underutilized fruits have excellent flavour and attractive colour and are suitable for several processed products. In spite of these quality attributes most have not undergone any conscious phase of domestication and human selection. A few of the underutilized fruits e.g. durian (in Thailand, Vietnam, China), longan (in China, Thailand, Vietnam), carambola (Malaysia, Vietnam), jackfruit (Bangladesh, India, Sri Lanka, Malaysia), ber (India, China, Taiwan) and dragon fruit (Vietnam, China) have already gained importance and are commercially grown and marketed.

A workshop on "Underutilized Fruits and Nuts in Asia" was organized in Dhaka, Bangladesh in July 1992 jointly by the Commonwealth Science Council and International Centre for Underutilized crops, UK. The decision to held the workshop arise from the consideration that while Asia has a wealth of fruit and nut species, the majority are underutilized and often available only in local markets. The development of underutilized fruits could not only contribute to crop diversification, farm incomes and the improvement of nutrition, but also provide valueable exports and additional employment on the land and in postharvest processing and marketing. The workshop also defined "underutilized" as (i) crops that are cultivated locally, but that are underutilized, (ii) commonly cultivated crops for which new uses can be identified (value added products for example), (iii) crops that are not presently cultivated in a particular country or region, but whose value has been proven elsewhere under similar climatic condition and (iv) species that are harvested from the wild. It follows that the definition of underutilized depends on the country or locality, what is considered underutilized in one area may not be in another. The following are some of the important underutilized tropical and subtropical fruits of Asia which await future exploitation.

JACKFRUIT (*Artocarpus heterophyllus*)

Jackfruit belongs to Moraceae family. The tree grows wild in the rain forests of the Western Ghats of India. It is now widely cultivated throughout the tropical low land in both the hemispheres (Mitra, 1998). The major jackfruit producers are Bangladesh, India, China, Thailand, Myanmar, Indonesia, Sri Lanka and Malaysia. In the Western Hemisphere, except for Brazil and parts of West Indies, it has never been more than a curiosity.

The genus *Artocarpus* (X=14) comprises some 50 species of tropical monoecious evergreen trees. Jackfruit, with its many and varied uses, is a favourite fruit. The perianths (bulbs) are eaten fresh when ripe and young fruits are used for making vegetable curry, pickles and many other culinary preparations. A number of value-added products developed from jackfruit are increasingly in use. Technologies for development of jam, jelly, squash, RTS, fruit candy, fruit roll, halwa, fruit cheese, fruit murrabah, pickle and pappad have been standardized. The dehydrated, shredded ripe bulbs can be stored for a longer time and are used for preparation of fried chips. The outer peel of ripe jackfruit is used as cattle feed and the seeds are eaten boiled or roasted. Starchy flour is also made out of mature seeds. The timber of jackfruit is a prized wood for making furniture and for other uses as door frames etc. The leaves of jackfruit trees are commonly used for feeding goats and sometimes used as elephant fodder. The latex from the bark contains resins which is used to plug holes in earthen vats and buckets. Thus, the tree is useful to the people in many ways.

Since jackfruit is an allotetraploid, it is highly heterogenous and propagation through seeds has resulted in generation of large variability. There is no named cultivar of jackfruit. The types differ according to shape (conical, roundish, oblong); bearing (irregular, regular, thrice a year); peel colour (greenish, brown, brownish); fruit weight (2.5-16 kg); yield (15-1450 fruits); bulbs/fruit (35-380); TSS (15-32%); acidity (0.10-0.40%); flavour and taste (Mitra and Mani, 2000). Several selections like Siddu, Shankara, Swarna Halsu, Konkan Prolific, Palar 1 Jack, PPI-1 Jack, Lalbaugh Madhura, Nelugudigae, Ramachandra, NSP, JT5, JT40, JT42, Swarna Monahar, Swarna Poorti etc. have been developed by different institutes and universities in India. In other growing countries e.g. Malaysia (varieties Mantin, Mastura, Takam Yellow), China (varieties Changyou, Siji, Xiangmi No.1, Xiangmi No. 17) Philippines (EVIRAC Sweet, Burabod, Cerventes Gold), Vietnam (Sieu Som, La Bang, Vien Linh, Mit Dua), Sri Lanka (Father Long, Maharagama, Kothmale, Hirosa) and in Bangladesh (Bari Kanthal 1, BAU Kanthal 1) have been developed (Mitra, 2023)

Jackfruit can be grown in almost all types of soil, even suitable for wastelands, dry and semiarid condition. It is possible to propagate jackfruit by different vegetative propagation methods like cutting, air-layering, stooling, grafting and budding. The tree usually starts bearing between six to eight years after planting. The flower appears between December and February. However, in some types, flowering may occur two to three stages in a year (Mitra, 2000). Jackfruit is a monoecious tree, numerous flowers are borne on club shaped rachis. The female spikes are borne on fruit-stalk while the male spikes appear both on fruit-stalks as well as on the terminal branchlets. The axis of the inflorescence, the ovaries and perianths all grow simultaneously and develop into a multiple fruit, botanically called a sorosis.

Immature fruits are usually harvested during the spring to be used as vegetable. The fruits usually take 90-100 days to reach maturity and harvesting is done by cutting off the fruit-stalks carrying the fruits. A jackfruit tree at its full bearing stage may produce 200-500 fruits annually. Jackfruit have storage life of 3 to 10 days. However, at 11-12^{o}C temperature and 85-90 per cent relative humidity, fruits can be stored for 20-30 days.

LONGAN (*Dimocarpus longan*)

Longan is a subtropical fruit of Sapindaceae family. It is a highly esteemed arilloid fruit species in Asia. There is no complete agreement as to the exact origin of the longan. It is believed to be originated in mountainous China from Myanmar through southern China or between southwest India and Sri Lanka. The crop is mainly grown in southern China, Taiwan, Thailand with small plantations in Vietnam, Cambodia, Laos, Queensland (Australia) and Florida (United States) (Mitra and Pan, 2018)

Longan can be eaten fresh, dried or quick frozen. The fruit can be peeled, pitted and canned. The juice of most cultivars is sufficiently sweet for processing without addition of sugar. Dried longan is one of the main exportable items of Thailand.

There are over 300 to 400 longan cultivars in southern China and about 30 to 40 are cultivated commercially. Chuliang, Wu Yuan, Fu Yan, Biew Kiew, Chompoo, Yang Tao Ye are the important cultivars of longan grown in China, Thailand and Taiwan. NRC for Litchi, Bihar released the first longan variety 'Gandaki Longan 1 and recommended for its cultivation in India (Nath et.al., 2018). The preferred method of vegetative propagation in Thailand is marcottage. In China and Australia, the preferred methods are budding and whip and tongue grafting. Tree spacings vary from 50-300 trees ha^{-1}.

Orchards in China and Thailand in an 'on' year consider pruning and thinning of flower buds and fruits as one of the most important techniques to overcome the alternate bearing phenomenon. Flowering of longan in China and Thailand occurs during December to March (southern hemisphere equivalent: June to September) and fruit matures from July to September (January to March). Trees from marcottage normally commence cropping three to four years after planting. In Thailand, the average yield in well-grown orchards is 120kg for a mature tree.

RAMBUTAN (*Nephelium lappaccum*)

The rambutan or hairy litchi is a delicious, juicy fruit of fairly good quality. The white translucent, sub-acid sweet flavoured aril is the edible flesh of the fruit. It belongs to Sapindaceae family, indigenous to Malayarchipelago. From Malaysia, the centre of production, it spread westwards to countries, such as Thailand, Myanmar, Sri Lanka, India and eastern Vietnam, Philippines, Indonesia and Hawaii. (Mitra, 2017)

Rambutan mainly serves as fresh fruit or a desert mixed with other fruits or is used for canning or made into fruit syrup. The oil of its seed is used for soap-making. The root has medicinal uses while the tannin it contains is used for dyes. There are many named cultivars of rambutan in southeast Asian tropical region. Some of the important cultivars are Seematjan, Lebakboeloos, Si Chomphee, Rong Rian, Si Thong, Seekonto, Rongrien, Seenjonja etc. In India, ICAR-CHES has selected CHES-14, CHES-27, and CHES-31 (Karunakaran *et.al.*, 2016)

The asexual propagation of rambutan includes patch and forkert budding and inarching. Rambutan is usually planted at 8m x 8m or 6m x 6m (with regular pruning) distance. Planting of different cultivars in orchard, to enhance pollination, is advocated.

In Thailand, the rambutan produces fruits twice a year, the first, main crop is in June and a lesser one is in December. The fruit growth and development period require 90 to 120 days after full bloom. Yield may vary from year to year. Individual trees, 8 years old or older, can produce as much as 200kg fruit tree^{-1} year^{-1}. After harvesting, fruit stalks should be trimmed down as close to the fruits as possible. Keeping the harvested fruits within a plastic film of sufficient thickness to avoid water loss at a temperature of 13-15^{0} C will prolong the shelf life of the fruits destined for market.

BAEL (*Aegle marmelos*)

Bael belonging to genus *Aegle* and family Rutaceae, consist of 2-3 species of which only one is cultivated. It grows wild in sub-Himalayan tracts of the central India, Sri Lanka, Pakistan, Bangladesh, Thailand and most of the South East Asian countries.

Bael is known for its high medicinal and nutritional properties. Almost every part of the bael tree is used. The fruit is very rich in sugar, riboflavin (Vitamin B_2) and minerals. The ripe fruit is a tonic, restorative, laxative and good for heart and brain. The mature fruit is astringent, digestive and stomachic, and is usually prescribed for diarrhoea and dysentry. Ripe fruits can be used for the preparation of beverages (ready to serve nectar, squash) and toffees. The unripe fruits are commonly used for the preparation of preserve, candy and dry products (powder). Bael fruit peel constitutes about 20-25% of the total fruit weight depending upon the varieties/genotype. The peel being very hard is not liked by animals as such. However, it can be fed to animals in ground form. The ground form mixed with concentrate is relished by cattle (Kaushik and Dhawan, 1996).

The bael tree has wider adaptability to adverse soil and climatic condition. It can be grown on poor and neglected soils including waste lands without much care and inputs. They can survive in soil having sodicity up to 30 per cent exchangeable sodium and salinity 9 dSm^{-1} Ece. They can be grown up to an altitude of 1200 m, not much influenced by freezing temperature (Singh and Ali, 1992).

Most of the bael tree available in India are seedling type in origin which caused great variability. A few selections have been made in Uttar Pradesh, Bihar and West Bengal (Srivastava *et al.*, 1998) and Gujarat (Singh *et al.,* 2023). The important selections are Narendra Bael-5,7, 9,16 and 17; Pant Aparna, Pant Sujata, Pant Urvashi, Goma Yashi, Thar Divya, Thar Neelkanth, Thar Srishti, Thar Prakriti, Thar Shivangi, CISHB-1 and 2 etc. Extensive exploration conducted in various states indicate considerable variability in physico-chemical characters, like fruit shape (spherical, semi-spherical, flattened-round, elleptical, oval, oblong, pyriform); length (6-26 cm); width (4-20 cm); weight (0.4-3.2 kg); fibre, more to less, muscilage, less to high; seeds, few to numerous (10-300); pulp (40-60%); fibre content (1.4-7.6%); acidity (0.36-0.80%); vitamin C (14.0-20 mg/100 g); TSS (20-46%); flesh colour (creamy-yellow, whitish-yellow, deep yellow); peel thickness (1.0-4.0 mm); stem end cavity, shallow to deep. Diversity also exists in vegetative growth, leaf shape, spread, fruiting habit, maturity period (February-September) and productivity. Due to severe deforestation and genetic erosion in wild types, bael needs proper evaluation and conservation of genetic diversity.

Normally, a seedling tree bears after 7-8 years while the vegetative propagated plants start bearing 4-5 years after planting. The flower appears in the month of May-June and the fruit matures in next April-May. A 12- to 15-year-old bael tree produces 300-500 fruits. Ripe bael could be made available 2-3 months ahead of normal ripening by treating the fruits with ethrel at 1000-1500 ppm and keeping the fruits at 30^{o}C after harvesting them in January. It takes 18-24 days for the fruit to be artificially ripened (Mitra, 1999).

AONLA (*Emblica officinalis*)

Aonla is the oldest minor fruit of India. The tree is hardy, prolific bearer and a suitable choice for arid regions of India (Mitra, 1999). Aonla fruit is a rich source of vitamin C (500-600mg/ 100g). It also contains proteins and different minerals like calcium, phosphorus and iron. The high vitamin C content of fruit makes its wide use in Ayurvedic medicine. The fruit contains kaempferol, quercetin and rutin. All these compounds are partial cardiotonic. The fruit also contains phyllemblin, which regulates blood pressure and respiration in normal tune. The fruit is however, not consumed in the fresh form due to its highly acidic and astringent taste. More than 50 processed products are prepared from aonla fruits to exploit nutritional qualities. Conventionally, aonla fruits are used for preparation of murabba, *Chyavanprash*, powder, chutney etc. However, they can be used for products like candy, segments in syrup, supari and churan (Tandon and Sood, 2003).

Aonla is a deciduous tree of family Euphorbiaceae. Aonla is believed to be originated in India and is distributed to Sri Lanka, Cuba, Puerto Rico, USA (Hawaii and Florida), Iran, Iraq, Pakistan, China, Malaysia, Thailand, Vietnam, Philippines, Trinidad, Panama and Japan. The crop has extensive adaptability to grow under diverse climatic conditions ranging from hot tropical plains to humid subtropical mid-elevation hills.

Since very little attention has been give for systematic development of aonla, existing variability are not conserved. Aonla has been propagated by seeds, thus, variability exists for size of trees, size of fruits, colour of fruits, yield and tolerance to insect, pest and diseases (Singh, 2003). Superior selections like Kanchan, Krishna, Chakaiya, Neelum, Balwant, etc. were made which has become a base of commercial cultivation of aonla in India.

Aonla can be propagated both by sexual and asexual methods. Soft wood grafting and patch budding are in use. Grafts or budding are planted at 10 m x 10 m. Flowering occurs on determinate shoots of spring-season growth in the month of March. Although, fertilization completed within 36 hours of pollination, the embryo remain dormant and ovary showed no symptom of growth for about four to four and half months. The fruit growth started at the end of August and continued up to November.

Aonla plants start bearing quite late, usually after 8-10 years when raised from seeds. The budded plants started fruiting early i.e., after 4 to 5 years. The fruits are light green at first, when they mature, the colour becomes dull, greenish-yellow or rarely brick-red. If the fruits are allowed to remain on the tree till the next flowering takes place, it gives a false impression that the fruits are from current season flowering. The mature fruits are hard and unyielding to the touch and so are well suited for bulk harvesting as well as distant transportation and marketing. Aonla fruits can be stored at 0 to 2^{o}C and 85-90% relative humidity for 8 weeks. A full-grown grafted tree produced about 200 kg fruits every year.

BER (*Ziziphus muritiana*)

Ber is an ideal fruit tree for arid and semi-arid regions in tropical and subtropical climate where most of the fruit crops cannot be grown either due to lack of irrigation facilities or adverse climate and soil condition. Central Asia is believed to be the origin of ber which includes north-west India, Afghanistan, areas of Tajikistan, Uzbekistan and China. It is mainly grown in India, different countries in Central Asia, China and Taiwan. The genus *Ziziphus* belongs to the family Rhamnaceae. The fruits of *Z. mauritiana* is rich in minerals and vitamin-C. The fruits are mostly eaten fresh but the other forms, such as dried, candied, pickled and other products like squash or juice and ber butter can also be prepared and used. The leaves are used as a fodder in the dry region and the tree is a host plant for rearing of the lac insect (*Laccifer lacca*).

The important cultivars includes Gola, Umran, Nazuk, Chhuhara, Banarasi Karka, Narma, Seo, Thornless, ZG 3, Chonchal, Noki, Narma Banarasi, Ajmeri, Chameli, Aligang, Darakhi etc. Budding (shield budding) has been found to be the best and commercial method of ber propagation. The different *Ziziphus spp.* Like *Z. oenoplia, Z. rugosa, Z. xylocarpa* are used as rootstock. Planting is usually done at 5m x 5m or 6m x 6m spacing. The ber fruit is borne in the axils of leaves on the young growing shoots of current season. Therefore, a regular annual pruning in ber is very much necessary to induce a good and healthy growth which will provide the maximum fruit bearing area on the tree. The fruit growth and development period tooks about 100-130 days depending on the cultivars and climatic condition. The maturity indices of ber fruits are attainment of full size of a particular cultivar with softening of pulp and development of characteristic yellow or golden-yellow colour. The average yield from10 to 20 years-old trees of different ber cultivars varies between 80 and 200kg tree^{-1} year^{-1}. Ber fruits can be stored for 20-30 days at 1^0- 3^0 C temperature and 85 -90 per cent relative humidity.

CARAMBOLA (*Averrhoa carambola*)

Carambola, belonging to the family Oxalidaceae is native to the Indochinese – Indonesian centre of origin of cultivated plants. Carambola is currently growing in the tropics and subtropics between latitudes 0^o and 30^o North and South. The important countries includes are Malaysia, Taiwan, Australia, India, southern China, Thailand, Florida, Hawaii and Brazil.

Carambola content a relatively high oxalic acid and sour in taste which makes it little commercial value for consumption as a fresh fruit. However, new sweet-flavoured cultivars with a low oxalic acid content are rapidly becoming popular. Fruits are important sources of minerals like potassium, iron, calcium, sodium and phosphorus.

The acid types are only consumed after cooking, and the sweet carambolas are ideal for fresh consumption. Vacuum packing fresh slices of carambola is largely use in restaurants.

The carambola is a slow-growing evergreen and relatively small tropical tree, rarely exceeding 8-9 m in height. The trunk is short, sometimes twisted, with smooth, grayish, coffee or dark-coloured bark.

The important cultivars of carambola are Arkin, B-2, B-10, B-17, Golden Star, Kaput, Demak, Hong Hug, Far Dee, Jungle Gold, Thai Knight, Tean Ma etc. Carambola grows best between 21^o and 32^oC temperature with annual rainfall between 1500-3000 mm.

Carambola can be propagated by seed, budding (chip), grafting (side, top, approach) and air-layering. Normally the trees are planted at 9 m x 9 m or 10 m x 10 m spacing, however, 7 m x 3 m or 6 m x 3 m are also possible for high density orcharding.

Fruits are harvested when 50-70% of the surface coloured (colour may vary according to cultivars). The optimum storage temperature range for carambola is between 5 and 10^oC. The cvs. Arkin and Golden

Star can be stored for up to 44 days at a temperature of 5^{o}C and 85-90% RH. A well-managed tree of 5-6 years in age produced 400-500 kg fruits annually.

DURIAN (*Durio zibethinus*)

Durian is one of the popular seasonal fruits in South East Asia. It is popular because of its taste and strong odour. The fruit is usually consumed fresh, but it can be processed into paste, or the flesh can be frozen or powdered or added into other products such as ice cream, cakes and confectionery, seeds roasted and eaten.

The durian is a tropical fruit tree species of the Malvales order, in the Bombaceae family. Borneo is believed to be its center of diversity and has spread to China, Thailand, Malaysia, Brunei, Indonesia and the Philippines. The fruit is rich in carbohydrate, protein fat, minerals and vitamins.

The important cultivars growing in the ASEAN countries includes Chanee, Deception, Gibbon, Transvestite, Suluk, Sunam, Sukun, Petruk, D2, D10, D24, MDUR78, MDUR79, Monthong, Umali, Des806, etc. Durian are mostly propagated by seeds. Patch budding is also quite successful in durian. Plants are spaced at 10 -12m apart in the orchards and more than one clone or cultivar is planted for cross pollination. Flowers are cauliflorous in group of 3 -20 arising from older branches. The duration between fruit set and maturity varies among the cultivars and it requires between 95 -120 days. At maturity, the colour of the fruit spines changes from dark green to light green or grayish green with browning tips and fruit emits characteristic odour.

Fruits are harvested from the tree by climbing on it or allowed to drop naturally and collected. In general, a tree of 8 -12 years in age produced 150 -300 fruits year^{-1} each weighing 0.5-1.5kg. Durian is difficult to store once it starts ripening. The fruits at maturity stage showed higher respiration rate even on the tree. However, ripe fruits could be stored for 6 - 8 weeks at 4 - 6^{0} C and 85 -90% relative humidity.

DRAGON FRUIT *(Selenicereus* sp.*)*

The vine-cacti dragon fruit or pitaya is known to have been used for thousands of years by the indigenous people of the Americas. In the mid nineteenth century it was introduced by the French priests to Indochina and in 1995 Vietnam was the first country to sell dragon fruit in the world markets, under the name Dragon Pearl fruit. Long overlooked outside its native range in Central America, has become an increasingly popular fruit in markets spanning from Asia to Europe due to its exotic appearance and potential health benefits. Nowadays this crop is grown and marketed in over 30 countries. In the last 10 years, the production of dragon fruit has increased markedly in China, Vietnam, Malaysia, Thailand and Israel. In India, the present are under dragon fruit is estimated at about 4000 ha which is aimed to increase to 50, 000 ha in the next five years.

Dragon fruit has a high economic potential as fruit crop in arid regions where water is scarce and the plant is exceptionally drought tolerant. In view of the global climate change and the scarcity of water in extensive regions, the species promise to constitute a significant option for sustainable dry land agriculture.

Dragon fruit brings numerous benefits to human health, mostly for control and management of oxidative stress. All the different parts of the plant (stems, flowers, peels and flesh) contain bioactive compounds. These include betalains, flavonoids, polyphenol, terpenoids and steroids, saponins, alkaloids, tannins, and carotenoids, which have proven as effective, healthier, safer and sustainable alternatives to synthetic drugs for the prevention and treatment of many human diseases. The unique vine-cacti fruit has a bright future because of its nutraceuticals value, yields are high, and fruits can be produced almost year-round which is huge market advantage. With the changing pattern of global warming, being a high temperature sustaining crop, dragon fruit could be an alternative fruit crop in the future.

Being a new crop in most of the growing countries, very few research inputs on cultivation and postharvest management were available before 2000, however in the last 20 years dragon fruit researchers around the world selected many good varieties for cultivation in their own country and have standardized the propagation, production and postharvest management technologies. In most countries both red-fleshed and white fleshed dragon fruits are growing which was mostly introduced from Vietnam. Consumers are intrigued by the exotic nature of dragon fruit with their bright red skin and greenish scales. However, consumers' common feedback is that though it has a delicate flavor and has antioxidant benefits, the taste is sometimes bland and not sweet. In Israel, researchers have developed several varieties and hybrids such as Yossi, Golden, Nilly, Mouyal, Desert King, Julia, Tantan etc. which are sweet with excellent flavor.

JAMUN (*Syzygium cuminii*)

The jamun is a tall, evergreen tree indigenous to India. The tree is ideally suited for windbreak and roadside plantations. The fruits are nutritious contains minerals (iron, calcium, phosphorus), protein, fat, fibre and carbohydrates.

The ripe fruit is delicious as dessert. The ripe fruit is very useful in curing diarrhoea and diabetes. It is stomachie, carminative and diuretic, apart from having cooling and digestive properties which help to cure diabetes, diarrhoea, dysentry. Recent studies have shown that it markedly lowers blood pressure. The seed powder of jamun reduces the quantity of sugar in urine very quickly and permanently. It is also used as a lotion for the cure of ringworm. The ripe fruits are also used for preparation of juice, squash, vinegar, jellies and wine. A delicious ready to serve beverage based on 25% jamun juice, 18^{o}Brix and 0.6% acidity has been standardized (Roy, 1997).

The tree is found growing in Thailand, Philippines, Israel, Algeria, Madagascar, West Indies and in some other countries. The tree is very hardy and grown easily in neglected and marshy areas where other fruit plants cannot be grown successfully. It is found throughout India but there is no organized orchard production of fruit in the country.

The jamun belongs to Myrtaceae family. Some of the varieties/selection developed in India are Goma Priyanka, Katha Jamun, Rajendra Jamun, Rajamun, Narendra Jamun 6, Krian duat, Paras, Konkan Bahadoli, Chintamani Selection 1, CISHS-Jamwant, etc.

Jamun is mostly propagated by seeds. The seedling trees produced the fruits of variable size and quality hence vegetative methods of propagation are preferred. Several vegetative methods like cutting, air-layering, inarching, veneer grafting and budding (shield, patch, forekert) are possible.

The trees are planted at 10-12 m spacing in a square system of planting. The best time of planting in the main field is July-August. However, it can also be transplanted in spring i.e., February-March. The trees are not usually pruned; however, at the later years the dry twigs and cross branches should be removed. Jamun is a cross pollinated tree. The pollination is done by honeybees, houseflies and wind.

Seedling jamun trees starts bearing after 8 to 10 years while it takes 6 to 7 years to bear for a vegetatively propagated plant. The yield increased from 10 kg to 70-80 kg $year^{-1}$ for a full-grown tree. The ripe fruits are picked singly by hand and in all cases, care should be taken to avoid all possible damage to fruits.

KARONDA (*Carissa carandas*)

The karonda is a non-traditional fruit crop which thrives well as a rainfed crop. Once established, the plant hardly needs any care and gives yield with minimum management. This fruit crop is a monitory reward to tribal communities in various parts of India. A native of India, now grows well in South Africa, Australia, India, Malaysia, Sri Lanka, Bangladesh and Myanmar.

Ripe fruits are sub-acidic to sweet in taste with peculiar aroma. The fruits may eaten as a dessert when ripe or used in the preparation of fruit products such as jelly, Jam, squash and chutney. The dried fruits may become a substitute for raisins. The fruits can be candied just like cherry. The wine prepared from ripe fruits contains about 14-15% alcohol and is very much liked by wine fanciers. The unripe fruits yield milky white latex which can also be used in preparing chewing gum and rubber. Fruits can also be used in dyeing and tanning industries. Karonda fruit is considered to be antiscorbutic. Root extracts are used in lumbago, chest complains and venereal diseases. The wood of karonda plant is white, hard and smooth and is used for making spoons and combs. The plant makes excellent hedge almost impossible to penetrate.

Karonda is an evergreen, branched, spinous shrub or small tree belongs to Apocynaceae family. Karonda clones are classified according to fruit colour as green-fruited, pink-fruited and white-fruited. A number of varieties e.g. Thar Kamal, Pant Monohar, Pant Suvarna, Konkan Bold, Pant Sudarshan developed in India are available for commercialization (Meena *et al.,* 2023). Karonda can be grown on wide range of soils including poor, rocky, sandy soil of arid regions. It is very well suited to waste lands and on field boundaries. The trees are usually propagated seeds, however, vegetative propagation by cutting, layering, grafting (inarching, softwood) and budding (shield) are possible. The trees are planted at 2.0 m x 2.0 m and pruned regularly. Karonda flowers in March-April which continues even up to November in some parts of eastern India. Flowers are borne both terminally and axillary. About 120-130 days required from fruit set to maturity and each tree produces 4 to 5 kg fruits. Because of its soft flesh and high moisture content, the storage life of karonda is very short. It may be stored for a week at $13^{o}C$ and 95% relative humidity. A number of varieties e.g. Pant Suvarna, Pant Sudarshan, Pant Monohar, Konkan Bold, Maru Gaurav, Thar Kamal, CHES-K-II-7 and CHES-K-V-6 have been developed in India

PHALSA (*Grewia subinaequalis*)

The phalsa plant is indigenous to India and belongs to the family Tiliaceae. It is drought-resistant can be grown easily even in hot, dry tracts where most other fruits fail to grow. The edible part of fruit varies from 69 to 93%. Ripe phalsa fruits are sub-acidic and good source of vitamin A and C and are fair sources of phosphorus and iron. The popularity of phalsa fruit is due to its attractive colour ranging from crimson-red to dark purple and its pleasing taste. The ripe fruits are used for making refreshing drink in summer having cooling effect. Several beverage *viz.*, nectar, concentrate, squash and crushed phalsa packed in glass bottles remain acceptable for up to 8 months in cool storage. The shoots of the plants after pruning can be utilized either for making baskets or supporting vegetable crops.

Phalsa is usually propagated by hardwood cutting, however, air-layering, stooling and softwood grafting are also possible. Annual pruning is essential for securing high yield of better grade fruits. Flowering in phalsa starts from February-March and continues till May. Phalsa fruits followed a double sigmoid type of growth curve and the respiration curve is non-climacteric type. Fruits mature after 60-65 days of fruit set. The crop starts ripening by the last week of April when limited fruits are available in the market. All the fruits do not ripe at the same time. Therefore, picking continues from end of April to first week of June. It is essential to collect the ripe fruits daily from each plant. The ripe fruits are highly perishable and, therefore, they should be marketed as soon as possible (Mitra, 1999). The average yield from a mature plant is 6.0-10.0 kg.

Table 1. Nutritive values of fruit (values per 100 g edible portion)

Fruit	Moisture (%)	Protein (g)	Fat (g)	Carbohydrates (g)	Energy (Kcal)	Minerals			Vitamin C (mg)
						Ca (mg)	P (mg)	Fe (mg)	
Aonla	81.9	0.5	0.1	13.7	58	50	20	1.2	600
Bael	61.5	1.8	0.3	31.8	137	85	50	0.6	8
Carambola	91.9	0.7	0.1	6.1	28	4	11	1.0	50
Jackfruit	76.2	1.9	0.1	19.8	88	20	41	0.5	7
Jamun	83.7	0.7	0.3	14.0	62	15	15	1.2	18
Phalsa	80.8	1.3	0.9	14.7	72	129	39	3.1	22
Karonda	91.0	1.1	2.9	2.9	42	21	38	39.1	10
Longan	72.9	1.0	0.5	25.2	61	2	6	0.3	8
Rambutan	82.9	0.9	0.1	14.5	64	3	6	1.8	31
Durian	68.0	2.5	2.5	28.8	144	20	63	1.2	46
Ber	81.0	0.95	1.2	15.5	63	0.04	0.02	0.5	110
Dragon fruit (Red)	88.7	0.72	ND	10.2	48	4.2	ND	0.2	28

ND: Not detected

Research priorities

- Survey of the available germplasm
- Methods of propagation.
- Agronomy of different fruit crops.
- Selection of the most suitable clones/varieties.
- Investigation on pollination and problems with fruit setting.
- Reduction of the juvenile period.
- Work on nutritional value.
- Post-harvest management
- Development of value-added products.

Conclusion

The tropical and subtropical regions of Asia is bestowed with wide range of diversity in several minor/underutilized fruits, which are growing wild/semi-wild, are unattended and underutilized. Most of these species have a wide adaptability as well as high degree of tolerance and hence can thrive well under most adverse situations.

In spite of rich germplasm existing in Asia, for most of the underutilized fruits, breeding or conservation programme have not been developed seriously so far. Many of these fruits are nutritionally very rich and are of great medicinal value. These fruits hold promise for sustainable agriculture, particularly for small farmers by augmenting their income with the least risk. Our urgent task would be to develop/select suitable variety/genotype and to standardize production protocol and to popularize these fruits.

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11. Potential of underutilized fruit and nut crops of temperate region

M. K. Verma*, Javid Iqbal Mir and D. B. Singh
* Dirctor, ICAR- Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir
Email: mahenicar10@gmail.com

ABSTRACT

The identification of new species, their characterization, conservation and sustainable utilization is the key to improve agricultural productivity and sustainability, therefore contributing to national development, food security and poverty alleviation. Variation in climatic conditions and short term abrasions in weather parameters has raised levels of uncertainty, vulnerability and risk of investments in horticulture. In the face of warmer temperatures due to climate change, winter chill requirements will become harder to meet in many important temperate-fruit and nut-producing areas. Different agro ecological /phytogeographical regions of Western Himalayan Regions hold rich diversity in both the cultivated, underutilized and the wild temperate horticultural crops. Due to this a wide range of natural population has been built up both at species and genotypic level in the region. In the present context of climate change, the diversification of temperate fruit with various underutilized horticultural crops is one of the possible solutions to this major challenge as their cultivation can bridge the gap between increasing demands and supply of food.

Prospects of underutilized temperate fruit and nut crops in India

In western Himalayas (WH), 80% people depend upon agriculture and allied activities. Geographically, Jammu and Kashmir, Himachal Pradesh and Uttarakhand which comprises the western Himalayas are located at Latitude 28 43-37 06 N and Longitude 73 26 – 81 02 E, and altitude varies from 300 to 7800 m MSL and is known for greater diversity of species of *Malus, Pyrus, Prunes, Vitis, Ribes, Rubus, Fragaria,* etc. In North West Himalayan region, most of the area consists of difficult hilly terrain of different types (low, mid and high) which are unfit for cultivation of high input demanding crops. Such lands can easily be put to use for growing with low input in order to diversify the present day horticulture, and to meet the demands of increasing population, nutritional security and fast depletion of natural resources as well as the growing and changing human needs in the region. These untapped fruits are nature's wonderful gift to the mankind; indeed, they are life-enhancing medicines packed with vitamins, minerals, anti-oxidants and many phyto-nutrients (Plant derived micronutrients). Therefore it becomes possible to exploit the untapped potential of the region through location specific horticulture and subsequently expanding the area under lesser known horticultural crops through adoption of modern scientific viable technologies. Underexploited horticultural crops have a vast potential for production of value added products' with high therapeutic, medicinal values and antioxidant properties have high export potential.

Underutilized exotic temperate fruit and nut crops

i) Berries

Berries are considered soft fruit and include botanically different types of fruits such as blackberries, blueberries, strawberries, cranberries, gooseberries and currants and raspberries. These types are used as desserts as well as in processing. They are canned, frozen or made into jams, jellies or preserves. The juices are used in beverages and ice cream.

The most important vitamin in berries is vitamin C. Berries are also regarded as good source of β-carotene, thiamin, riboflavin and nicotinic acid. Anthocyanin is a major pigment in berries.

Blackberries (*Rubus fruticosus)*

Sweet, succulent blackberries are summer delicacies in the northern temperate regions. Binomially, brambles are a small perennial shrubs belonging to the vast *Rosaceae* family of bush berries, in the genus: *Rubus*. Depending upon cultivar type, blackberry bush can be classified into erect, semi-erect, and trailing types. Technically, blackberry is an aggregate fruit consisting of small drupelets arranged in circular fashion. Each drupelet composes of juicy pulp with single tiny seed. Each berry measures about 3-4 cm in length containing about 80-100 drupelets.

Blueberries (*Vaccinium sps.)*

Sweet, juicy blueberries are rich in natural **pro-anthocyanin** pigment anti-oxidants. These tiny, round blue-purple berries have long been attributed to the longevity and wellness of indigenous people living around subarctic regions in the Northern hemisphere. Botanically, it is a deciduous shrub belonging within the family of *Ericaceae*, in the genus, *Vaccinium.* Broadly, *vaccinium* species are classified according to their growth habit as high-bush and low-bush berries. High-bush blueberry (*Vaccinium corymbosum*) is a highly branched, erect deciduous shrub with rich foliage. It grows up to 10-12 feet tall in cultivated orchards and bears clusters of small, cream-white flowers during spring, which subsequently develop into tiny berries after about two months. Low-bush blueberry (*Vaccinium angustifolium*) is a short, erect plant that grows about one-two feet in height and spread through underground rhizomes.

Black currants (*Ribes nigrum*).

Black currants are one of very popular, summer season berries. Indeed, they are incredibly rich in several valuable health benefiting phyto-nutrients, and anti-oxidants that are vital for our health. Blackcurrant is a small shrub belonging to the family of *Grossulariaceae*, in the genus; *Ribes.* Currants are native to central and northern Europe and Siberia. The currant (Ribes) plant is a fast growing, deciduous, small shrub reaching about 5-6 ft in height. In general, currants grow best in the regions where summers are humid but winters severe and chilling. During the season, *Ribes nigrum* bears pendulous chain of small berries. Each currant berry has a size of about 1 cm in diameter, very dark purple, almost black with a glossy skin, and a persistent calyx at its apex. It can carry about 3-10 tiny, edible seeds. Currants can come in different colors. Berries of red, white and pink currants feature translucent pulp, sweeter in taste.

Cranberries (_Vaccinium macrocarpon_).

Unique, wild and natural by habitat, cranberries are rich in phyto-nutrients (naturally derived plant compounds), particularly pro anthocyanidin antioxidants, which are essential for all-round wellness. The berries are indeed containing numerous chemical substances that may offer protection from tooth cavities, urinary tract infection, and inflammatory diseases. This berry-plant is described as an evergreen dwarf, creeping shrub or a low-lying trailing vine, belonging in the family of *Ericaceae*, in the genus: Vaccinium, and subgenus: *Oxycoccos.* The plant is actually a dwarf, creeping shrub, or vine, which runs up to 10 to 20 cm in height. It features slender, wiry, not so thick, woody stems bearing small, evergreen leaves. Cranberry season generally lasts from October until December. The fruit is small, round, red color berry. Each berry features four centrally situated tiny seeds enclosed inside capsules. The berry is very acidic in taste, having pH in the range of 2.3 to 2.5.

Raspberry (*Rubus idaeus*)

Wonderfully delicious, bright-red raspberry is among the most popular berries to relish! They are rich sources of health promoting plant-derived chemicals, minerals, and vitamins that are essential for optimum health. Botanically, raspberry is a small shrub belonging to the family *Rosaceae*, in the genus: *Rubus*. It grows very well under temperate climates. The berry is native to the Europe but today widely cultivated in many temperate regions all over the world under supervised farms. Technically, the whole berry is an aggregate of small "drupe" fruits, which are arranged in circular fashion around a hollow central cavity. Each tiny drupelet features small juicy pulp with a single, tiny whitish-yellow seed. Raspberries have a taste that varies by cultivar, and ranges from sweet to acidic, a feature quite similar to strawberries. Raspberry has conical shape, weighs about 2-4 g and contains 80-100 drupelets arranged in concentric whorls.

Gooseberries (*Ribes uva-crispa* L.)

Gooseberries are small, round to oval berries of European origin. They grow in the wild all over the temperate climates of Europe, North America, and Siberia. Botanically, they related very closely to currants, and belong to the same family of *Grossulariaceae,* in the genus, *Ribes*. Packed with pigment antioxidant polyphenolics and vitamins, the berries come in different color, flavor, and shapes. Gooseberries (R. uva-crispa L.) are one of the four wild Ribes species (*R. alpinum L., R. rubrum L. and R. petraeum Wulf.*) growing in the Northern Hemisphere. As in currants, gooseberry grows best in regions where summers are humid but winter is severe and chilling. Gooseberry plant is a fast growing, small deciduous shrub growing about 4-6 ft in height, featuring sharp thorns all along its woody branches. The bush begins fruiting 2-3 years after plantation. Berries come in many shapes, colors, and taste. They can be round, oval, pear-shaped or elongated, green, white, yellow, purple, red-brown or black color, sweet and tart. Their outer surface can be smooth or fuzzy (hairy) with conspicuous veins. Inside, a berry may hold 15-30 tiny edible seeds. In general, the berries measure 1-2 cm in width and weigh about 4 g to 10 g.

Strawberries (*Fragaria X ananassa)*.

Delicious, rich-red, sweet, yet gently tangy strawberries are among the most popular berries. These berries are native to Europe, however, nowadays cultivated in many temperate regions all over the world as an important commercial crop. Botanically, the plant is a low-growing runner (creeper) belonging to the family of *Rosaceae*, in the genus: *Fragaria.* Strawberry is a small, low-lying, spreading shrub. It bears small white flowers which eventually develop into small conical, light green, immature fruits. They turn red up on maturity with each berry featuring red pulp with tiny, yellow color seeds piercing through its surface from inside. Its top end carries a green leafy cap and stem that is adorning its crown. Each berry features conical shape, weighs about 25 grams and measures about 3 cm in diameter. The berries have the taste that varies by cultivar type, and ranges from quite sweet to acidic.Although wild varieties are sometimes available in the market, large-scale production uses the modern "plasticulture" system. In this method, raised beds are formed each year, fumigated, and covered with plastic which prevents weed growth and crop spoiling.

ii) Other exotic underutilized fruits and nut crops

Kiwi fruit (*Actinidia chinensis***)**

Kiwi fruit, also known as *Chinese gooseberry,* is one of the delicious fruits with full of promising health promoting phyto-chemicals, vitamins and minerals. This widely recognized, wonderfully unique fruit is native to eastern Chinese "Shaanxi" province. Kiwifruit plant is a semitropical, deciduous, large woody vine belonging to the family of *Actinidiaceae* in the Genus, *Actinidia*. During each season which lasts from September until November, the kiwi vine bears numerous oval shaped, fuzzy, brown colored fruits. Each kiwi berry weighs up to 125 g. internally; its flesh is soft, juicy, emerald green with rows of tiny, black, edible seeds. Fruit texture is similar to strawberry or sapodilla, and the flavor resembles a blend of strawberry and pineapple fruits. "Gold Kiwifruit," developed by hybrid technique by agricultural research department in New Zealand, has a smooth, sparse hairs, bronze skin, a pointed cap at one end and distinctive golden-yellow flesh with less tart and more tropical flavor than green-kiwifruit.

Quince (*Cydonia oblonga***)**

Quince fruit is a member in the *Rosaceae* family of pome-fruits. Quince is rarely eaten raw but used in cooking where just a small section of this fruit would impart the whole recipe with a pleasant fruity aroma. This flavorful fruit is native to the Asia Minor regions and once popular in the households as delicacy. Binomially, quince is the only fruiting tree in the genus: Cydonia. Quinces are medium sized semi-tropical deciduous trees, growing to about 10 to 15 feet in height. Pink-white flowers appear during the late spring and early summer, which develop into golden color pear-shaped fruits. The fruit is larger than average apple and bumpy; appear somewhat like large guava, avocado, or as short-necked pear fruit. The quince fruit weighs about 250-750 g or more in some varieties. Inside, its flesh is light yellow, gritty and has several seeds at its center as in apples. Raw quince has intense fruity smell, and together with its bright yellow color instantly attracts the fruit lover's attention. However, raw fruits, even after ripen, generally astringent and tart in taste. Its ripe fruits can be processed in to excellent marmalade and toffees.

Persimmon (*Diospyros virginiana*)**.**

Persimmon fruit is a golden yellow, round or oval, flavorful, smooth textured delicacy from far East Asian origin. Its sweet, delicious flesh is packed with several health promoting nutrients such as vitamins, minerals, and anti-oxidants vital for optimum health. Botanically, persimmons belong to the family of *Ebenaceae*, in the genus: *Diospyros*. This delicate fruit is native to China. Persimmons are either multi-trunked or single-stemmed deciduous trees, which may grow up to 25 ft in height. Persimmon trees classified broadly into two general categories: those that bear "astringent fruit" (whilst unripe) and those that bear "non-astringent" fruits. An astringent cultivar, which is commonly cultivated in Japan known as *"Hachiya,"* is high in *tannins* and must be allowed to ripen fully until it attains jelly-soft consistency before being fit to eat. A non-astringent persimmon, on the other hand, contains less tannin and can be eaten while it is crispy, as in apples.

Pecan nut (*Carya illinoensis* Koch)

Are classified in family Jugalandaceae is called as 'Queen of nuts'. It has a native of southern east United States of America. Fruit mature in September –October months. Alternate fruit bearing is more pronounced in pecan nuts. Hundred gram of Kernel is containing 71g fat, 92g protien, 14.6g carbohydrates and 2.3g fiber. Fruit also contain calcium, phosphorus, potash, iron, manganese and vitamin A.

Husk Tomato (*Physalis* spp.)

They belong to the family Solanaceae and genus *Physalis.* It is herbaceous annual or perennials, mostly native of tropical north and South *America*. it is called 'Husk tomato' , 'strawberry tomato', 'Tomatallo', and winter cherry' in Europe and north America , while cape –Goose berry' or Raspberry in northern part of the country . The species *P. ixocarpa* and *P. peruvaina* produces large fruit as compare to other species. Average fruit weight varies from 30 -60-g.fruit can be stored easily at ambient temperate up to three weeks during winter. Total soluble solid varies from 6.0 to 9.5 per cent.

Hazelnuts or Filbert (*Corylus* spp.)

Nut belongs to the family Betulaceae. The common hazelnuts are classified as *Corylus* a*mericana*, the beaked hazelnut as *Corylus cornuta*, the European filbert as *Corylus avellana pontica* and the cobnut as *Corylus avellana granis*. The giant filbert is classified as *Corylus maxima*. In India, Hazel nut (*C. Colurna*) is known as "Winri", "Wiri", "Warrawi", "Wuriya" in Kashmir, Thangi , Thangoli in Pangi (Chamba, HP), "Bhutia badam" in Garhwal and Kapasi in Kumaon region of Uttarnchal Pradesh .The plants are usually 2-3 m tall , each plant has separate male flowers borne in catkins and female flower borne in clusters.

Sea buckthorn (*Hippophae* spp.):

Locally called "Ames", "Chharma", "Dhurchuk", "Gartsak" and "Sarlais" is one of the wild resources in the higher Himalayas. It belongs to the family Elaegnaceae and genus *Hippophae*, grows abundantly in higher Himalayas and other countries like China, Russia and Mongolia. It is deciduous thorny shrub or small tree of 9- 12 m height above the ground with profuse branching and has a life span of 100-150 years. It grow naturally on the river side's and sun facing slopes in part of Ladakh, Chamba, Kinnuar , Lahul-Spiti, Kullu in Himachal Pradesh at an elevation of 7000 to 12,000 feet. It can resist winter temperature as low as -43^{0}C. The fruit of sea buckthorns starts ripening from first week of October and remaining on the plant up to December. The fruits are orangish –yellow in colour and contain 90-95 percent yellow coloured sour juice. The fruits of sea buckthorn contain 12.1 percent protein, 12.3 percent fat, 9.4 percent carbohydrates 150mg/100g calcium, 50mg/100g phosphorus and 116mg/100g iron. The seed oil is also rich in vitamins K and E, corotenoides, flavonoides, steroids, linoleic and linolenic acid. Oil extracted from seeds, pulp, tender branches and leaves is used for making various life saving medicines and drugs to combat various diseases.

Processing and product diversification of berries and other untapped temperate fruits

Berries and other untapped and underutilized temperate fruit crops are used as desserts as well as in processing. They are canned, frozen or made into jams, jellies or preserves. The juices are used in beverages and ice-cream.

Future fruits and nutraceuticals

The term nutraceuticals, is derived from the words "nutrition" and "pharmaceutical", is a food or food product that provides health and medical benefits, including the prevention and treatment of disease. A nutraceutical is demonstrated to have a physiological benefit or provide protection against chronic disease. Their bioactive ingredients, the phytochemicals, sustain or promote health and occur at the intersection of food and pharmaceutical industries. They play a crucial role in maintaining optimal immune response, such that deficient or excessive intakes can have negative impact on health. Phytochemicals, are non-nutritive plant chemicals that have either defensive or disease protective properties. These phytochemicals, either alone and/or in combination, have tremendous therapeutic potential in curing various ailments. Phytochemicals with nutraceutical properties present in food are of enormous significance due to their beneficial effects on human health since they offer protection against numerous diseases or disorders such as cancers, coronary heart disease, diabetes, high blood pressure, inflammation, microbial, viral and parasitic infections, psychotic diseases, spasmodic conditions, ulcers, osteoporosis and associated disorders. Majority of untapped fruits of future importance, such as strawberry, blackberry, blue berry, currants, crane berry, gooseberry, rosehips, kiwi, lingon berry, red currant, rasp berry, sour cherry, apricot, peach etc contain phytochemicals of nutraceutical importance.

Table 1. Processing and medicinal value of underutilized exotic temperate fruits and nut crops

Name of fruit	Products prepared	Medicinal value
Blackberries	Juice, Wine, Jam, Syrup,	Diarrhoea, gout, arthritis, Blackberry shoots boiled into a tea is said to have been used for mouth irritations such as canker sores.
Blueberries	Jams, juices, syrups and baked products. Also dairy, confectionery and beverages	Antiseptics, Diuretics, Anti-inflammatory, Ant hyperglycemic and Ant carcinogenic.
Cranberries	Concentrate, Sweetened dried cranberries, Frozen cranberries, Sliced cranberries, Cranberry puree, cranberry puree concentrate, powdered cranberry, sauce, jams, jellies etc.	Antiseptics, Diuretics, Anti-inflammatory, Ant hyperglycemic and Ant carcinogenic.
Gooseberries	Jam, Jelly, Juice, Sauce, Cupcakes	Appetizing, tonic, diuretic, laxative, useful in inflammations, enlargement of the spleen and abdominal troubles. The fruit is considered to be a tonic, diuretic and purgative in the Punjab.
Raspberries	Candy Jellies, Jam, Canned, Used as ingredient in the preparation of sauces, candies, yogurts, ice creams and infusions.	Antiseptics, Diuretics, Anti-inflammatory, Ant hyperglycemic and Ant carcinogenic.
Strawberries	juice, nectar, wine, Puree, wine	Anti oxidant, Anti Cancer, For healthy Immune system
Pineapple guava	Juice, Salad, Sauce, Eaten Raw, Used as dessert fruit, Slices, Candies, Preserves, Jellies, Marmalade,	Therapeutic mechanisms against cancer, bacterial infections, inflammation and pain.
Chinese *ber*	Eaten as a snack, or with tea, canned, jujube tea, juice, vinegar, pickles, wine.	Antifungal, antibacterial, antinuclear, anti-inflammatory, sedative, antispastic, antifertility/contraception, hypotensive and Antinephritic, cardiotonic, antioxidant, immune stimulant, and wound healing properties

Japanese persimmon	Eaten raw, Dried, fresh, cooked,	Stomach ailments and diarrhea, Fever, Blood pressure, Cough, prevents heart attack,
Currants	Jam, Jelly, eaten raw,	Kidney diseases and menstrual and menopausal problems, enhancer to assist women in becoming pregnant, effective treatment for pre-menstrual syndrome
Medlar	Eaten fresh, Salad, Pie, jam, jelly and chutney.	soothing the throat and is a popular ingredient for cough drops, soothe the digestive and respiratory systems
Quince	Jam, Jelly, Quince pudding, Murabah, Wine, Brandy, Cider	Treat sore throat and to relieve cough, relieves intestinal discomfort. remedy for pneumonia and lung disease
Pecan nut	Eaten fresh, used in sweet deserts, savory dishes, pecan pie,	Lower the risk of gall stones, reduce high cholesterol,
Husk tomato	Eaten raw, Salads, jams, jellies, dried, pie.	Used as a remedy for abscesses, coughs, fevers and sore throats
Hazelnut	To make pralines, chocolates, paste, hazelnut butter, flour,	Anti cancer medication
Seabuckthorn	Juice, Syrup, Skin cream, pie, jam, lotions, liquors, juice as baby food, beer,	Treatment for inflammatory disorders, Cancer prevention, effective in bone marrow,

Future Perspectives

To strengthen the work on genetic improvement following strategies would be requiring for effective implementation and to achieve goals.

1. Systematic planning for explorations for minor temperate fruit including wild texa particularly for those crops, whose economic importance is known for commercial exploitation.
2. Need based introduction of new crops, new varieties with specific traits.
3. Mostly minor temperate fruit crops are hardly and resilient, once established in field gene bank then agronomic practices should be developed considering the climatic condition suited to them.
4. Priority should be to conserve the material in field gene bank and protocol should also be developed for *in vitro* conservation and cryopreservation as well.
5. *In situ* conversation by the various government agencies and policy planners to protect the ecological niches, where large variability is existing e. g. hazelnut in pang , dry type apricot in Leh and Ladakh and Kinnuar chilgoza in Kinnuar , and walnut in Jammu and Kashmir.
6. Molecular characterization of underutilized temperate fruits will provide the information on identification of use full genes and other molecular markers, which will help in genetic improvement work.

There is need to investigate value addition useful for products and processing, neutraceutical, ornamental and other potential applications.

12. Approaches for conservation and utilization of wild fruit genetic resources of the Western Ghats

R. Vasudeva
Dean (Forestry), College of Forestry, Sirsi 581 401
University of Agricultural Sciences, Dharwad, Karnataka
e-mail: vasudevar@uasd.in; vasukoppa@gmail.com

India harbours four of the 34 hotspots of biological diversity of the world. The Western Ghats, a rolling ribbon of mountains spread along the Western part of India, is regarded as one of the world's eight ‘hottest hotspots of biological diversity'. This mountain range contains unique flora and fauna and is declared as one of Worlds' Natural Heritage Sites by the UNESCO. Over 5000 species of flowering plants, 139 species of mammals, 508 species of birds, including 22 endemics, 225 species of reptiles, and 179 species of amphibians live in the region. The Western Ghats of India is also a rich repository of about 200 tropical fruit species and also well-known for harbouring a rich variety of medicinal plants. Over 20% of the medicinally important species are endemic and threatened because of the unscrupulous harvesting in these Ghats.

Forest Genetic Resource (FGR) is a component of the genetic diversity which is of actual or potential use either for production systems or for the ecosystem functioning in a forest. Conservation of FGRs is fundamental to the sustainable and productive management of the forest ecosystems. However genetic diversity occurs at various levels of organization from the ecosystem, their sub-specific populations, and individual genotypes to the molecular level, of the gene. Hence it is essential that all levels of genetic diversity be considered in the utilization and conservation prioritization process.

Today biological diversity of a country is regarded as its “resource capital”. Understanding spatial distribution of this plant resource is a prime pre-requisite for its sustainable utilization. Unfortunately, primary data on quantitative estimates of the resources, their geographical spread and the levels of regeneration in their natural habitats does not exist even for an important eco-region such as the Western Ghats.

Asia is rich in biodiversity including the edible plant species. It has more than 400 edible tropical fruit species, which are important sources of supplemental food, nutritionally balanced diets, and enhancing both household incomes and national revenues. In forests, the rich diversity of fruit species plays an important role as sources of food and shelter for other plant and animal species, providing stability in complex natural ecosystems.

There are about 117 cultivated species of fruits and nuts with 175 wild relatives of which only 25 species have been domesticated for the use in India. The mention of use and cultivation of fruits can be seen in epics like ‘Ramayana’.

In India various native fruits, such as aonla (*Emblica officinalis)*, bael fruit (*Aegle marmelos*), jackfruit (*Artocarpus heterophyllus*), jamun (*Syzygium cuminii*), karonda (*Carissa congesta*), Kokum (*Garcinia indica*) and phalsa (*Grewia subinaequalis*) with lot of diversity in a wide range of agro-ecological situations throughout the tropics, subtropics and temperate regions, which could be grouped as underutilized.

However, a serious concern exists that fruit germplasm is rapidly disappearing due to logging and clearing of land, and the substitution of traditional fruit varieties with improved varieties.

Many species with potential to become commercial crops, and many related species of existing crops, which could be important for breeding purposes or for use as rootstocks, are rapidly getting lost.

Some of these fruits yield juice with excellent flavour, which can be converted into blended beverages and these could play an important role in meeting the demand for nutritious, pleasantly flavoured and attractive natural food of high therapeutic value. Encouraging local people to produce these fruits can help in significantly checking uncontrolled harvesting from the wild and assisting in the retention of the various species in their native habitats where they perform best.

Fruit trees provide important adaptive values and tend to be more resilient to climate change due to their perennial nature. Hence diverse native fruit trees are used by farming communities to improve nutrition in their food and augment the farm ecology, hence farmers also hold valuable information on the diversity and its uses. World over, there is a renewed interest in documenting the use values of fruit trees. Use of tropical fruit species is a part of the Traditional Knowledge (TK), which is a rational and reliable knowledge developed through generations of intimate contact with the nature by the local people.

Further, the impact of unscrupulous extraction of some of these resources is also not very well understood. Earlier work on understanding the occurrence and distribution of plant resources are scanty, isolated and never done adopting a uniform sampling strategy throughout the Western Ghats at a fine geographic scale. Hence there is a critical need to map the plant resources at local, regional and national levels throughout the country adopting uniform sampling strategy and develop a database.

In this context, mapping of these resources reflecting the spatial distribution would greatly help in understanding their structure and dynamics in natural habitats, allow assigning conservation values of different sites/recognizing hotspots of plant diversity within an ecoregion, and eventually in formulating strategies for sustainable utilization of plant resources. Most importantly this would also offer a perspective on the economic value of forest resources in the Western Ghats. Realizing this importance, National Bio-resource Development Board (NBDB), of the Department of Biotechnology, New Delhi commissioned a national initiative which broadly aimed at: a) quantitatively assessing the geographic distribution and population status of the plant resources of the Western Ghats, b) identifying the threats to these plant resources and c) setting up a Western Ghats eco-region-specific database of plant resources.

The programme also aimed at developing thematic maps of the density and distribution for all the economically important species along the Western Ghats as well as analyzing the spatial and temporal patterns of change in specific plant resources along the Western Ghats.

Central to the genetic resource utilization and conservation is the maintenance of sufficient inter and intra-specific genetic variability. However, it is a challenge in those species subjected to intense harvesting pressures. There have been number of isolated approaches proposed to address the utilization and conservation of genetic resources. Unfortunately, most approaches are aimed at conserving the "resources" *per se* and have seldom taken into account the genetic diversity. *Ex-situ* and *in-situ* methods followed in the conservation of crop genetic resources have been extended to forest genetic resource conservation as well without critically evaluating their appropriateness.

New approaches are therefore needed to integrate national conservation activities for maximum effect in both production forests and fully protected area systems. Complementary Conservation Methods (CCM) are increasingly being viewed as newer approach to utilize and conserve genetic resources, which is essentially a decision-making process to adopt an appropriate method, protocol to achieve a lasting conservation. In CCM, *in situ* conservation of genetic resources are reinforced with the efforts of *ex situ* and vice versa while an enabling policy environment is created. Newer approaches such as 'on farm conservation' and '*circa situ* conservation' of resources is far more participatory in nature and effective in involving communities for domestication and utilization.

Key to the conservation and utilization are steps such as the scientific documentation of their geographic distribution and associated Traditional Knowledge (TK) relating to their uses, promoting good practices that maintain on-farm diversity. TK refers to the rational and reliable knowledge, practice and belief of indigenous people developed through generations of intimate contact with the nature by the local people. It would include detailed information on species of a locality, use-values of local biodiversity, harvesting and management practices and manipulation of disturbance regimes.

The utilization of genetic resources has now entered an arena of Access and Benefit Sharing (ABS) system following the Nagoya protocol. The provisions outline the frame work for the development of legal and ethical bio-prospecting agreements between the 'provider' (host country / community) and 'user' (party outside to the community/country) of TK. National Biodiversity Authority in India is the national organization involved in the protection of TK and its use which encourages documentation and benefit sharing. In addition, rapid agricultural expansion, changing land use pattern and with other social pressures have led to the depletion of genetic resource diversity. Therefore, it is essential that this knowledge is documented and the genetic resources are regularly monitored for their conservation status. Most importantly a broad framework for the rapid valuation process of the genetic resources derived from the forest ecosystems from the ABS viewpoint is necessary.

New tools, technologies, protocols are required to rapidly and precisely characterize / monitor diversity, assess the dynamics / loss across landscapes and as well as to achieve lasting conservation. New technologies offer unprecedented abilities to monitor change, create new ways of collecting data. Information and virtual tools. Space technologies, and genomic data are some of the newer and rapidly evolving technologies. Ubiquitous devices such as cell phones and people connected to cloud computing systems will revolutionize the types of data we collect for effective utilization and conservation.

13. Genetic Resources and Varietal Wealth of Semi-Arid Fruit Crops

A. K. Singh, D. S. Mishra,VikasYadav, Jagdish Rane
Central Horticulture Experiment Station (ICAR-CIAH), Godhra, Gujarat

Introduction

India is origin of many fruit crops and the most of crops is limited to its growing region only. In spite of their high nutritional and medicinal properties, their commercial cultivation is not still in vogue. Most of minor fruit crops are underutilized and are utilized in the core recipes of many *ayurvedic* formulations. These fruit crops are neither grown commercially on large scale nor traded widely, but cultivated, traded, and consumed locally. These fruits have many advantages like easier to grow and hardy in nature, producing a crop even under adverse soil and climatic conditions. So, exploitation of these fruit crops can be a solution of health and nutrition insecurity, poverty, and unemployment to the masses of dwelling in aberrant agro-climatic conditions. The consumption of minor fruits can provide nutrition to the poor and needy masses by meeting the nutrient requirements of vulnerable groups. These fruits are a rich of source of carbohydrates, fats, proteins, energy, vitamins: A, B_1, B_2, B_3, B_6, B_9, B_{12}, C, folic acid, and minerals: Ca, P, Fe, and dietary fiber. These fruits are rich in bioactive compounds to prevent and cure various diseases like marasmus, night blindness, anemia, diabetes, cancer, hypertension, bacterial, fungal and viral infection, and hidden hunger. The minor fruits have potential to give health and economic security to the people by giving employment and by fetching good returns from their sale in raw form as well as value-added products. In India, minor fruit crops of semi-arid region for food system are: bael,aonla, ber,chironji, karonda, ker, phalsa, pilu, jamun, tamarind, ber, lasoda, wood apple, custard apple,fig, cape gooseberry, phalsa, mulberry, manila tamarind, timru, mahua, timru,palmyra palm, sugar datepalm, etc. These fruit crops are rich source of vitamins (ascorbic acid, thiamine, niacin, pyridoxine and folacin), minerals, fat, protein, and dietary fiber. These crops can be grown with minimal management under aberrant agro-climatic conditions.Most of the important semi-arid fruits are indigenous and it is easily available, can play major role for socio-economic upliftment of poor masses of the country in changing climatic scenario.India is facing the problems of hidden hunger, nutrient and micronutrient deficiencies, poverty, and unemployment. These fruit crops are present around us in unsystematic manner. So, cultivation of these crops in systematic manner and efficient utilization of marketing systems and channels for fresh fruits and processed products can motivate the growers towards growing these crops and can uplift the economy of country. There is tremendous scope of utilizing these crops in different promising value added products to the food system and nutraceutical industry. Use of these crops often declines due to changes in farming practices, changes in market forces, and cultural erosion that results from modernization, migration, urbanization, and land degradation. For sustainable food system, these minor fruit crops can play vital role for livelihood and economic security to the people living in the aberrant agro-climatic conditions across the world.

According to FAO classification, on the basis of growing period which is within the 75–119-day range is classified as semi-arid. In these areas rainfall is 2 times less than the potential evapo-transpiration throughout the year. Therefore, successful fruit production depends on stored soil water and rain water harvesting in addition to rainfall. In these areas, physical constraints like low and erratic rainfall, high temperature, high wind velocity, low fertility, poor soil structure, and salinity of soil and ground water are the deterrents to assured crop production. Semi-arid and arid zone areas account for almost 60 % of the total cropped area of the country (Hiwale, 2015). Nevertheless, these environmental conditions offers great opportunity for production of some hardy fruit specieswhich are a rich source of antioxidants and other health promoting phyto-chemicals (Krishna *et al*., 2018) and development of high quality produce in a number of fruit crops such as date palm, ber, aonla, bael, pomegranate, and lasoda (Singh et al., 2020). Many of the indigenous fruit species found growing semi-arid rain fed areas of country have been found to yield satisfactorily under stressful agro-climatic conditions owing to their tolerance capacity for abiotic stresses like bael, aonla, phalsa, wood apple, jamun, manila tamarind etc. Some of these species have been domesticated to the cultivation level while others need to be domesticated and commercially exploited for the economic upliftment of resource poor farmers of these regions (Singh *et al*., 2020). The group of such fruit crops has been referred as minor fruit crops. The term "Minor Fruit Crops" is applied, in the general sense, to a group of crops presently growing in a scattered and unattended way and are found on homestead land, wasteland *etc.* in spite of their potential for commercial exploitation. The plants belonging to this group are hardy and grow well even in fragile soil and climate (Diengngan and Hasan, 2015). Most of the underutilized fruit crops of the semi-arid tropics are often available only in the local markets and are practically unknown in other parts of the world (Roy and Bauri, 2019). Today, consumers are becoming increasingly conscious of the health and nutritional importance of their food basket. These fruits can grow under adverse conditions and are also known for their therapeutic and nutritive value and can satisfy the demands of the health-conscious consumers (Krishna *et al*., 2018). However, production and trade of minor tropical fruits are gaining importance globally, mainly in recognition of theircontribution to a healthy diet (Altendorf, 2018). Hence, there is a need to intensify research efforts in diversification and popularization of such underutilized fruit crops. To achieve this, there is a need to create demand for such fruit crops in the domestic and international markets. The recent awareness regarding the potential of these ecologically fragile lands for production of quality produce has not only opened up scope for providing nutritional security for the people of these regions, but also for bringing in new areas to increase horticultural production.Semi-arid fruit species like aonla (*Emblicaofficinalis*), bael (*Aegle marmelos*), chironji (*Buchanania lanzan*), karonda (*Carissa congesta*), phalsa (*Grewia asiatica*), khirni (*Manilkara hexanda*), jamun (*Syzygiumcuminii*), kokam (*Garcinaindica*), Malabar tamarind (*G. cambogia*) and tamarind (*Tamarindus indica*) ber (*Ziziphus mauritiana*), lasoda (*Cordia dichotoma*), wood apple (*Feronialimonia*), custard apple (*Annona squamosa*),fig (*Ficus carica*), phalsa (*Grewia subinaequalis*), mulberry (*Morus nigra*), manila tamarind (*Pithecellobium dulce*), timru (*Diospyrus melenoxylon*),Indian date (*Phoenix syslvestris*)mahua (*Madhuca indica*)and palmyra palm (*Borassus flabellifer*) have tremendous nutritional value and form the part of diet of local inhabitants.These future new generation crops are awaiting their popularization and full utilization as they remain only as plants of local importance.

Advances in Semi-Arid Fruit Crops

The journey of research and development in arid and semi-arid fruit crops of tropics and sub-tropics began with the initiation of *adhoc* scheme in which research on some selected crops began which was financed by AP Cess fund of ICAR in 1976. Later, this scheme was merged during 6th Five Year Plan to form the Cell III of the All India Coordinated Fruit Improvement Project (AICFIP) in the year 1978. However, during 7th Five year plan, Cell III of AICFIP was again restructured to form All India Coordinated Research Project on Arid Zone Fruits. Currently, this project is having 18 centres running in eleven states of country, viz., Rajasthan (04), Maharashtra (04), Gujarat (02), Uttar Pradesh (02), Tamil Nadu (01), Karnataka (01), Andhra Pradesh (01), Punjab (01), Haryana (01) and Madhya Pradesh (01). The present manpower provisions in the Project consists 38 Scientists, 36 technical, and 44 supporting personnel. The main objective of project is to develop suitable and sustainable technologies for growing fruit crops like ber, date palm, aonla, pomegranate, fig, custard apple, bael, tamarind, and jamun. During 7th Five Year Plan, Planning Commission of India approved the establishment of National Research Centre on Arid Horticulture (NRCAH) at Bikaner which came into existence on April 01, 1993 and then upgraded to Central Institute for Arid Horticulture (CIAH) on September 27, 2000. During the same year on October 01, 2000, Central Horticultural Experiment Station, Vejalpur, Panchmahal(Godhra) was merged with CIAH as its Regional Station to work on semi-arid fruit crops. However, this journey of research and development of arid and semi-arid fruit crops in India was further fuelled the book 'Arid Fruit Culture' (Chundawat, 1990) which has paved the way of research in minor fruit crops.

Present National Scenario

The vast land resources available in arid and semi-arid regions of country offer great deal of opportunities for cultivation of variety of crops. Under rainfed conditions crops like aonla, custard apple, wood apple, ber, bael, lasora, mulberry, wild noni, and karonda are grown without much difficulty (Chundawat, 1990). Since last three decades, considerable area has come up under semi-arid fruit crops in different agroclimatic regions of country.

Aonla, now grown on 93,000ha area with the production of 10,75,000 tones. However, area and production over the years is stagnant which is expected to pick up momentum in coming years. These increases in area and production have become possible due to research and development efforts made by the different organizations of NARS. At the same time, regular plantation of semi-arid fruit crops like jamun, bael, aonla, ber, chironji, karonda and jamun in the form of commercial orchards is now coming up in several parts of country specially in Gujarat, Rajasthan, Uttar Pradesh, Haryana,Kernataka, Tamil Nadu, Punjab and Maharashtra due to research efforts of CIAH-CHES, Godhra and other organizations of NARS (Singh *et al*., 2020)owing to increased awareness regarding health benefits of these fruits as well as possibility of value addition and income generation.

In international markets, under exploited semi-arid fruits are regarded as a novelty or niche product. Only a small number of varieties tend to be available either through ethnic markets targeting migrant consumers, mostly of Asian origin, or premium retail channels targeting affluent consumers. Demand is also set on an upward trajectory in key developed markets, most importantly the US and EU, mainly in response to increasing health awareness and changing dietary preferences (Altendorf, 2018).

Diversity and Conservation of Plant Genetic Resources

In India,the local inhabitants of Western Ghats, Maharashtra, Gujarat, Rajasthan and North Eastern States of India were traditionally reliant on local fruit species like tamarind, aonla, ber, bael, mahua, noni, chironji, custard apple etc., apart from mango and other major fruit crops for their livelihoods. Due to unsustainable market pressures and rapid urbanization, majority of these species have come to near extinction. Therefore, cconservation of genetic resources of underutilized fruits through holistic approach is required which includes both *in-situ* and *ex-situ* conservation strategies (Diengngan and Hasan, 2015; Singh *et al*., 2020).The diversity of some of the underutilized fruits is well studied while for other underutilized fruits relatively less attention has been given so far. In this connection, crop specific surveys in targeted diversityrich areas were undertaken in arid and semi-arid regions of Gujarat, Madhya Pradesh, Uttar Pradesh, Chhattishgarh, Haryana, Punjab, etc. and a large number of germplasm of semi-arid fruits were collected over the years for systematic evaluation, characterization and conservation of indigenous germplasm at CHES, Godhra (Singh *et al*., 2020). The present status of underutilized fruit crops conservation in India is 1717 at ICAR-NBPGR and its collaborative centres (10 regional stations) which is the main Indian statutory body responsible for plant genetic resource collection and conservation (Table 2), whereas the major research institutions working on underutilized fruit crops in the country are maintaining 1127 accessions in their field gene banks (Meena*et al*., 2020). In addition to this, the major ICAR research institutions like ICAR-CIAH, Bikaner, CHES, Godhra, CAZRI, Jodhpur and their collaborators(AICRP on Arid Zone fruits) workingon semi-arid fruit crops in the country are maintaining 1127 accessions in their fieldgene banks (Table 3). Furthermore, 357 accessions belonging to eleven underutilized semi-arid fruit species are being cryo-preserved in gene banks (Malik *et al*., 2010). Germplasmof various underutilized fruit crops were evaluated for development of varieties at CHES, Godhra on the basis of desirable horticultural traits. Out of which varieties like GomaYashi(bael), GomaPriyanka(jamun),chironji(TharPriya) and tamarind (GomaPrateek) have been become popular at national level as evidenced by commercial scale plantation at the farmer's field (Singh *et al.,* 2018c, Singh *et al.,* 2010a). A wide range of variability with regard to yield, qualitative and quantitative character in different underutilized seni-arid fruit crops, viz. jamun (Singh and Singh, 2005a, 2012b and 2019d, Singh *et al*., 2020), bael (Saroj*et al.* 2004, 2008, Singh *et al.* 2015, Sharma *et al.* 2013, Singh *et al.* 2014f, 2014g, 2016c, 2019b,2019e), karonda (Singh *et al.* 2014), khirni (Singh *et al*., 2016b), tamarind (Singh *et al.*, 2006, Sharma *et al.*, 2015, Singh *et al.*, 2021), wood apple (Singh *et al*., 2016f, Yadav*et al.*, 2018), custard apple (Yadav*et al.,* 2017 and 2018), mahua (Bhargava *et al.,* 2017, Dhakar*et al.,* 2015, Singh and Singh 2005c), wild noni (Arya *et al.*, 2014, Patel *et al.*, 2014, Rathod *et al.*, 2016, Singh and Singh 2015e, Singh *et al.*, 2013b), chironji (Singh *et al.*, 2006 and 2016d), phalsa (Singh *et al*., 2019a and 2019f) and manila tamarind (Singh*et al*., 2020) have been reported. At present, ICAR-CIAH (Table 3) and its regional Centre CHES, Godhra are maintaining a large number of diverse germplasm of underutilized semi-arid fruits in field repository (Table1, 2&3).

Table 1.Germplasm conservation of semi-arid at National Field Repository of CIAH, Bikaner

Crop	Scientific name	No.	Crop	Scientific name	No.
Bael	*Aegle marmelos*	21	Manila tamarind	*Pythocelobium dulcae*	03
Ber	*Ziziphus mauritiana*	318	Jharber	*Ziziphus rotundifolia*	22
Cactus pear	*Opuntia ficus-indica*	24	Jamun	*Syzygigium cuminii*	2
Phalsa	*Grewia subenaequalis*	05	Lasora	*Cordyamyxa*	15
Pomegranate	*Punica granatum*	154	Kair	*Capparis decidua*	06
Fig	*Ficus carica*	02	Karonda	*Carissa carandus*	05
Mulberry	*Morus*spp.	15	Wood apple	*Feronia limonia*	03

Singh*et al.*, 2020

Table 2.Germplasm conservation of semi-arid fruit at National Field Repository of CHES, Godhra.

Crop	Scientific name	No.	Crop	Scientific name	No.
Aonla (Indian gooseberry)	*Emblica officinalis G.*	26	Manila tamarind	*Pythocelubium dulcae*	25
Bael	*Aegle marmelos*	215	Jamun	*Syzygium cuminii*	68
Capegooseberry	*Physalis peruviana*	06	Palmyra palm	*Borassus flabellifer*	2
Phalsa	*Grewia subanaequalis*	25	Karonda	*Carissa carandus*	40
Badhal	*Artocarpus lacucha*	04	Fig	*Ficus carica*	07
Mulberry	*Morus* spp.	15	Chironji	*Buchanania lanzan*	30
Mahua	*Bassia latifolia*	30	Wood Apple	*Feronia limonia*	65
Tamarind	*Tamarindus indica*	25	Khirni	*Monilkara hexendra*	30
Custard apple	*Annona squamosa*	70	Lasoda	*Cordia myxa*	04

(Singh et al., 2020)

Table 3.Status of collection and conservation of underutilized fruits at ICAR-NBPGR and its collaborative centres and other institutions.

Crop	No. of accessions maintained			
	NBPGR, New Delhi	RS, HAU, Bawal	PAU, Abohar	CAZRI, Jodhpur
Ber	487	47	34	40
Aonla	159	6	-	-
Bael	57	10	-	-
Karonda	50	4	-	13
Timroo	24	-	-	-
Manila Tamarind	24	-	-	-
Mahua	153	-	-	-
Kair	-	22	-	20
Khirni	74	-	-	-
Phalsa	36	4	-	-
Pilu	207	-	-	-
Jamun	198	-	-	-
Tamarind	248	-	-	-
Total	1717	93	34	73

Meena*et al.*, 2022

different germplasm of minor fruits under rainfed semi-arid condition (Singh *et al*. 2013a). Singh *et al.* (2015a) observed inter-varietal morphological variability in terms of leaf base margin and apex in bael varieties under central Gujarat conditions. Morphological variations in terms of vivipary, metaxenia and cauliflory in baelgermplasm have also been recorded (Singh *et al.*, 2018b) under dryland conditions of western India.

Morphological, floral, phenological and pollination behaviour in different germplasm of hot semi-arid fruits have been studied in detail, viz. bael (Singh *et al.* 2008, 2011a, 2011b, 2012a 2012b, 2014a, 2019a, 2019e, 2018a and 2018b), jamun (Singh and Singh 2012b, Singh *et al*. 2007a, 2010a, 2011a and 2019d), khirni (Singh and Singh 2005d, Singh *et al.*, 2016b and 2019c), tamarind (Singh and Singh 2005b, Singh *et al.*, 2006, 2008 and 2010), chironji (Singh *et al.*, 2006 and 2010), phalsa (Singh *et al.*, 2019a), karonda (Singh *et al.*, 2014), custard apple (Vikas*et al.*, 2017 and 2018), wood apple (Yadav*et al.*, 2018), mahua (Singh *et al.*, 2005 and 2008) and wild noni (Singh and Singh 2018, Singh *et al.*, 2013b, 2016b and 2014b) under rainfed hot environment of western India.

Varietal wealth

The underutilized fruit crops grown in hot arid and semi-arid regions particularly western part of country play a critical role in improving nutritional and livelihood security in rural and tribal areas as the availability of fruits is either low or not accessible to them. During past several years, massive efforts have been made by the NARS organizations in the development of improved varieties of underutilized fruit crops. Most of the resultant varieties are developed through clonal selections from locally adapted genotypes which have been proved worthy as they are potential source of stress related genes and have wider adaptability with desirable yield and quality traits under arid and semi-arid environments (Table 4).

Table 4. Improved varieties and technologies of minor fruit crops for semi-arid and arid (Pal *et al.*, 2014; Singh *et al.*, 2020, Meena *et al.*, 2022)

Crops	**Varieties**
Bael	GomaYashi, TharDivya, TharNeelkanth,TharSrishti, TharPrakriti, TharShivangi,TharGauri, TharBhavya,NB-5, NB-8,NB-7, NB-9,NB-10, NB-11,NB-16, NB-17, CISHB-1, CISHB-2,CISHB-3, Pant Aparna, Pant Shivani, Pant Sujata and Pant Urvashi
Aonla	GomaAishwarya, NA-4, NA-5, NA-6, NA-7, NA-10, NA-25, NA-26, BSR-1, Laxmi 52, Anand-1, Anand-2
Ber	Umran, Gola, Seb, KomaKirti, TharSevika, TharBhubhraj, TharMalti, BanarasiKarka , Mehrun, Elaichi, Kaithali
Jamun	GomaPriyanka, TharKranti, KonkanBahadoli, Jamwant,Paras,Rajamun, Rajendra Jamun-1,
Custard apple	TharAmrit, Pink Mammoth,Balanagar, Mammoth, Red Sitaphal, Yellow Sitaphal**,** PhuleJanki, NMK Gold, and Sindhan
Mulberry	TharLohit, TharHarit, Saharanpur Local-1, Saharanpur Local-2, S-13, S-34, S-146, S-7999, S-1635, ChakMajra
Karonda	Pant Manohar, Pant Sudarshn, Pant Suverna, Konkan Bold, Thar Kamal
Tamarind	GomaPrateek,TharRashmi,Prathisthan, PKM-1, T 263, Urigam, Ajanta, Yogeshwari, DTS 1 and DTS 2, AnantRudhira
Lasoda	Thar Bold, Paras Gonda, Puskar Local, MaruSamridhi, Karan Lasoda
Khirni	TharRituraj
Phalsa	TharPragati
Chironji	TharPriya
Mahua	TharMadhu, NM-2, NM- 4, NM-7, NM- 9
Manila tamarind	PKM (MT) 1
Fig	Poona Fig, Dianna, Dinkar, Conadria, Excel, Chalisgaon
Wood apple	Thar Gaurav, TharPrabha

Orchard Establishment

Orchard establishment is a long term investment and requires thorough planning starting from site selection, spacing, selection of species and varieties, quality of planting material, planting design and density. While site selection, important associated factors are local climate, and availability of quality water, availability of labour, proximity to the market, transport and processing units. The orchard should be protected from high wind velocity to create favourable microclimate. Wind breaks consist of planting of trees, shrubs or erection of artificial barriers on the windward side of an orchard for protection from wind. The most effective windbreak is a double row of tall trees, alternately placed. In the space between wind break trees, a hedge of karonda, phalsa may also be planted. The fruit plants raised in the nursery are generally used to establish new orchards. For success in dry lands, plants must have root architecture with a strong tendency to penetrate deep into the soil. Sometime plants raised in nursery beds or containers become soil or pot bound respectively and lost potential tap root during the process of plant lifting. Therefore, *in-situ* technique of orchard establishment is found suitable under arid and semi-arid conditions (Nath *et al.*, 2000). In this method, seeds of root stock species are sown right there on the field at the recommended spacing during the month of July with the onset of monsoon. The rootstock plants raised in this manner develop deep tap root system and hence they have more drought resistance. The seedlings are protected till next summer and when they attain pencil size thickness in monsoon, budding with suitable scion cultivars or elite genotype is done. This technique is found most suitable for the crops like ber, jamun, bael, gonad, wood apple, custard apple and aonla(Singh *et al.* 2009; Singh *et al.*, 2020). Among the fruit tree species, two methods of planting (i.e., auger hole and pit methods) were tested using 5 and 10 kg of gypsum in each auger hole and 10 and 20 kg of gypsum in each pit as soil amendments. After seven years *Ziziphus mauritiana*, *Syzygium cuminii*, *Emblica officinalis* and *Carissa carandus* were the successful species for these soils showing good growth and also initiated fruit setting in semi-arid alkali-sodic Soils of Haryana, India(Dagar*et al.*, 2001). Innovative orchard establishment method for minimizing drought and edaphic stresses in fruit crops grown in shallow basaltic soils of semi-arid region was standardized by NIASM, Baramati, Maharashtra (Minhas*et al.*, 2015). In the medium rainfall region of eastern Uttar Pradesh, application of FYM, pond soil, gypsum, and pyrite in sodic soils resulted in better establishment and growth of aonla and bael plants (Sharma *et al.*, 2013).

High Density Planting

The plant density mainly depends upon the plant type, soil fertility, varieties, growth habit of tree, rootstock used and management practices play important role in deciding optimum spacing in an orchard. Accordingly different systems of planting,viz. square, rectangular, traiangular (alternate), quincunx, hexagonal, contour and hedgerow system of planting may be chosen. Generally, adjacent planting is followed in arid regions and in poorly fertile soils. In this system two plants are placed closely keeping double space between rows (Singh *et al*., 2011). In the plains, planting, is generally done in square or rectangular system while on sloppy lands, fruit trees are planted on contour terraces, half-moon terraces, trenches and bunds, and micro-catchments. On marshy and wet areas mounding and ridge-ditch method of planting have been suggested. The trenches and bunds made across the slope are staggered. In a micro-catchment, which may be triangular or rectangular, trees are planted at the lowest point where runoff accumulates. In a micro-catchment, which may be triangular or rectangular, trees are planted at the lowest point where runoff accumulates (Sharma *et al.*, 2013).The planting distance 6 x 6 m or 8 x 8 m for ber cultivation is optimum. Date palm, bael and aonla are planted at 8 x 8 m or 10 x 10 m distance (Table 5).

Table 5: Recommended spacing for different fruit crops of semi-arid regions

Crops	Spacing (m)	No. of plants ha^{-1}
Phalsa	2×2	2500
Ber	6×6	277
Karonda	4×4	625
Aonla	8×8	156
Fig	6×6	277
Mulberry	6×6	277
Bael	8×8	156
Gonda	6×6	277
Wood Apple	5x5	400
Custard Apple	5x5	400
Wild noni	5x5	400
Tamarind	8x8	156
Chironji	5x5	400
Khirni	5x5	400

High density planting studies in pomegranate revealed that the maximum plant height was recorded at 2m x 2m spacing, whereas plant height, stem girth, average number of fruits, average weight of fruit and yield was obtained under 4.5m x 3.0 m spacing under Rahuri conditions (Anon., 2013). High density planting is also beneficial in aonla (Singh *et al.*, 2010, Singh *et al.*, 2018) and ber, bael, chironji (Singh *et al.*, 2016) and jamun (Singh *et al.*, 2018) fruit trees to achieve high yield under semi-arid conditions.

ICAR-CIAH,RS, CHES, Godhra has released a semi dwarf bael variety GomaYashi can be planted at 5m x 5m, accommodated 400 plants ha^{-1} which can yield 25t ha^{-1} at the age of 8th of plantation with net return of 1.0 lakh/ha under rainfed and waste land conditions of Gujarat (Singh *et al*., 2019).Under rainfed semi-arid conditions of Gujarat, aonla cv. NA-7 was planted in double hedge row system of planting by accommodating 260 plants ha^{-1} has given the fruit yield of 23tonnes/ha with a net return of 2.43 lakh/ha at 11th year of planting (Singh *et al*., 2011). High density planting systems has been successfully demonstrated for earliness, improved yield, smooth handling and cultural practices using double hedge row system of planting in aonla (Singh *et al*., 2011). Moreover, by manipulating plant spacing using different planting systems like rectangular planting in hedge row, double hedge row, paired planting and cluster planting proved to be an important tool to achieve high quality produce.

Moisture Conservation and Mulching

Water being a scarce commodity in arid and semi-arid eco-system, the first and foremost requirement is to conserve the available soil or rain water. For conservation of rain water both *in-situ* and *ex-situ* technologies need to be adopted (Mishra *et al.*, 2020). Rainwater harvesting can help in supplying enough water to improve plant establishment and crop yield. Micro-catchment is one of the direct water harvesting system where small structures are constructed across land slopes which captures surface runoff and stores in plant root zone for subsequent use by the plant (Ali *et al.*, 2017). It has been observed that the micro-catchment slopes greater than 5% did not significantly affect run off at Jodhpur. The highest ber yield was obtained when 0.5% and 5%

slopes had 8.5 m and 7.0 m length of run, and 72 m^2 and 54 m^2 catchment areas per tree, respectively (Sharma *et al*., 1986).

Effective moisture conservation practice also includes various types of mulching material. Mulches increase the soil and water content under intermittent rain or irrigation. Generally, organic and inorganic mulches are commonly used to conserve soil moisture. Mulching helps in maintaining soil temperature and moisture, avoiding weed competition, improving soil structures and biological activities, resulting into increased crop yield. In addition, the use of organic materials as mulch can enhance soil fertility, structure and other soil properties (Singh *et al.,* 2016). Paddy straw mulch was found suitable for aonla crop to improve production under semi-arid conditions of Gujarat (Singh *et al.,* 2010). When compared to other mulches, plastic mulches are completely impermeable to water; it therefore prevents direct evaporation of moisture from the soil and thus limits the water losses. In this manner, it plays a positive role in water conservation. Under arid condition, it is reported that the organic mulches like grasses, weeds and crop residues reduce the soil temperature considerably during summer months, while during winter months clear/ transparent plastic mulch increase soil temperature. Black polythene mulch as well as paddy straw mulch both is found very effective in initial plant establishment and improved plant growth of pomegranate, acid lime, aonla and guava ber orchards in western India.

The quality and efficiency of water management determine the yield and quality of fruits. Water demand is a function of weather conditions, crop species and variety, stage of growth, soil water retention capacity and texture and irrigation system management. If water is scarce and supplies are erratic, then irrigation at critical stage and soil moisture conservation are the most important agronomic interventions to maintain yields during stress. Among the different systems, drip irrigation is an efficient tool of water application in most of fruit crops. In this system, water is delivered through drippers directly to the soil adjoining to the root system, which absorb the water immediately. Studies indicate that drip irrigation could save water from 33 to 55% with yield increase to a tune of 50% or more besides improving the quality of the produce in different fruit crops. Fertilizers and pesticides can also be delivered with drip irrigation system to the crops and thus minimizes their application losses. Most importantly, their split application can be made as per the requirement at different crop stages. The use of drip alone or in combination with mulching has been demonstrated as a successful technology for cultivation of pomegranate, kinnow, date palm etc. (Sharma *et al.,* 2013), and also emphasized the application of pitcher irrigation as water conservation approach for better establishment of fruit plants in dryland areas. It was attempted in cactus pear at CIAH, Bikaner, and the growth of cactus pear was better as compared to control. This technology can be used to establish other fruit crops too.

Water loss caused by transpiration can be reduced by use of radiation reflectants, stomata closing chemicals, and plastic films. Spraying of 4 to 6% kaolin, 0.5-1.0% liquid paraffin, and 1.5% power oil, after occasional rains in low rainfall areas, considerably reduces plant water losses (Pareek and Sharma, 1991). Chemicals such as phenyl mercuric acetate (PMA), decinyl succinic acid (DSA), abscisic acid (ABA), and cetylalcohol cause stomatal closure thereby reducing transpiration. Shelterbelt and windbreaks can reduce evapo-transpiration by reducing the wind speed and stabilizing microclimate.

Nutrient Management

Soils of arid and semi-arid regions are poor in organic matter that affects nutrient use efficiency as well as soil moisture retention (Singh *et al.,* 2016). Fruit plants are nutrient exhaustive crops and deplete soil fertility extensively thus necessitates the judicious application of fertilizers. The balanced nutrition in fruit plants is required at appropriate time according to the age of plants. The application methods also play important role for availability of nutrients to the plants. In ber orchards, besides 10-15 kg organic manure, annual application of 100 g N, 50 g P2O5 and 50 g K2O per tree is recommended. Fertilizer doses should be raised according to the age of plants and soil fertility of the region. Application of 15-20 kg FYM per tree has been found beneficial in aonla, custard apple, and tamarind. At MPKV, Rahuri, in addition to 50 kg FYM, 625 g N, 225 g P2O5 and 225 g K2O has been recommended for application to 5-year-old pomegranate trees. In 6 to 7-year-old fig trees planted at 5 m x 5 m spacing, fertilization with 900 g N + 250 g K improved fruit production (Sharma *et al.,* 2013).

Organic fertilization can improve fruit crop tolerance to soil stresses like salinity, drought, alkalinity and excessive amounts of toxic elements. A number of studies have shown that the organic manure application increases water as well as nutrient use efficiency of soil due to increased organic matter content and other soil physical, chemical and biological properties which in turn favours better plant growth and development that help in counteracting the adverse conditions near rhizosphere. Foliar application of nutrients has been also recommended as a means of improving plant growth especially in the early stages of development as it provides the required nutrient directly to the location of demand in the leaves and results in rapid absorption, being independent of root activity and soil water availability.Vermi-compost gained popularity due to recent interest in organic farming and is mostly used in fruit crops. It is rich source of micro and macronutrients, vitamins, growth hormones and enzymes. Organic content was found to be significantly higher with the application of FYM and vermicompost, while bulk density was decreased. In recent past, use of different grade water soluble fertilizer through drip has been increased due to its improved fertilizer use efficiency and plant growth, yield and quality of produce. Micronutrients are often found deficient in semi-arid and arid soils and play significant role in production of high grades fruits. Foliar feeding of nutrients such as nitrogen (0.5-2.0% urea), zinc (0.05-1.0% zinc sulphate) and boron (0.05-1.0% borax) has given beneficial results in these areas (Pareek and Sharma, 1991).

Post- harvest management

Grading and packaging are the important practices to fetch better price in the market. The packages protect the produce from damage loss as it maintains quality and retains freshness. Corrugated fibre board box (CFB), wood box with suitable cushioning materials are most suitable and economically-viable packing container for transportation of semi-arid horticultural produce. Cushioning material should be physiologically inactive. Moulded pulp tray, honeycomb, cell pack are better than the traditional material like straw and grasses (Singh *et al*., 2020). A large quantity of fruits and vegetables produce goes waste due to unavailability of adequate storage facility in semi-arid dryland areas. Proper storage facility like cool storage, CA and ZECC storage can reduce the post-harvest loss to greater extent and can improve the farm income (Singh *et al.,* 2007c 2010a, 2018a, 2019a and Singh and Singh, 2012).

The fruits grown in semi-arid regions have been prepared into various processed products by the people utilizing their acquired traditional knowledge like sun drying, pickling etc. However, with the application of modern techniques, the quality of products could be improved considerably. The pre-treatment of many fruits with hormone and harmless chemicals results in better quality end products (Meghwal, 2016). Solar drying and electric tray dehydration of fruits and vegetable help to reduce dust load on the product and retain natural colour. Techniques for preparation of different products from underutilized fruits have been standardized (Mishra, 2018, Reddy *et al.*, 2018).

Malnutrition in resource poor areas of semi-arid region is a major problem particularly in women and children. Fruits like tamarind, custard apple, bael, khirni, karonda, phalsa, mulberry, wild noni, wood apple etc. are a rich source of vitamins, minerals and dietary fibres. Bael fruits contain higher in riboflavin than many fruits. Fruits like wood apple and custard apple are rich in carbohydrates and minerals which are vital for the maintenance of body and physiological function. These fruits are highly perishable in nature, the marketing of which is a major problem, fruits gets spoiled within 2–3 days of harvesting, if not consumed (Singh *et al.* 2007c 2018a, 2019a). Also with the glut in the market, the prices of these fruits drop down drastically making it uneconomical for the farmers to sustain production; the result is that the farmers uproot the trees owing to low price in the market. To avoid this situation, there is a need to extend shelf-life of these fruits and to develop post-harvest value addition technologies which are simple and adaptable at the farm level. This will not only result in developing small-scale industry but it will also provide employment to the rural masses throughout the year resulting in increased income of both farmers and workers. Efforts made at the CIAH Bikaner and region research Centre CHES, Godhra were successful and many products viz., dried and dehydrated fruits, RTS, squash, fruit bars, candies, fruit concentrates, powders, wines, and condensed fruit juices through solar drying, were prepared and demonstrated to stakeholders for further commercialization. The tamarind pulp is pressed and preserved in large masses and in dry conditions the pulp remains good for about 1 year. There is tremendous scope for preparing beverages from ripened fruit of chironji. Kernels are being used for the preparation of different kinds of sweets. The products like squash, RTS, and nectar may be prepared from the pulp of the fruits. Value added products of different hot semi-arid fruits are given in Table 6.

Table 6: Value-added products of underutilized fruits

Underutilized fruit crop	**Value-added products**
Bael	Preserve, RTS, nectar, ice cream, slab, squash, cider, canned bael slices, pickles and powder
Aonla	*Murabba*, candy, jam, juice , sauce, shreds, powder, pickle
Ber	Jam, candy, preserve, powder, murabba, beverages, pickle, dried ber
Chironji	Dried kernels, fruit bar, sweets
Karonda	Pickle, candy, jelly, jam, preserve, wine,Chutney
Wood apple	Squash, powder, pickle, chutney, jelly, fruit bar
Khirni	Dehydrated fruits, fruit bar, RTS, jam
Jamun	Juice, RTS, squash, syrup, carbonated drink and wine
Phalsa	Juice, squash, syrup
Lasoda	Pickle, culinary
Custard apple	Jam, beverages, ice cream
Tamarind	Tokku (chutney), panipuri masala, Juice concentrate, pulp powder, jam, syrup, candy toffee, tamarind karnel powder
Timru	Bidi, dried fruit
Pilu	Squash, dried *peelu*, wines
Kair	Pickle, dried fruits
Mulberry	Juice, squash and syrup
Mahua	Biscuits, cakes dried powder, seed oil and wine
Manila tamarind	Biscuits, squash and syrup
Aloe	Candy, jelly, pickle, cold cream, crack cream, moisturizer, gel
Fig	Fig paste, concentrate, powder, nuggets, jam

Singh *et al.* 2019, Hiwale, 2015, Singh *et al.* 2010, Yadav*et al.* 2018a and 2018b

CONCLUSION

Keeping in view the agro-climatic conditions of semi-arid region, it is need of hour to create awareness among farmers regarding the various technologies like high-yielding varieties, floor management water harvesting practices, use of organics, IPM, IDM, bio-pesticides, biofertilizers, preparation of value-added products and their marketing can enhance the farm income under prevailing conditions of semi-arid region. Unproductive land can be made productive by selecting the crops having ability to grow under aberrant agro-climatic conditions by proper planning and amalgamation of suitable technologies holistically. As most of the semi-arid fruits cannot be directly used for the table purpose, and thus fetches low prices in the market. Therefore, through processing and value-addition and their efficient marketing, farmer's economic status can be effectively improved with better health and nutritional security. Therefore, focusing attention on such fruit crops is an effective way to help a diverse and healthy diet and to combat malnutrition, so called 'hidden hunger' and other dietary deficiency among the poor rural people and more vulnerable social groups specially tribes of country.

Researchable Issues

- Hot semi-arid underutilized fruits are still remained neglected. Genetic resources of these crops are still available on farmers' field or in forests which needs to be conserved.
- Research work on underutilized fruit crops should be expanded in order to maximize production and also to overcome disease and pest problems.
- The germplasm of semi-arid fruit crops need to be collected, documented and conserved in field gene banks.
- Ethno-botanical and nutritional value also needs to be assessed with scientific validation.
- Genetic improvement and development of new varieties for specific traits.
- Standardization of propagation techniques and timely supply of quality planting materials and development of location specific agro-techniques to exploit these crops commercially.
- Commercialization of processing, packaging and value addition in underexploited semi-arid fruit crops.

Future Strategies

- Identification of suitable growing areas in respect of each underutilized fruit crop suitable for different soil conditions.
- Market linked production and shift in attitude from subsistence farming to commercial orcharding.
- Location-specific farming systems involving underutilized crops need to be developed and popularized to ensure its adoption by the farmers of the region.
- Creating awareness among the growers for marketing of produce through cooperative or growers' association so as to fetch better price of the produce for grower's prosperity.
- Emphasis should be given on post-harvest technology to develop value added export oriented products. Small scale processing units should be established and promoted for commercialization of this fruit crop.
- Screening of genotypes for abiotic especially drought resistant and moisture stress.

- Fruit based cropping systems and cropping models should be developed to provide stability in income to the farmers.
- Developing suitable technologies for reducing post-harvest losses and supporting cottage industries.
- To create awareness among the people regarding it nutritional, health and environmental security for its commercialization.
- It is need of hour to develop herbal products useful against various ailments with scientific validation.

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14. Wild and underutilized fruits of Western Ghats

P.C. Tripathi*, Anuradha Sane, Kanupriya, V. Sankar, G. Karunakaran and R. Senthil Kumar

ICAR-Indian Institute of Horticultural Research, Bangalore 560 089
*Email: prakaashtripathii2000@yahoo.co.in

Western Ghats region of India is one of the biodiversity hot spots of the world. The topography, wide rainfall variation and varied temperature conditions make it home of several plant species. This plant wealth is being used in various forms by tribal and natives of the area since long. These wild fruits gain further importance due to the fact that one or the other kind of fruit is available in ripe form during round the year and serve as a source of food and medicine to tribal's throughout the year. These wild fruits are source of minerals and vitamins in the diet of the rural under privileged class. The potential productivity and floristic diversity of the area has attracted the experts. Among the edible wild fruits some are even superior to the presently cultivated ones. There are more than 50 wild edible fruit species are available in Western Ghats region. These belong to 25 families and 38 genera. Out of the 25 families the important ones as a source of fruits are *Apocynaceae, Anacardiaceae. Euphorbiaceae, Moraceae, Sapotaceae, Sapindaceae*. The duration of fruiting period of different species ranged between two to six months. The highest number of species mature in April - May. The availability of these fruits get reduced after October. Some of these fruits such as *Mangifera indica, Artocarpus heterophyllus, Carissa carandas, Emblica officinalis, Syzygium cuminii* have been given emphasis in order to identify superior clones, production technologies. The efforts collection, conservation and utilization on some of the fruits such as *Garcinia indica*, *Garcinia gummigutta* have been started at various research organizations. Some other fruits namely *Chrysophyllum roxburghii (family* Sapotaceae), *Canthium parviflora* Lamk syn. *Plectronia parviflora* (Lam.) Bedd. (Family Rubiaceae), *Elaeagnus conferta* Roxbsyn, *E. latifolia* L (family *Elaeagnaceae*), *Securina leucopyrus syn. Flueggea leucopyrus (*family Euphorbiaceae), *Elaeocarpus tuberculatus* Roxb (family Elaeocarpaceae), *Nephelium stipulacum* Bedd) syn.*Doratoxylonstipulatum,* (family sapindaceae) have potential for commercial cultivation.

Table 1 : wild fruits of western ghats

Botanical Name	Family	Botanical Name	Family
Allophylus serratus	Sapindaceae	*Flacourtia indica* (Burm.) Merr.	Flacourtiaceae
Aporosa lindleyana	Euphorbiaceae	*Flacourtia montana* Graham	Flacourtiaceae
Artocarpus hirsutus Lamk	Moraceae	*Garcinia indica*	Clusiaceae
Artocarpus lakoocha	Moraceae	*Garcinia gummigutta* (L) Roxb.	Clusiaceae
Borassus flabellifer L.	Palmae	*Garcinia xanthochymus*	Clusiaceae
Canthium dicoccum var. *umbellatum*	Rubiaceae	*Glycosmis mauritiana*	Rutaceae
Canthium *parviflora* Lamk	Rubiaceae	*Grewia tiliifolia*	Tiliaceae
Chrysophyllum roxburghii	Sapotaceae	*Margaritaria indica*	Euphorbiaceae
Carissa carandas L.	Apocynaccae	*Dimocarpus longan* Lour	Sapindaceae
Carissa gangetica Stapt	Apocynaceae	Nephalium stipulacum Bedd.	Sapindaceae
Cordia dichotoma	Cordiaceae	*Rourea minor* (Gaertn.)	Connaraceae

Elaeagnus conferta	Elaeagnaceae	*Rubus ellipticus* J.E. Sm.	Rosaceae
Elaeocarpus tuberculatus	Elaeocarpaceae	Salacia malabarica Gamb	Hippocrateaceae
Elaeocarpus munronii (Wt.)	Elaeocarpaceae	Scutia circumscissa	Rhamnaceae
Epiprinus mallotiformis	Euphorbiaccae	*Flueggea leucopyrus*	Euphorbiaceae
Flacourtia indica (Burm.)	Flacourtiaceae	*Zizyphus oenoplia L*	Rhamnaceae
Symplocos cochinchinensis	Symplocaceae	Zizyphus rugosa Lamk.	Rhamnaceae
Syzygium cumini	Myrtaceae	*Terminalia bellerica*	Combretaceae
Syzygium gardneri	Myrtaceae	*Xeromphis spinosa*	Rubiaceae
Syzygium jambos	Myrtaceae		

Table 2 : Indigenous Minor Fruits grown in western Ghats

Common name	Scientific name	Common name	Scientific name
Jack fruit	*Artocarpus heterophyllus*	Tamarind	*Tamarindus indica*
Aonla	*Emblica officinalis*	Phalsa	*Grewia tiliifolia*
Star Gooseberry	*Phyllanthus acidus*	Bael	*Aegle marmelos*
Bilimbi	*Averrhoa bilimbi*	Wood apple	*Ferronia limmonia*
Jamun	*Syzygium cumini*	Kokum	*Garcinia indica*
Ber	*Ziziphus jujuba*	Yellow mangosteen	*Garcinia xanthochymus*
Jherberi	*Ziziphus nummularia*	Malabar tamarind	*Garcinia gumigatta*
Rose Apple	*Syzygium jambos*	Governor's plum	*Flacourtia indica*
Pommelo	*Citrus grandis*	Mahua	*Madhuca indica*
Citron	*Citrus medica*	Pilu	*Salvadora oleoides*
Phog	*Calligonum polygonoides*	Ker	*Capparis decidua*
Sea buckthorn	*Hippophae rhamnoides*	Indian almond	*Terminalia catappa*

Several exotic minor fruits such as Rambutan, mangosteen, longan, avocado, water apple, hog plum, macadamia nut, kiwifruit, longsat, durian, passion fruit, dragon fruit, pulasan, carmbola, etc. were introduced during last few centuries and several are naturalized in Indian conditions (Arora, 1985; Arora, 1998. Pareek *et al.*, 1998; Table 2). Several fruit plant species as Rambutan, mangosteen, longan, avocado, water apple, hog plum, macadamia nut, longsat, durian, passion fruit, dragon fruit, pulasan, carambola etc. were introduced during last few centuries and several are naturalized in Indian conditions.

Table 3 : Exotic Minor Fruits grown in western Ghats

Common Name	Scientific Name	Family	Common Name	Scientific Name	Family
West Indian Cherry	*Malpighia glabra*	Malpighiaceae	Malay Apple	*Syzygium malaccense*	Myrtaceae
Durian	*Durio zibethinus*	Malvaceae	Mangosteen	*Garcinia mangostana*	Clusiaceae
Soursop	*Annona muricata*	Annonaceae	Rambutan	*Nephelium lappaceum*	Sapindaceae
Passion Fruit	*Passiflora edulis*	Passifloraceae	Custard Apple	*Annona squamosa*	Annonaceae
Atemoya	*Annona atemoya*	Annonaceae	Manila Tamarind	*Pithecellobium dulce*	Fabaceae

Dragon fruit	*Hylocereus.spp*	Cactaceae	Avocado	*Persia americana*	Lauraceae
Longan	*Dimocarpus longan*	Sapindaceae	Macadamia nut	*Macadamia integrifolia*	Proteaceae
Longsat	Lansium domesticum	Meliaceae	Manila Tamarind	*Pithecellobium dulce*	Fabaceae
Egg fruit	*Pouteria campechiana*	Sapotaecae	Java Apple	Syzygium samarangense	Myrtaceae
Surinam cherry	Eugenia uniflora	Myrtaceae	Tamarind	*Tamarindus indica*	Fabaceae
Carambola	*Averrhoa Carambola*	*Oxalidaceae*	Bread fruit	*Artocarpus altilis*	

Very recently rambutan, avocado, dragon fruit etc. have become popular in several parts of the country. As far the genetic resources of exotic fruits are concerned, the variability in these fruits is limited. Some of these fruits were introduced almost one century back and grown in home stead gardens. Most of the present accessions available in these fruits have been collected from these home stead gardens. The area under minor fruits is around 10 percent of the total area under fruits and production is less than 7 percent of total fruits production. Most the the minor fruits are cultivation in dry and less fertile lands thus the productivity is low except in jackfruit. Among them highest area is under jack fruit followed by kiwi fruit and Aonla. The cultivation of kiwifruit is confined to hill states of North India. The custard apple also occupied sizeable area under cultivation particularly in the arid and semi-arid regions

1.0 Major wild fruit species

Rich genetic diversity of wild and semi domesticated fruits found in Western Ghats. Some of the fruits found in different regions and their characters, variability and use in described in Table 4.

Table 4: Major wild fruit species of Western Ghats

Name and family	Description	Occurrence	Variability	Uses
Kala Hisalu (*Rubus biflorus* Buch.) Family- Rosaceae	A deciduous small shrub, fruits mature- June to July.	Found in in moist-shaded forests at an altitude of 1600 to 2800m.	Variability with respect to growth and flowering and fruit characters	Fresh fruit and jam
Banimboo (*Glycosmis arborea* (Roxb.) Family-Rutaceace	An evergreen, glabrous shrub of. It flowers and fruits almost round the year. The fruits are depressed, globose, dirty-yellowish or pinkish.	Found in abundant in forest up to 600m.	Restricted to some areas of Lower hills of Western Ghats	Fruit edible but rarely available in market
*Baccaurea sapida*Muell. Arg. Family-Phyllanthaceae	Evergreen tree up to 5 m height, with long branches from near the ground, particularly when the stem is laden with fruits	Khasi and Jaintia Hills. It is native to Southeast Asia.	Variability available in Lower hills	Ripened fruits are eaten and taste delicious. The rind of fruits is used for making chutney
Artocarpus hirsutus Lamk Family- Moraceae	A tree may reach a height of up to 35 m. The fruits ripe in May-June	native to western Ghats, prefers moist, deciduous forests up to 1000 mmsl	Variability found in Western Ghats and Eastern India	The mature carpels, seeds are consumed fresh. Tender fruit used in pickle

Chrysophyllum roxburghii Family -Sapotaceae	A tree up to 30 metres tall, with a trunk diameter of up to 40 cm	native to western Ghats, prefers moist, forests	Variability found in Western Ghats	Ripe fruits are consumed fresh, Can be use as rootstocks for Sapota
Cordia dichotoma	small to moderate-sized deciduous tree, fruiting in April- June	native to India	Variability found all over India	Fruits y used as a fresh fruits .Immature fruits are used in pickling
Garcinia gummigutta	medium tree found in Western Ghats	native to western Ghats, prefers moist, forests	Variability found in Western Ghats	fruit rind is used as spice in curries and its juice is used for reducing fat
Garcinia xanthochymus	medium tree found in Western Ghats, eastern India and NEH region	native to western Ghats, prefers moist, forests	Variability found in Western Ghats, eastern India and NEH region	Fruits are used fresh and fruit rind is used as spice in curries
Xeromphis spinosa Family- Rubiaceae	Small tree or shrub fruits matures in June-July	found in entire of Western Ghats	Variability found in Western Ghats	whole fruit expect the seed is consumed at ripe stage
Zizyphus rugosa LamK Family- Rhamnaceae	Small tree or shrub, spines. Flowering-December-January fruits mature in February- March	found in entire of arid regions	Variability found in arid regions	small tree or shrub, spines.
Garuga pinnata Roxb. Family- Burseraceae	Garuga is a deciduous tree of moist tropics growing up to 18 metres tall	Foundin Indian sub-continent,	Variability found in entire India	The fruits are eaten raw or pickled
Meyna laxiflora Roby Family -Rubiaceae	Large shrub or a small tree and commonly found in evergreen forests	Native of India may be in western Ghats. The plants are found in Western UP, West Bengal, North-east India and Deccan peninsula.	Variability found in entire regions	The fruits are used preparation of pick
Choerospondia saxillaris Roxb. Family -Anacardiaceae	An evergreen tree that can grow up to 10 metres tall, though is usually smaller.	The fruit tree is inhabitant to Nepal to North Eastern Hill states of India. found growing from 850–1900 m msl.	Variability found in entire regions	Fruits are consumed fresh, pickled and processed for making various products locally called as Mada and candy
Borassus flabellifer L Family -palmae(araeceae)	Robust tree.,may reach a height of 30 metres, unbranched stem,	Native to India subcontinent and south east asia, grows in wide range of conditions in dry to moist tropical and subtropical climate.	Variability found in entire regions	Fruits are used raw or cooked. The immature fruits are pickled

2. Conservation

Wild fruits

Lot of work on exploration and taxonomical aspects of wild fruit species have been done by different botanists and taxonomists. Lot of work on pharmalogical properties of these fruits have also been done in different regions of India. But there is no systematic conservation of wild fruits is flowed in India. Some of the wild species have been conversed by National Bureau of Plant Genetic Resources and it's regional stations in different regions of the country. Some of ICAR institutes, State Agricultural Universities, Research stations, and forest department have also conserved some species of the wild fruits grow in their jurisdiction (Table 5).

Table 5. Detail of some of the wild species conserved at different organizations

Institute	No. of species	Major species and No. of Accessions
IIHR, Bangalore	25	*Alangium savifolium, Flacourtia montana (11), Flacourtia indica (2), Garcinia xanthochymus (13), Garcinia gummigutta, Canthiumdicoccum, Antidesma bunius, Artocarpus laucha (1) Azimatetra cantha (2), Grewia subinaeqalis, Phyllanthus acidus(2), Salacia chinensis(2), Artocarpus hirsutus*
CHES, Chettalli	3	*Garcinia xanthochyma (13), Garcinian gummigutta, Garcinia morella,*
College of Forestry, Ponnampet, Kodagu	12 spp	*Alangium savifolium, Flacourtia montana, Flacourtia indica, Garcinia xanthochymus, Garcinia gummigutta, Grewia subinaeqalis,*
JLN-TBGRI, Trivandrum	>25 spp	*Garcinia imberti, Cycas annaikalensis, Goniothalamus malayanus, G. wayanadensis, Canthium travancoricum, Grewia palodensis, Calamus andamanicus, Syzygium parameswaranii, Hydnocarpus pentandrus , Garcinia talbotii, Baccaurea* spp.

Exotic minor fruits

Some of these exotic species were introduced in India during last 500 years from different regions. Some of them naturized in all over India and some are confined to some species areas due to some reasons such specific climatic requirements, dietary suitability. Thus a little variability is found in most of the exotic minor fruits in the country. Little of work on exploration of these fruit species have been done in India. These species are found in homestead garden in several regions of south India. But there is no systematic conservation have been so far in India on these crops. Recentlysome of the commercial varieties are these crops are being imported by several private firms, nurseries. Some of these species have been conversed by some of ICAR institutes, State Agricultural Universities and Research stations (Table 6).

Table 6. Detail of some of the minor species conserved at different organizations

Institute	No. of species	Major species and No. of Accessions
IIHR, Bangalore	11	Macadamia nut (5), longan (1), mangosteen (1), dragon fruit (1), Barbados cherry (1), Surinam cherry (2), Manila tamarind (1), snake fruit (1), avocado (4), miracle fruit (1), green sapota (1), Malayan apple (3), Peanut butter fruit (1), Olive (1), Quanquat (1),
CHES, Chettalli	13	Rambutan (150), Macadamia nut (1), longan (20), mangosteen (9), durian (3), dragon fruit(3), Pulasan (1), avocado (65), Passion fruit (12), Barbados cherry (1), Velvet apple (1), Green sapota (1), Malayan apple (32)
CHES, Hirehalli	3	Dragon fruit (56), Barbados cherry, Surinam cherry, avocado (16), miracle fruits (1)

Fruit Research station, Kullar	3	Rambutan, longan, mangosteen, durian
Fruit Research station, Burilar	3	Rambutan, longan, mangosteen, durian,
KAU, Thrissure	1	Rambutan
TNAU, Coimbatore and its regional centre	1	Avocado (60)

Characterization

Wild fruits

The fruits of most of the species are small only few species have bigger fruits .Among the species analysed, highest weight were recorded in *Garcinia xanthochymus* (127.78g) followed by *Artocarpus lacucha* (113.5g) and *Artocarpus hirsutus* (93.55g).The fruit weight was more than 50g in *Garcinia gummigutta* (60.30g), *Chrysophyllum roxburghii* (54.53 g) and *Garcinia indica* (52.63 g).The shape of fruit was globe to oblong is most of the fruits while it was cylindrical in *Averhoa blimbi*. There is large variability with regards to colour of fruits. It ranged from bright red, bright yellow, bright violet, black to green. As far as the total soluble solids are concerned, it was highest in *Chrysophyllum roxburghii* (22.0 ^{O} Brix) followed by *Cordia dictoma* (16.3 ^{O}Brix) and *Securina leucapyrus* (15.6 ^{O} Brix) and *Carissa carandus* (15.6 ^{O}Brix). Most of these fruits are acidic in taste. The titrable acidity was highest in *Garcinia xanthochymus* (7.2%) (Table 2). The previous work done on the nutritional value revealed that these fruits are rich in vitamins and minerals (Karuppuswamy *et al*.,2011). Due to the nutritional value, these fruits are the parts of the diet of local tribes since long. During recent years, a large variety of trees, shrubs, creepers, lianas, scrubs and herbs were removed during the process of conversion from native forest to cultivation. This has resulted in loss of native trees of which wild edible trees are an important component. Uthaiah (1995) reported large populations of wild fruit-producing trees in the region in the early to mid1990s. Many wild fruit trees had been felled due to changes in land use. During survey it was mentioned by many respondents that these fruits were available in abundance in forests and village forests few decades ago but now these fruits are rarely seen. All were of the opinion that these fruits should be conserved. Thus, the seeds and plantlets collected from forests and plantations were raised and twelve species were planted for conservation. Many saplings were distributed to the selected planters to conserve the biodiversity of these species. Although most of these species are now endangered but still some of these plants are available in reserve forest and selective sites. All the respondents emphasized need of conservation of these species for future.

Table 7: Fruit characteristics of some wild and minor fruits

Botanical name	Fruit Weight (g)	Fruit length (cm)	Fruit breadth (cm)	Rind colour	Flesh color	TSS (^{O}Brix)
Averhoa bilimbi	15.6	5.6	2.2	Green	white	5.2
Artocarpus lacucha	113.5	6.1	6.3	Green	white	6.7
Artocarpus hirsutus	93.55	6.45	5.3	Dull Yellow	Light yellow	
Securina leucopyrus	9.33	2.34	2.47	Whitish Green	white	15.6

Cordia dichotoma	3.11	1.27	1.61	Whitish pink	white	16.3
Chrysophyllum roxburghii	54.53	4.24	4.86	Green	white	22.0
Carrissa carendus	9.04	2.53	2.46	Violet	white	15.2
Syzygium cumini	2.12	1.51	1.1	Violet	Reddish	11.2
Rubus niveus	1.5	1.1	1.2	black	Reddish	13.2
Garcinia indica	52.63	4.15	4.86	Dull Red	Red rind	14.78
Garcinia gummigata	60.30	5.2	5.1	Dull yellow	Yellow rind	8.9
Garcinia xanthochymus	127.78	6.64	6.15	Bright Yellow	Yellow	12.70
Citrus aurantifolia	28.2	-	-	Yellow	white	7.2
Citrus reshni var *kodakithuli*	18.37	2.64	3.49	Bright orange	orange	11.2
Citrus maderaspatna	15.2	2.63	3.51	Bright orange	orange	13.2

Exotic minor fruits

A large collection of exotic fruits has been planted and evaluated at CHES, Chettalli. Some other research stations also have collected and evaluated. Some of varieties and elite lines of some fruits such as Rambutan, avocado, passion fruits etc have been identified and released (Table 7). Recent decades some of the commercial varieties of rambutan, avocado, mangosteen have been introduced by Govt and private nurseries.

Table 7: Promising lines of minor exotic fruits

Crops	Variety	Promising line
Rambutan	Arka Coorg Arun Arka Coorg Peetah (CHES)	CHESR-14 CHESR-26
Passion fruit	Kaveri	-
Avocado	TKD-1 Arka supreme, Arka Coorg Ravi	CHESA-1, CHESPA-III-1 CHESPA-XIII-1, Avocado-12
Malayan apple	-	CHESM-1

3. Utilization

The wild fruits species are source of food for several tribes and forest dweller since time immortal. Some of these species are used as rootstocks for cultivated species. Some species have potential to use in breeding programmes. Some examples are described as follows:

3.1. Use as rootstocks

Palepan (*Chrysophyllum roxburghii)* have potential to be good rootstocks for Pistachio, avocado and sapota, wild jack fruits

3.2. Use as new species

Some of the wild species can be used as new species for crop diversification with standardization of production technologies for these species. Wild jack, wild avocado, native hog plum, Chalta, Burmese grapes, Khirani are some examples**.**

3.3. Use of source of nutraceuticals

The fruits of Kokum, Jamun are well known from ancient times for their medicinal as well as nutritional properties. Laboratory and field research suggests that substances may have potential for various future applications, since they have shown cytotoxic, anti-inflammatory, anti-diabetic and anticancer effects in laboratory experiments. Similarly, the other fruits can also be explored for the medicinal and nutritional properties.

3.4. Processing and value addition

Some of wild fruits are used to prepare juices, pickles and other products. The wild hog plum pickle is very popular. The pickles of ker, Bhokar, losada are common in some part of India. These are sources of livelihood for the people of these regions. The processing and value addition of these fruits may helpful in employment generation in these regions.

4.0 Prospects

4.1 Accommodation of these crops in Farming system for crop diversification and also in agro forestry/social forestry programme

It is observed that many of these crops usually grow in wild areas without any much care and special attention. Hence the good way to promote, these fruits by introducing these plants in Farming system-. The thorny plants of Karonda, *Flacoutia*, Azima, Ziziphus can be introduced along the borders, so that it can also act as hedge protecting being a source of additional income.

4.2 Awareness not to neglect

Though these crops are grown in wild and have less attention, they have their own unique characters and qualities. Hence there is immense need to promote these fruits by creating awareness among the locals and popularisation of these fruits in the form of value-added products.

Future thrust

- Although some of these fruits are abundantly available in their habitat, it is required for collecting the core Germplasm collection for their conservation, characterization and characterization to mitigate the climate change driven problems in future. Therefore, collection and conservation of Germplasm resources needs special thrust for future benefits. In vivo and in situ conservation approaches may be explored for conservation.
- Promising germplasm accessions need to be evaluated for short listing new varieties possessing commercial attributes and processing qualities.
- Production technology and propagation techniques need to be standardization for commercial production and production and supply of quality planting material of newly developed varieties.

- Storage and handling studies are imperative for effective secondary agriculture activities.
- Keeping the unique Nutraceutical qualities of the fruits, value added products like RTS of health drinks and herbal drinks specialty fruits need to be explored and products popularized through appropriate production and marketing linkage chains.
- Since this group of fruits is an important source for health protective properties, like antioxidants, vitamins and secondary metabolites, etc., there is need to give special attention to probably explore them for addressing new outbreak of diseases and strange health problems.

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15. Unlocking the economic potential of jackfruit in India

Prakash Patil

Project Coordinator (Fruits), ICAR-Indian Institute of Horticultural Research, Bengaluru-560 089
Email id: Prakash.Patil@icar.gov.in

1. Introduction

The jackfruit, scientifically known as *Artocarpus heterophyllus* and commonly referred to as the jack tree, "poor man's food" finds its roots in the Western Ghats of the Indian Sub-continent. Its Malayalam name, Chakka, is believed by some to have influenced the English name "jackfruit." In recent years, it has gained prominence as a commercially grown crop. It is a popular and affordable choice in Southern Asia and other warm regions across the globe. In India, jackfruit cultivation spans approximately 1.93 lakh hectares, with an estimated one million trees thriving in backyards and intercropped with other commercial crops like betel nut, coffee, pepper, and cardamom plantations, especially in the southern regions. It is worth mentioning that jackfruit has a deep historical connection with India, where it was cultivated as early as 3,000 to 6,000 years ago. This versatile fruit is widely distributed in Assam, Tripura, Bihar, Uttar Pradesh, as well as the Himalayan foothills and South Indian states.

The primary economic product derived from the jackfruit is its fruit, which is valued in both its mature and immature stages. This fruit displays remarkable adaptability and offers a delightful natural sweetness, coupled with a high nutritional profile. Its pulp is rich in starch and fibres, making it a valuable dietary fibre source. The health benefits of jackfruit are associated with a wide range of physicochemical applications. Additionally, jackfruit contains isoflavones, antioxidants, and phytonutrients, indicating its potential for anti-cancer properties. It's worth mentioning that immature jackfruit exhibits potential in diabetes management, creating opportunities for the commercial use of freeze-dried immature jackfruit.

2. Research and Development in India:

Considering the extensive diversity of jackfruit crops, a significant development took place in 2000 when a status report on genetic resources of jackfruit in India and Southeast Asia, authored by Bhag Mal, V. Ramanath Rao, and R.K. Arora, was submitted to the International Plant Genetic Resources Institute (IPGRI). This report laid the foundation for the initiation of the Underutilised Tropical Fruits in Asia Network (UTFANET) project, which received funding from the International Centre for Underutilised Crops (ICUC). The primary objective of this project was to promote research on underutilised or neglected fruits.

This endeavour played a pivotal role in bringing jackfruit into the mainstream agricultural research efforts of the Indian Council of Agricultural Research (ICAR). In 2001, it was officially included as one of the mandate crops under the ICAR's All India Coordinated Research Project on Fruits. Simultaneously, ICAR supported several ad hoc schemes, one of which was executed at Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, West Bengal.

Furthermore, the Rural Bioresource Complex project, financially backed by the Department of

Biotechnology of the Government of India, was implemented by the University of Agricultural Sciences (UAS), Bengaluru in April 2005. This project aimed to empower growers and maximize farmers' profits. To foster awareness and interest, a multitude of jackfruit melas and diversity fairs were organized throughout the country, with a particular focus on South India.

Encouraged by the growing demand and interest, UAS Bengaluru, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth (DBSKKV) in Dapoli, University of Horticultural Science (UHS) in Bagalkot, and Kerala Agricultural University (KAU) in Thrissur had organized national and international seminars dedicated to jackfruit. In addition, the ICAR-AICRP on Fruits held a national consultation meeting specifically focused on jackfruit.

Considering these advancements and initiatives, the Asia-Pacific Association of Agricultural Research Institutions (APAARI) published a comprehensive status report on jackfruit in 2012. This report aimed to assess the progress made in jackfruit research and development and to lay the groundwork for future programs in this area. Subsequently, numerous organizations have engaged in research and development programs related to jackfruit, with a primary emphasis on preserving its diversity, identifying promising clones, studying pest dynamics, and exploring various value-added products.

3. Production status of jackfruit in India

India, the birthplace of jackfruit, ranks second globally in production. It's extensively grown in northern, eastern, and southern regions. Recent data from the National Horticulture Board and Department of Agriculture and farmer welfare (Adv. Est. 2022-23) shows that jackfruit is cultivated in 1.93 lakh hectares with an annual production of 32.73 lakh metric tonnes (Fig 1 & 2).

In the last five years (2018-2022), jackfruit cultivation area increased by 4.6%, with a remarkable 2.36-fold surge from 2012-13 to 2013-14. Between 2011-12 to 2022-23, total jackfruit production grew 3.14-fold.

Kerala leads in jackfruit cultivation area (45%), while Tamil Nadu achieves high production (4%) with just 2% of the total area. Assam (11.65%), Jharkhand (8.10%), Odisha (7.02%), West Bengal (6.37%), and Chhattisgarh (5.38%) also contribute significantly. Despite Karnataka's small cultivation area (0.8%), it contributes 2% to India's jackfruit production (Fig 3 & 4).

An agriculture study revealed a 2.8% reduction in Kerala's jackfruit cultivation area and a 16% drop in production from 2005-06 to 2014-15. In Assam, jackfruit cultivation area expanded by 22.73% from 2001-02 to 2010-11, with a 20.90% production increase. West Bengal reports the highest jackfruit output (50145 lakhs), followed by Kerala (24950 lakhs), and Tamil Nadu.

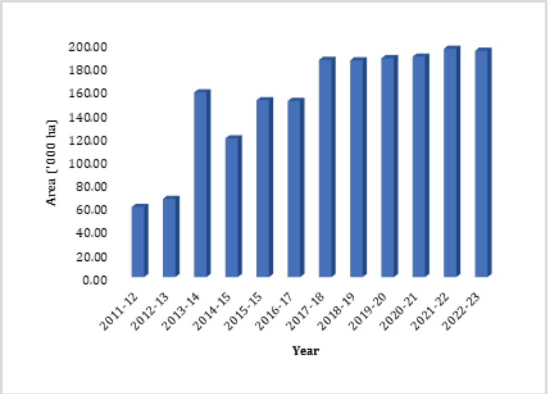

Fig. 1: Trends in jackfruit cultivation in India for past 12 years

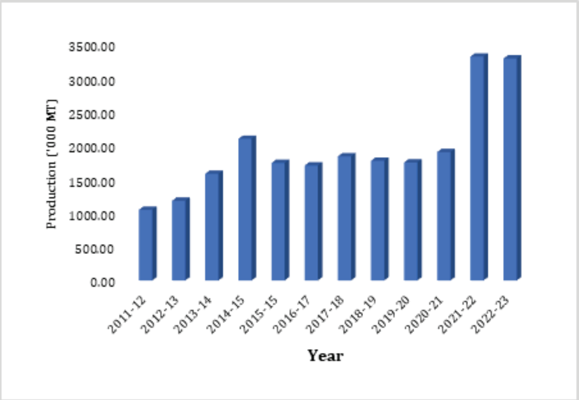

Fig. 2: Trends in jackfruit production in India for past 12 years

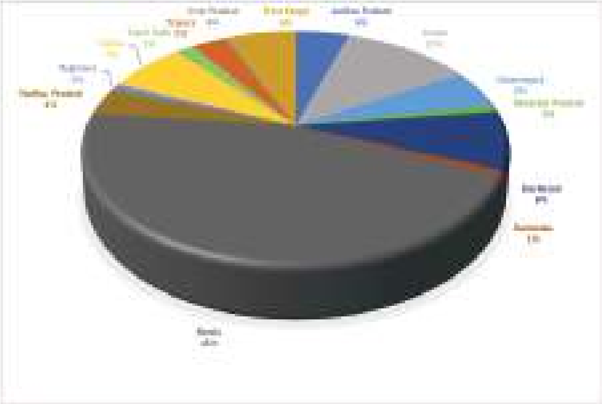

Fig. 3: Area under jackfruit in India during 2022-23

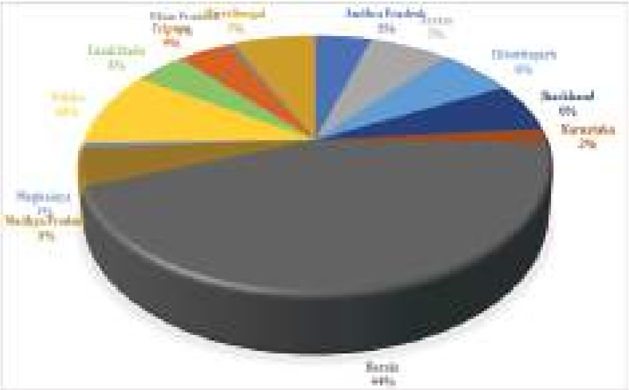

Fig. 4: Production of jackfruit in India during 2022-23

1. Varieties developed in India

India has developed a diverse range of jackfruit varieties, each tailored to unique regional preferences. Before formal classification, local names and selections were based on characteristics like yield, quality, sweetness, and specific culinary uses. These local types were given names such as Gulabi (rose scented), Champa (Michelia sp. flavor), and Hazari (high-yield).

In North India, raw jackfruit's demand as a vegetable spurred focus on rind thickness and pulp softness. Varieties like NJT1, NJT2, NJT3, and NJT4 excel in pulp quality for table use, while NJC1, NJC2, NJC3, and NJC4 are culinary favourites. Uttar Pradesh is renowned for its production of exceptionally sweet fruits, including Barka and Kapa varieties.

The North-Eastern Hilly Region reveals soft (Pakikhua) and firm pulp (Khoja) varieties that ripen during specific periods. In South India, jackfruit is categorized into Type 1 (Varikka) with firm pulp and Type 2 (Koozha) with softer, sweeter flesh, used in curries and canning. Muttam Varikka stands out with crisp, non-fibrous, golden pulp, and Rudrakshi yields off-season crops.

Karnataka has popular selections like Lalbhag Madura, Kempu Rudrakshi, and Tubagere jackfruit. The Indian Institute of Horticultural Research (IIHR) facilitated in identifying farmers varieties viz., Siddu and Shankara jackfruits with coppery red flakes has been very popular with great demand of its planting material. Collections under UTFANET project led to medium-sized fruits suitable for table use.

State Agricultural Universities evaluated clonal selections for table use. Promising varieties like Palur-1(TNAU) yields 80 fruits per tree with golden-yellow firm flakes, PPI Jack (TNAU) offers high yields and twice-yearly fruiting, PLR(J)-2 (TNAU) features larger, high-quality fruits with excellent shelf life, Swarna (UAS) bears fruit prolifically with medium-sized, juicy flesh, Konkan Prolific (RFRS) yields firm, spiny fruit and early bearing, Sindoor hold great potential for large-scale cultivation and a three-hundred-year-old elite jackfruit tree was discovered in Karnataka's Kachahalli.

Table 1: Comparison of jackfruit released varieties

Characters	Palur-1 Jack	PPI Jack	Konkan Prolific	PLR (J)-2	Swarna	Sindoor
Organization	TNAU (1992)	TNAU (1996)	RFRS, DBSKKV (2004)	TNAU (2007)	UAS (2010)	KAU (2016)
Pedigree	Clonal selection	Clonal selection		Clonal selection		Clonal selection
Bearing habit	-	tree trunks	Fruit bears in bunches	tree trunks	trunk, 1° branches and also on 2° branches	Not available
Bearing season	March-June	April-June	January – February flowering	-	Not available	Bear fruits twice/ year
Off season bearing	Oct- Dec	Nov - Dec	-	-	Not available	-
annual yield	80 fruits/tree 900 kg/tree, 12 kg/fruit	105 fruits/tree 1785kg/tree, 17kg/fruit	73 fruits/tree 450 to 550 kg/tree 5.70 kg	95-110 fruits/tree 1800 kg/tree 16 to 19.50kg	6-8kg	25 fruits/ tree / year 11-12 kg
Flakes/fruit	115-120	-	-	-	-	-
Flake colour	Golden yellow firm flakes	-	-	-	-	Sunset orange flakes
TSS	19°B	-	25°B	-	25 to 26°B	-
Acidity	-	-	-	-	-	Table purpose
Special character	Suitable for HDP	commercial planting and home gardens	bearing from 6 to 7 years of planting		Thick flakes and a very thin rind (< 1 cm)	

5. Economics of jackfruit cultivation

Jackfruit cultivation is not widely considered a major commercial crop, leading to limited documented information on its economics. However, in Tripura, during the peak season, Bisramaganj market sees an average daily sale of 30,000 jackfruits, while Melghar market sells around 10,000 pieces. Prices range from Rs. 700 to Rs. 2,200 per hundred fruits. In Kerala, 50,000 tonnes of tender jackfruits are sent to North India annually. A jackfruit grower in Maharajapuram near Thiruchirapalli can earn Rs. 2 lakhs per annum from 20 trees, with each fruit fetching Rs. 200-250. In Panruti, known as the jackfruit paradise, wholesale rates range from Rs. 6,000 to Rs. 12,000 per tonne, with an average price of Rs. 8,000 during

April-May. The fruits are typically sold to middlemen at rates of 50-75 per fruit, with an average price now elevated to Rs. 150 per jackfruit. During the peak season, 5 lorry loads of jackfruits are sent daily from Panruti, with around 650 loads sent to various parts of the country, including Mumbai, Bengaluru, and Andhra Pradesh, according to a mandi owner in Panruti.

6. Extent of loss of jackfruit

The extent of jackfruit loss is significant due to limited data availability. In many countries, including India, jackfruit is often grown as an intercrop, leading to a lack of data on cultivation, production, yields, and market trends. Information on local consumption, exports, wastage during peak seasons, and raw material usage for processing is also lacking.

In India, the precise amount of wasted jackfruit is uncertain but estimated at around 75 per cent. Kerala discards approximately 35 crores worth of jackfruit annually, accounting for about 75% of its total harvest. Meghalaya reports losses of around Rs. 434 crores worth of jackfruit each season due to fruit rotting in the open. In the North Eastern States, there is an estimated surplus of approximately 118,000 metric tons of jackfruit per year, with Tripura contributing a significant portion of 93,000 metric tons.

7. Various processed products from jackfruit

Jackfruit consists of three main parts: the bulb/flakes (30-32%), seeds (13-15%), and rind (5-55%) in its ripe stage. The most economically valuable product is the fruit itself, consumed both when immature and ripe. However, the sweet pulp has a limited shelf life, resulting in substantial post-harvest losses (30-35%) during peak seasons. This pulp is used fresh as a dessert or preserved in syrup, while ripened pulp flavours items like ice cream and beverages. Fresh pulp is also used in making jams, chutneys, jellies, and candies, while dried pulp is processed into chips.

8. Marketing potential of jackfruit

8.1 Status of manufacturing and processing company of value-added products of jackfruit

Detailed market information, including market presence, size, share, and growth for various value-added jackfruit products under different brands in India, is challenging to obtain as brands tend to keep such data confidential. Nevertheless, secondary research has provided comprehensive insights into the market size and pricing of various value-added jackfruit products across different brands in India (Table 2).

Table 2: Various manufacturing and processing company of value-added products of jackfruit

Jackfruit products	Brands
Ready to Eat, Curry	The Jackfruit Company, Wakao
Canned Jackfruit	Twin Elephant
Chips	Urban Platter, Flavours of Calicut
Jam	Natur Up, Nature Land
Pickle	Urban Platter, Addme
Cut Fruit (Cut & Peeled)	Living food company
Flour	Jack Fruit 365, Wakao, Korah's
Squash	Jumbo
Fruit Bar	Go Desi

Source: Connect2india.com/global/Jackfruit-export-from-india/1 & https://www.cgmfpfed.org/new/news_upload/TC_20230405_094042.pdf

In regions where jackfruit is abundant, it is traditionally consumed locally, with limited access to distant markets due to its size and perishable nature. However, recent years have seen a shift towards value-added and processed jackfruit products, with approximately 25% of production directed towards manufacturing of value-added products.

Increased global demand, driven by climate change concerns and the rise of vegan culture, has led to a surge in jackfruit exports from India to various countries, including West Asia, Germany, and Great Britain. India exported around $ 2.3 million worth of jackfruit to over 75 countries in 2020-2021, with a total volume of approximately 2,300 metric tons.

The entire jackfruit tree is valuable, with leaves serving as cattle feed and termite-resistant wood suitable for construction and furniture. Unripe jackfruit, known for its meat-like texture when cooked, is gaining popularity in vegan dishes in the UK, US, and Germany. Brands like The Jackfruit Company and Upton's Naturals offer a variety of jackfruit-based products, including curry, pasta, and noodle meal kits.

1.2 Exports for jackfruit value added products from India

India's jackfruit exports of value-added products have prominent destinations, with the United Arab Emirates leading the way, importing jackfruit from India worth 0.37 million USD in the period of 2020-2021 (April to November). India's top 5 jackfruit trading partners, including the United Arab Emirates, United Kingdom, Nepal, Thailand, and Viet Nam, collectively contribute to a total export value of 1.41 million USD, representing 61.3% of India's overall jackfruit export volume. In this group, the United Arab Emirates holds the largest market share at 16.09%, followed by the United Kingdom at 0.32 million USD. The top 10 countries together contribute 89.13% of India's jackfruit export value (Table 3).

Table 3: Exports for jackfruit value added products

Country	Value (USD Million)	Share (%)
United Arab Emirates	0.37	16.09
United Kingdom	0.32	13.91
Nepal	0.26	11.3
Thailand	0.24	10.43
Viet Nam	0.22	9.57
Malaysia	0.16	6.96
Saudi Arabia	0.16	6.96
Qatar	0.15	6.52
Australia	0.11	4.78
Germany	0.06	2.61
Total	**2.05**	**89.13**

Source: Connect2india.com/global/Jackfruit-export-from-india/1 & https://www.cgmfpfed.org/new/news_upload/TC_20230405_094042.pdf

The following table gives insights on a monthly report of November 2020 on jackfruit export from India to the top 8 trading partners.

In November 2020, India's major jackfruit exports were primarily destined for the following countries: United Arab Emirates (0.04 million USD), Kuwait (0.02 million USD), Qatar (0.02 million USD), Singapore (0.02 million USD), and Australia (0.01 million USD) as detailed in Table 4. These top 5 importing nations collectively accounted for 52,190 units and 0.11 million USD in export value, representing a significant share of 78.57% of the total export volume for that month. It's important to note that specific export data for value-added jackfruit products is currently unavailable, and the provided data is sourced from Connect to India export data.

Table 4: Country wise trends for jackfruit export (USD Million)

Sl. No.	Country Name	Qty in kg	Value (USD Million)
1	United Arab Emirates	22010	0.04
2	Kuwait	8370	0.02
3	Qatar	12180	0.02
4	Singapore	7660	0.02
5	Australia	1970	0.01
6	Bahrain	4560	0.01
7	Oman	3820	0.01
8	Saudi Arabia	6170	0.01
	Total	**66740**	**0.14**

Source: Connect2india.com/global/Jackfruit-export-from-india/1 & https://www.cgmfpfed.org/new/news_upload/TC_20230405_094042.pdf

Jackfruit offers substantial potential for value addition, enabling the creation of diverse products from immature to ripened stages, crucial for commercial purposes given its size and transportation costs. The Indian jackfruit product market was valued at ₹1,252 Crore in 2017-18 and is expected to reach ₹1,580 Crore by 2021-22. The unorganized sector dominates the market, holding approximately 95% market share.

Chips and papads make up around 70% of the market value and 80% by volume, primarily produced from mature jackfruits. Various preservation methods are employed for processing jackfruit. Projections suggest an annual Compound Annual Growth Rate (CAGR) of 4.78% until 2022-23, with slightly lower growth rates (around 3.2%) for chips and papads during the period from 2023-24 to 2025-26. In contrast, categories like Seed Flour, Jackfruit Pulp, Dehydrated Jackfruit, and Canned Jackfruit Bulb are expected to experience higher growth rates of approximately 8% per annum, mainly due to export markets. These segments present significant opportunities for the processing industry.

Based on the above estimate about the jackfruit products' market size in India, further projections have been provided till 2025-26 (Table-5).

Table-5: Market size of jackfruit products in India (in ₹ Crore)

Product	2017-18	2018-19 (E)	2019-20 (E)	2020-21 (E)	2021-22 (E)	2022-23 (E)	2023-24 (E)	2024-25 (E)	2025-26 (E)
Chips	600.96	629.69	659.78	691.32	724.37	758.99	783.28	808.35	834.21
Papad	325.52	341.08	357.38	374.47	392.37	411.12	424.28	437.85	451.87
Seed Flour	150.24	157.42	164.95	172.83	181.09	189.75	204.93	221.32	239.03

Jackfruit Pulp	62.6	62.6	62.6	62.6	62.6	62.6	67.61	73.02	78.86
Dehydrated Jackfruit	25.04	25.04	25.04	25.04	25.04	25.04	27.04	29.21	31.54
Canned Jackfruit Bulb	12.52	13.12	13.75	14.40	15.09	15.81	17.08	18.44	19.92
Others	75	83	91	100	109	118	125	132	140
Total	**1252**	**1312**	**1375**	**1440**	**1509**	**1581**	**1649**	**1721**	**1796**

Source: Connect2india.com/global/Jackfruit-export-from-india/1 & https://www.cgmfpfed.org/new/news_upload/TC_20230405_094042.pdf

Jackfruit-based product production in India has consistently grown from 2017-18 to the projected 2025-26. Key items like chips, papad, and seed flour are expected to increase, while jackfruit pulp remains stable, and other products show modest growth. Overall, total production is predicted to rise from 1252 units in 2017-18 to 1796 units in 2025-26 due to rising demand for value-added jackfruit products (Table 5). The overall market size is projected to rise from 58,552 MT in 2017-18 to 68,356 MT in 2025-26, reflecting rising demand for jackfruit products (Table 6).

Table 6: Market size of Jackfruit products in India (in MT)

Product	2017-18	2018-19 (E)	2019-20 (E)	2020-21 (E)	2021-22 (E)	2022-23 (E)	2023-24 (E)	2024-25 (E)	2025-26 (E)
Chips	24,038	25,187	25,623	26,066	26,516	26,974	27,027	27,079	27,132
Papad	21,701	22,739	23,132	23,531	23,938	24,352	24,399	24,446	24,494
Seed Flour	3,339	3,498	3,559	3,620	3,683	3,746	3,928	4,119	4,319
Jackfruit Pulp	3,130	3,130	3,039	2,950	2,864	2,781	2,916	3,058	3,206
Dehydrated Jackfruit	501	501	486	472	458	445	467	489	513
Canned Jackfruit Bulb	835	875	890	905	921	937	982	1,030	1,080
Others	5,008	5,527	5,893	6,258	6,622	6,985	7,188	7,398	7,613
Total	**58,552**	**61,456**	**62,621**	**63,803**	**65,002**	**66,220**	**66,907**	**67,618**	**68,356**

Source: Connect2india.com/global/Jackfruit-export-from-india/1 & https://www.cgmfpfed.org/new/news_upload/TC_20230405_094042.pdf

Consumption pattern of jackfruit

There is limited reliable reference material on the market size of jackfruit, which can be categorized into rural and urban markets. In India, the total jackfruit consumption under the fruit category was estimated at 3,06,122 tons (Table 7).

Table 7: Jackfruit consumption estimation in India

Jackfruit as a fruit	Unit in Ton
Rural consumption	2,69,920
Urban consumption	36,202
Total consumption	3,06,122

Source: Census of India (2011), Household Consumption of Various Goods and Services in India (20ll-12), Ministry of Statistics and Programme Implementation, Government of India, 2014

9. Future thrust

Despite India's significant jackfruit production, approximately 70% of it remains underutilized due to a lack of value addition. India lags in global jackfruit value addition efforts, with limited awareness among the public. While Maharashtra, Kerala, and Karnataka have made some progress in value addition, other major jackfruit-producing states like West Bengal, Assam, Tripura, and Odisha need to organize events to enhance fruit popularity and marketing potential.

Key strategies for jackfruit include diversifying varieties, perfecting cultivation techniques, promoting value-added products, developing low-gum types with high carotenoids, identifying year-round bearing varieties, encouraging nurseries and entrepreneurial groups, mechanizing flake separation, documenting Indigenous Traditional Knowledge, forming growers' associations, identifying custodian farmers, creating value-added products, and supporting health claims with clinical studies.

By addressing these aspects, India can tap into the full potential of its jackfruit industry and contribute to its sustainable growth.

16. Breeding of Pummelo for Certain Economic Traits

M. Sankaran
Principal Scientist and Head, Division of Fruit Crops,
ICAR-Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru-560089
Email: kmsankaran@gmail.com, m.sankaran@icar.gov.in

1. Introduction

Citrus grandis (L.) Osbeck, often known as a pummelo, shaddock, or jabong is mono-embryonic citrus species that originated from the Malayan and East Indian archipelago. It belongs to the family Rutaceae and subfamily Aurantioidae (2n=18). It is the biggest fruit under the genus *Citrus* andhence, also called with the botanical name, *Citrus maxima*, meaning "the biggest citrus". Pummelo along with mandarin and citron is considered to be one of the ancestral species of the genus *Citrus* and is the best source of female parent material in the development of several citrus fruits *viz*. sweet orange, grapefruit and Tangelo. The major pummelo producing countries of the world include China, Thailand, Vietnam, Malaysia, Indonesia, Taiwan, India and Japan (Scora and Nicolson, 1986). In Southeast Asia and other parts of the world, pummelo is quite popular and is one of the five most widely cultivated and consumed citrus fruits, alongside oranges, mandarins, lemons, and grapefruit. Owing to its prominence, The global production of pummelo (including grapefruit) was approximately 9.3×10^6tons in 2019 (FAO, 2021). Apart from direct consumption of the fruit, it has been a part of many religious customaries like Chhat Puja (a festival of Bihar) in India and other parts, throughout Southeast Asia. Along with the fruit, the flowers and seeds are also used for numerous medicinal purposes and even for perfume extractions. Pectin found in the peel of the fruit is used in food and pharmaceutical industry (Shakya, 2002). Other by-products from the fruit include juice, candies, and marmalade and are also used in the canning industries (Izquierdo & Sendra, 2003).

Although pummelo, nutritionally stands parallel to other citrus fruits *viz* sweet oranges and mandarins, its commercial exploitation still lacks in India due to its very thick rind, which makes the segment's extraction very difficult. While, on the other hand the thick rind offers immense potential for the export of the fruits, as it provides ease in handling and transportation. Pummelo fruit contains low TSS, high acidity and large number of seeds as compared to other citrus fruits. The taste of the fruit varies from mildly sweet and blend to sub-acid with a faint touch of bitterness (Morton, 1987). The bitterness of the fruit becomes the major constraint of consumer acceptance. Bitterness not only forms an important attribute of taste in citrus fruits, but also comprises numerous antioxidant, anticancer and antiviral antiallergic and anti-inflammatory properties and often negatively affects consumer acceptance of citrus fruits. Apart from commercial non-availability of thin rind and less bitter (sweet types) fruit types, the lack of pre-selection indices or availability of molecular markers for the identification of bitter /non-bitter genotypes becomes the major concern in the popularisation of pummelo cultivation. In India, genetic variability has been observed in terms of fruit size and shape, tree vigour, susceptibility to diseases, pulp colour, juice recovery and level of acidity in fruits, *etc*. This provides the basis for the availability of sufficient diversity and the need for genetic characterization for better utilization of crop resources. Pummelo show very diversity in their morphological traits such as size and shape of canopy, color, type, ripening season of the fruits and the number of seeds per fruit. There are many morphological and molecular marker systems available for plant scientists to characterize genetic resources and cultivars in citrus. Due to cross-pollination and monoembryonic nature, the pummelo exhibits a significant genetic variability for both its qualitative and quantitative characteristics. In this chapter, an attempt has been made to compile the research work related to breeding of pummelo and its problems and prospects

2. Diversity in Pummelo

Huge variability exist in pummelo due to its monoembryony and high heterozygous in nature. The pulp of the pummelo is firm with crisp carpellary membranes and juice sacs. Commercial pummelos do not exhibit traces of bitterness as exhibited in grapefruit when eaten. Fruits are obovoid to pyriform in shape and seeded. “Chandler,” a Thai variety, and an Indonesian variety, “Djeroek Deleema Kopjar,” are pink-fleshed. Chinese varieties “Goliath,” “Mato,” and “Shatinyu” are white fleshed (Kumar et al., 2015). Israel produces Goliath, Chandler, and “Tahiti” varieties for domestic and export markets. “Banpeiyu”: It is a Malaysian cultivar widely grown in that country, high-quality fruit, large size sub-globose in shape, seeded, and light-yellow fleshed. “Wendan” and “Chumen Wendan”: Early, flesh white, soft, juicy, peel thin, widely grown in the Fujian province of China. “Pingshan”: Major variety of pummelo in Fujian, China. Large oblate fruit weighing 1 kg or more, matures mid-September, is seedless, pale red albedo, with a superior eating quality (TSS 11–12%, acids 6.3–6.4%), edible part 55–60%, and good storage ability. “Anjiangxiang”: Is a pummelo of the Hunan province of China, seeded, tolerant to cold and drought, it matures in late September to early October, and the flesh is juicy and fragrant. “Diangjiang”: Pummelo grown in the Sichuan province of China, the fruit is oval, large, juicy, few seeds, sweet, fragrant, and matures early November. “Shatinyu”: Grown in the Guangxi province of China, 0.6–1.5 kg fruit weight, pyriform fruit, light-yellow flesh, crisp, sweet, late maturing (October–December); however, fruit can be stored until the next April (Chen and Lai, 1992). Chen-Wei (2000) reported a rare seedless pummelo variety Sijiyou, that flowers 4 times a year and with an average fruit weight of 800-1000 g. The first crop was harvestable in mid-November and the second by March-April of the next year while, the fruits of third and fourth crops do not mature usually. The fruit quality of the first and the second harvests was regarded as superior over the latter. Long (2000) described a sport of Guanximiyou pummelo called "Longyan Hongyou", which was significantly indistinguishable to the parent in its morphology with large fruits of 1450 g average weight, smooth orange-yellow rind and pleasant acidic sweet flavour. Similarly, the fruit pulp was tender, and very juicy (with a juice rate of 48per cent) but the flesh colour of the sport was purplish red instead. Ding and Yuanond (2002) stated that Feicuiyou, a promising pummelo variety had characteristics such as juicy green sacs with a pleasant flavour and long storage life. Fruits were medium in size and weighed 0.7 to 1 kilogram with a light green rind. Zheng *et al.* (2002) worked on ‘Gong Shui Bai You’ a new variety of pummelo (Citrus maxima) that could be stored for up to 150 to 200 days at room temperature. The tree was compact and the fruits were from lower seeds to almost seedless.

Bharali (2004) determined the physical and biochemical changes in Rabab Tenga, a pummelo variety with white pulp. To determine the optimum time of harvest, these fruits were analyzed at 20-day intervals, starting from 60 days to 200 days after the fruit set (DATS). At 200 days after the fruit set, the fruits recorded maximum fruit weight (673.00 g), fruit volume (1107.33 cc), fruit length (14.55cm), fruit diameter (13.62 cm), rind weight (238.33 g), seed number (100.66), seed weight (38.77 g), and volume of juice (205.50 ml). Lin and Yu (2005) studied on a pummelo cultivar called ‘Yuhuanyou’. They noted that the fruits of this cultivar matured in early November which were are large in size (1 to2.5

kg), with an orange-yellow rind with a light yellow flesh, which is tender, crispy, and juicy but showed problems of fruit cracking. Zhou *et al.* (2005) carried out a study on the performance of cv. Aonlan, is a cross between diploid acid-less pummelo cultivar and a tetraploid white seedy grapefruit cultivar in Guangdong province. The fruits were early maturing i.e., from late August to early September and are large in size (mean weight of 489.3gm). The shape of fruits was regular, flat or round with a polished green rind. The fruits are usually seedless and a tender and juicy flesh with good flavour.

2.1. Diversity in pummelo tree canopy

Swingle (1948) stated that pummelo is a huge, spiny tree with angular twigs and winged leaves which are large and broad. Webber and Batchelor (1948) described *Citrus grandis* as a species having a cylindrical smooth and plain trunk of 0.76 to 1.22 meters in height. The trunk is green when young and eventually turns light brown as it gets older. Reuther *et al.* (1968) inferred that the pummelo plant is a large and spiny tree with angular young branches. Their leaves are large, broad and winged. Hossain (1983) reported the presence of closed or open heads and even occasionally umbrella-shaped heads in pummelo plants. Barrett (1994) studied the morphology of pummelo US 145 and reported that the tree was moderately vigorous and upright spreading with fruits bearing as single and in clusters.

Zheng *et al*. (2002) studied 'Gong Shui Bai You' a new variety of pummelo (*Citrus maxima*) which had a compact tree stature. Lin and Yu (2005) observed that the pummelo cultivar 'Yuhuanyou' performed well in the area of Yongtai country, Fujian province, China. The trees were observed to be vigorous with spreading branches, early-bearing and productive. The plants were found to be hardy, tolerant to heat and drought, and suitable for hilly regions and higher altitudes. Zhou *et al.*(2005) carried out a study on the performance of cv. Aonlan, is a cross between 2x acid-less pummelo cultivar and a 4x white seedy grapefruit cultivar in Guangdong province. The trees performed well in the local condition and were characterized by a spreading shape, vigorous growth, good adaptability, and high productivity.

2.2. Fruit characterization

Swingle (1948) in a study conducted on two varieties (red-pulped and pink-pulped) of pummelo grown in Bangladesh reported the fruit shapes ranged from globose to oblate or pyriform. Webber and Batchelor (1948) detailed pummelo as a fruit characterized by its thick peel and large pulpy vesicles. The fruit's diameter ranges from 10 cm to 30 cm, with a light-yellow surface. They classified the fruit into two primary shapes: the flattened oblate or globose shape, which lacks a distinct neck, and the elongated pear-shaped variety with a neck-like extension. The study also highlighted variations in seed quantities among different pummelo genotypes, some containing numerous seeds while others had minimal to none. Additionally, the research provided insights into rind thickness among various pummelo varieties: The Kaopan variety displayed rind thickness ranging from 0.95 cm to 1.90 cm, the Moanalva variety showed a range of 2.54 cm to 3.16 cm, and the Siam variety of Kaopan had rind thickness ranging from 1.27 cm to 1.90 cm. This information contributes to a better understanding of the diversity in fruit shape, seed presence, and rind characteristics across different pummelo cultivars.

Kamaluddin (1966) described pummelo fruits as having spherical, subglobose, or pyriform shapes. The fruit's pulp exhibited a diverse range of colors, encompassing white, rosy mild red, and pink hues.Reuther *et al.* (1967) provided a comprehensive overview of the morphological characteristics of various pummelo genotypes. Notably, the Banpeiyu and Kaopan cultivars exhibited subglobose to spheroid fruit shapes, with Kaopan's apex slightly depressed. The Mato Buntan variety displayed ovoid to pyriform fruits, while the Hirato Buntan had oblate fruits slightly depressed at both ends. In terms of rind thickness, Mato Buntan, Kaopan, and Hirato Buntan showed medium-thick rinds, whereas Banpeiyu's rind was thick. The flesh of Banpeiyu was described as soft, juicy, and possessing an excellent flavor characterized by a harmonious balance of sugar and acid, albeit with a subtle touch of bitterness. Kaopan's pulp was moderately juicy, offering sweetness with mild acidity. In contrast, the Mato Buntan fruit had a crispy and somewhat tough texture, with lower juiciness and sweetness, accompanied by hints of bitterness and a high density of seeds.

Purseglove (1968) highlighted the variation in mature pummelo fruit diameter, spanning from 10 cm to 30 cm, influenced by genetic factors and environmental conditions. The fruits were notably large and could assume either a globose or pear-shaped form. For instance, in the Tosa Buntan cultivar, the recorded dimensions were 19.5 cm in length and 8.5 cm in diameter, while the Anseikan cultivar displayed measurements of 10.82 cm in length and 11.20 cm in diameter. The color of the pulp ranged from yellow to pink and contained mono-embryonic seeds. Reuther *et al.* (1968) inferred from their studies that pummelo, like other citrus, is a modified form of berry called a hesperidium. The peel of the fruit is termed the rind and consists of two layers i.e., the outer thin layer was called flavedo and the inner layer was called albedo. Subsequently, several workers namely Salar (1974), Ahamad (1976) Ahamad (1982), Hossain (1983), Hossain (1985), Barrett (1994), Chen and Wu (1994) Yamada *et al.* (1995), Chen *et al.* (1997), Chen-Wei and Rao-Jung (1999) Fan-Qi Rong (2001). Rahman (2001), Rahman *et al.* (2003), Susandarini *et al.* (2013), Gaikwad *et al.* (2015), Singh *et al.* (2015), Nishad *et al.* (2018), Roy *et al.* (2020) and Bankar *et al.* (2021) carried out the pummelo varietal characterization mainly to know the diversity.

2.3.2. Fruit biochemical characterization.

The evaluation of biochemical parameters reveals the occurrence of wide range of constituents which decides the quality attributes of fruits. Chen *et al*. (1997) stated that the ascorbic acid content was 52.3 mg/100 g in pummelo (*Citrus maxima*) cultivar. Chen-Wei (2000) reported that Sijiyou was a rare pummelo variety and had soluble solids content of 9.25-11 per cent and were of relatively good eating quality. Long-YanYou (2000) stated that "Longyan Hongyou" was a mutation of the Guanximiyou pummelo variety. This sport exhibited juice containing 12 percent soluble solids and 41.03 mg of ascorbic acid per 100 ml. Ding and Yuanond (2002) stated that Feicuiyou, a promising pummelo variety with ascorbic acid level being very high, reaching 108.04 mg/100 ml (2-3 times more than other pummelo varieties).

Bharali (2004) studied changes in biochemical parameters in Rabab Tenga (pummelo, white flesh) fruit to determine the optimum time of harvest and recorded TSS of 10.85% with reducing sugar of 5.85 % and sugar acid ratio of 9.32 at 180 DAFS. Lin-Yu (2005) stated that pummelo cultivar Yuhuanyou had solids content of 12.5 per cent and a pleasant sweet acid flavour with ascorbic acid content of 55.90 mg/100 ml.

Zhou *et al.* (2005) studied the performance of *cv*. Aonlan, a cross between diploid acid less pummelo cultivar and a tetraploid white seedy grapefruit cultivar in Guangdong vitamin C content (ascorbic acid) reached 49.2 g/100 g while total sugars were found to be 8.26 %. Zhou *et al,* (2006) observed TSS of 10.5%, titratable acidity of 0.72 % and Ascorbic acid of 402.0 g/ml in a hybrid between grapefruit and pummelo cultivar Wentan in Guifeihongyou.

Pichaiyongvongdee and Haruenkit (2009) reported that the chemical composition of the pummelo juice samples showed the high content of total soluble solids ranging from 7.14-9.45 Brix, titratable acidity ranging 0.38-0.98 (g /100ml) as citric acid, and the pH range was 3.69 - 4.05 while the ascorbic acid was in the range of 37.03-57.59 mg/100ml. Cheong *et al*. (2012) compared two pummelo cultivars (Citrus grandis (L.) by analysing their physicochemical properties, volatile and non-volatile components (sugars and organic acids). They inferred that white pomelo was characterised by mild acidity and a higher pH value, while pink pomelo was found to be higher in its organic acid content, of which, citric acid was the main organic acid. The total acid content and titratable acidity of pink pomelo juice were comparable to those of grapefruit juice. Roy *et al.* (2014) observed significant variation in fruit quality like TSS (8.63– 10.00° Brix), total sugar (5.56 – 8.20 %), ascorbic acid (34.98 – 62.61 mg/100 ml juice) and titratable acidity (0.34 – 0.66 %) obtained among different pummelo germplasm. Singh *et al.* (2015) during their diversity study observed that Devenahalli pummelo from Karnataka had low acidity and high TSS (>10°B) with red pulp. Pummelo from Yarcaud, Tamil Nadu had highest juice content (22.60%) followed by fruits from Nagaland (21.65%) which are larger in size (1,232.30 g). Pummelo from Bihar as Clone No. 8, 28, 31, 35, and 39 had high TSS (>10°8) confirmed its potential for better consumer acceptance than others. Port Blair pummelo had low acidity, but due to low TSS (6.90 °B), may not be liked by consumers.

Kumar *et al.* (2015) collected different varieties of pummelo and analysed for their biochemical and phytochemical properties. Results revealed that TSS ranged from 6.2 to 12.5˚Brix while the juice acidity was in the range of 0.80-2.52%. Acidity was found maximum (2.52 %) in juice of white fleshed pummelo from Jonapotha, Nagaland and minimum in red-fleshed pummelo from Port Blair, Andaman and Nicobar Islands (0.80%). Total phenols were maximum (16.57 mg/100ml) in peel of white-fleshed pummelo from Jonapotha, Nagaland and were maximum (10.16) in juice from Red-fleshed pummelo, Tamenglang, Manipur.

Gaikwad *et al*. (2015) characterized physical, morphological and biochemical features of 30 pummelo genotypes. Fruit chemical characterization disclosed that CG-9 had the highest ascorbic acid content (40mg/100g). CG-29 recorded highest TSS content (10.8 ºB) and titratable acidity (3.7 %). Nishad *et al.* (2018) during their study to determine variation in 16 pummelo (*Citrus grandis* L. Osbeck) genotypes observed that the TSS in pummelo juice ranged from 8.27–12.33°Brix. The total sugars in pummelo cultivars ranged from to 49.96–102.76 g $L^{-1}$and total phenolic content ranged from 22.18–48.0 mg GAE 100 mL^{-1} in different genotypes. Significantly a higher ($p < 0.5$) phenolic content (> 40 mg GAE 100 mL^{-1}) was found in cultivars PS4, PS5, PS12, PS13, PS14 and intermediate content (30–40 mg GAE 100 mL^{-1}) in PS7, PS3, PS8, PS9, PS10, and PS17 and lowest content (< 30 mg GAE 100 mL^{-1}) in PS1, PS2, PS18, PS15 and PS16. Total flavonoid content ranged from 0.6–2.62 mg QE 100 mL^{-1}. Genotypes PS13, PS8, PS12, and PS4 had significantly higher content (> 1.5 mg QE 100 mL^{-1}) than other genotypes. The ascorbic acid content (0.06–0.43 g L^{-1}) was found higher in the fruits under present study than that reported in Malaysian cultivars.

Gaikwad *et al.* (2019) analysed thirty pummelo genotypes for several chemical characters like total soluble solids, acidity, ascorbic acid and sugars where the fruit chemical characterization disclosed that CG-9 had the highest ascorbic acid (40mg/100g). Best total soluble solids were determined in CG-29 (10.8 ºB). CG-29 recorded the highest titratable acidity of 3.7 % in contrast to 1.08 % for CG-23. Roy *et al.* (2020) characterized.12 different pummelo germplasm in new alluvial zone of West Bengal for biochemical characters. A significant variation was found in ascorbic acid content (34.98 – 62.61 mg/100 ml juice). The TSS/acid ratio ranged between 13.08 and 27.79 while sugar/ acid ratio ranged between 8.42 and 24.12. Banar *et al.* (2021)investigated on different qualitative characters of pummelo genotypes grown in konkan region and observed that the genotype NRCC-3 had maximum TSS (12.41°B) and good ascorbic acid content (54.46 mg/100g). NRCC-2 recorded maximum reducing sugar (2.13%). ARF had highest acidity (1.04%) and lowest pH (3.19).

There are two forms of bitterness in pummelo, i.e, immediate bitterness during fresh consumption and delayed bitterness after processing. The bitterness in pummelo during fresh consumption also called as the primary bitterness is caused due to flavonone glycoside called Naringin (4,5,7-trihydroxy flavonone-7-rhamno-glucoside) (Haenen *et al.,* 1997; Burda and Oleszek, 2001). The secondary bitterness also known as delayed bitterness accumulates gradually over a period of time (few hours) when the fruits are processed into juice, it is also observed in the fruits after freezing or mechanical damage (Zaare-Nahandi *et al.,* 2008). This delayed bitterness is due to the accumulation of limonoids called limonin (limonoate D-ring-lactone) which occurs in both bitter and non-bitter citrus species.

Davis (1947) discovered a new colorimetric method using alkaline diethylene glycol for the determination of the bitter rhamnoglycoside naringin and other flavanones that are present in citrus fruits. It is a rapid procedure to the assay of naringin in the juice and coloured flavedo of grapefruit, and of hesperidin in other citrus fruits.

Fisher and Wheaton (1976) designed an assay for resolution and quantitation of naringin and naringenin rutinoside in grapefruit juice. It was done by high-pressure liquid chromatography (HPLC) using a micro C-18 column and eluting with a water-acetonitrile system. These flavonoids were detected at 280 nm. Yusof *et al.* (1990) studied on naringin content from the skin, juice and seed of musk lime, mexican lime, rough lime, pummelo and mandarin orange through HPLC method. Naringin could only be found in pummelo and rough lime but could not be detected in other fruits. The skin of pummelo contained a higher naringin (3910 µg/g fresh weight) than the juice (220 µg/g fresh weight).

Ohta and Hasegawa (1995) noticed that Pummelo juice contained an average of 18 ppm limonin and 29 ppm total limonoid glucosides. Compared to other juices, pummelo contained very high concentrations of limonin and very low concentrations of limonoid glucosides. Pichaiyongvongdee and Haruenkit (2009) studied the distribution of limonin and naringin in seven pummelo cultivars grown under Thai pummelo fruit conditions. The limonin content in the seeds ranged from 1375.31- 2615.30 pm, with the lowest amount in the juice being 10.07-29.62 ppm. Naringin was found in a greater amount than limonin in all fruit parts of the cultivars studied. Hui Ni *et al.* (2014) investigated pectinase and naringinase to improve the production of juice by increasing the juice yield by eliminating the juice bitterness in pummelo. Compared to control, the enzymatic treatment significantly ($p< 0.05$) increased the juice yield, soluble pectin, total soluble solids (TSS) contents and the clarity, while decreasing the concentrations of bitter chemicals naringin, and limonin.

Zhang *et al.* (2014) reported that naringin, the predominant flavanone glycoside showed the highest content in both flavedo and juice of citrus of C. grands Guuanxamiyu' from the Pinghe of Fuijan (FJ) region compared with the Dapu of Guangelong (GD) and Nanbu of Sichuan (SC) regions. However, its contents in the flavedo of *C. grandis* "Shatianyu" from the Pingle of Guangxi (GX) was significantly lower than GD and SC regions. Kumar *et al.* (2015) observed regarding the naringin (51.42-129.66 mg/1) and hesperidin (0.44-3.35 mg/1) contents among the different accessions. Naringin was the predominant flavonone glycoside along with hesperidin was recorded highest in Pummelo from Salem (Tamil Nadu) as compared to the other accessions. Nishad *et al,* (2018) during their study to determine variation in pummelo (*Citrus grandis* L. Osbeck) genotypes conducted Liquid chromatographic analysis where the naringin content ranged from 89.36–419.41 µg mL^{-1} and genotype PS8 and PS13 had the highest naringin concentrations. Intermediate concentration was observed in genotypes PS7 and PS12 (> 200 µg mL^{-1}). Rani *et al.* (2019) identified that Naringenin was high followed by catechin and other compounds. Naringenin levels play an important role in determining the bitterness of pummelo. Among all the accessions observed, the pink pulp accession 22(4) had high amount of naringenin (601.66 ng/ml) and the low level (100.02ng/ml) was recorded in white pulp accession 20(1) which may be useful as a parent for development of less bitter pummelo.

2.4. 1.Breeding methods

2.4.1. Selection

The diversity analysis gives an idea about the extent of variability with in a species so that diverse parents/clusters may be selected for purpose of crop improvement. Ara *et al.*(2008) evaluated twenty-four cultivars of pummelo for their morphological characters in Bangladesh and observed significant difference in the plant height ranging 2.79 to 4.43 meters. The tallest plant (4.43 m) was recorded in Raj-43 while the shortest plant (2.79 m) was recorded in Rang-46. Gaikwad *et al.* (2015) studied diversity among 30 different pummelo genotypes for their physical, morphological, and biochemical characteristics and reported variations in their tree shapes as twenty-two trees were spheroid in shape, seven trees were obloid in shape and the remaining one tree was ellipsoid in shape. Dubey *et al.* (2019) conducted cluster analysis using the unweighted pair group method of arithmetic average (UPGMA) on a dataset encompassing 18 quantitative and 10 qualitative variables related to pummelo. Employing the Jaccard similarity coefficient, their analysis yielded the following outcomes: Firstly, based on qualitative data, all 18 pummelo genotypes were grouped into two primary clusters denoted as Cluster A and Cluster B, distinguished at a similarity value of 0.72, with each cluster containing nine pummelo selections. Subsequently, within Cluster A, a further division occurred at a similarity value of 0.62, resulting in the emergence of subclusters A1 and A2, where Cluster A2 included only two selections, namely PS-5 and PS-18. On the other hand, Cluster B split into two subgroups, B1 comprising solely the PS-2 pummelo accession, and B2 containing the remaining eight accessions. Notably, within Cluster B2, pairs of pummelo accessions, including PS-10 and PS-12, as well as PS-13 and PS-17, exhibited 100% genetic similarity. These findings offer valuable insights into the genetic relationships and categorization of pummelo genotypes based on their characteristics and genetic profiles. Kaur *et al.* (2019) evaluated morphological characters of 46 accessions of pummello collected from different parts of India on the basis of 42 phenotypic characters including leaf, fruit and seed characters is presented in the paper. The clustering pattern of the UPGMA dendrogram and the euclidean distance divided these accessions into five main clusters out of which, Cluster I was the largest cluster comprising of 14 accessions while cluster II consisted of seven accessions and cluster III had ten accessions. Cluster IV was smallest with only two accessions, while cluster V consisted of 13 accessions. The results derived from this study indicated significant level of variability present within the pummelo group in India, which can be used as important source of genetic diversity and for future breeding programmes. Nandi *et al.* (2019) studied the variability within pummelo (*Citrus grandis* Osbeck) genotypes collected from fourteen districts in West Bengal. A total of 124 genotypes were carefully chosen, taking into account traits reported by local farmers (including factors such as fruit bearing frequency, maturity, and fruit yield) and through on-site observations of tree and fruit characteristics. Utilizing cluster analysis, these genotypes were grouped based on ten key quantitative fruit characteristics, resulting in the formation of fifty-six distinct clusters. Notably, all these clusters exhibited considerable genetic distance from each other, and among them, cluster 49 was the largest, containing 55 pummelo genotypes. Cluster 43 and cluster 52 were other notable clusters, each comprising three genotypes. These findings hold significance for the selection of diverse genotypes in breeding programs aimed at enhancing pummelo quality traits. Shahnawaz *et al.* (2019) conducted cluster analysis on a set of fourteen pummelo (*Citrus maxima* Merr.) fruit varieties, resulting in the classification of these varieties into four distinct groups. Cluster I, Cluster III, and Cluster IV each included three varieties, while Cluster II encompassed five different varieties. Within these clusters, specific associations among the varieties were observed. In Cluster I, which included CHS Pink, CHS White, and Devanahalli, CHS Pink and CHS White were closely related, whereas Devanahalli, positioned at a distance of 0.24 cm from the other varieties, exhibited weaker associations. Cluster II comprised NRCC Pummelo-1, NRCC Pummelo-4, White Pummelo, NRCC Pummelo-3, and NRCC Pummelo-5. NRCC Pummelo-1 and NRCC Pummelo-4 displayed a close association, with an average distance of 0.002 cm, while NRCC Pummelo-3 and NRCC Pummelo-5 were less closely associated, with an average distance of 0.09 cm. Cluster III consisted of three varieties: NRCC Pummelo-2, Pink Pummelo, and PTF-4, where Pink Pummelo and PTF-4 demonstrated a close association, having an average distance of 0.008 cm, while NRCC Pummelo-2 was somewhat less associated, positioned at a distance of 0.14 cm from the other varieties. Similarly, Cluster IV included the varieties PTF-1, PTF-2, and PTF-3, with PTF-2 and PTF-3 closely associated at an average distance of 0.08 cm, while PTF-1 exhibited weaker associations, positioned at an average distance of 0.22 cm from the other varieties. These cluster analyses shed light on the relationships and associations among the different pummelo fruit varieties, aiding in their categorization and characterization. Dubey *et al.* (2019) characterized different indigenous pummelo genotypes based on 19 quantitative and 9 qualitative traits. Principal component analysis (PCA) for quantitative traits indicated that six PCA had Eigen-value greater than one. The cumulative variation explained by six components, viz. leaf length, fruit width, leaf length: width ratio, leaf area, petiole area and lamina wing ratio accounted over 86.12 % variability. Kaur *et al*. (2019) conducted a study on 46 accessions of pummello where the Principal component analysis based on 42 morphological characters showed significant variation among all the accessions. The least variation was observed in qualitative characters, while the quantitative characters significantly differed. The two-dimensional (2-D) plot generated from PCA showed three groups which were found to be like the clustering pattern of the UPGMA dendrogram. The analysis gave 36 principal components out of which first ten principal components contributed 69.52% of the total variability. The PCA identified traits were most significant that were responsible for grouping of certain genotypes into specific cluster and hence, revealed some aspects of interrelation among genotypes that were not discernible by the UPGMA analysis. Nandi *et al.*, (2019) explored the genetic diversity within a collection of 124 pummelo (*Citrus grandis* Osbeck) genotypes originating from various regions of West Bengal. The PCA, which focused on ten core quantitative characteristics of pummelo, identified four principal components. These four components collectively accounted for 69.357% of the total variance observed. Notably, the first two components were particularly informative, as they carried highly loaded characteristics (with values exceeding 0.5). These characteristics, derived from the PCA for quantitative variables, encompassed fruit weight, fruit diameter, fruit length, rind thickness, seed number, and seed weight. These findings highlighted the significance of these traits in capturing the genetic variability within the pummelo genotypes under investigation. Shahnawaz *et al.,* (2019) evaluated fourteen pummelo (Citrus maxima Merr.) varieties for genetic diversity using both morphological and molecular methods. The PCA analysis revealed that the first three principal components collectively explained a substantial portion of the total observed variability, amounting to 80.26%. The first principal component, which accounted for 46.01% of the variation, contained variables with higher scores on PC1, exceeding 0.21 in absolute value. The second principal component contributed 25.07% to the total variation, and the third component explained 09.18% of the observed variation. These results demonstrated the effectiveness of PCA in identifying the key variables contributing to the genetic diversity observed among the pummelo fruit varieties under investigation. Thejangulie *et al.* (2022) in their assessment of pummelo genetic variability in the mid-hill regions of Arunachal Pradesh, identified crucial traits for the selection process, with the number of seeds per fruit (131.40), fruit weight (68.17), peel thickness (64.79), and titratable acidity (56.96) displaying the highest genetic advance values. These traits were deemed essential for effective breeding and varietal improvement. Furthermore, Principal Component Analysis (PCA) demonstrated that the first four components collectively explained a significant portion of the total variance, with PC-1 (36%), PC-2 (19.6%), PC-3 (16.5%), and PC-4 (12.9%) contributing to 84.9% of the total variance across the variables. This PCA analysis provided valuable insights into the underlying factors driving variability among the pummelo genotypes, aiding in informed decisions for future breeding and selection endeavors. Mitra *et al.* (2011) recorded the highest PCV (82.5873) and GCV (82.5057) were observed for fruit acidity, followed by TSS/acid ratio (72.4895, 71.8177), and peel weight (62.1905, 61.8967). Traits such as fruit weight, peel weight, peel thickness, number of segments, and number of seeds, along with segment weight, exhibited substantial variation, signifying their heightened susceptibility to environmental influence compared to other traits.

Roy *et al.,* (2014) during the study of performance of pummelo germplasm at West Bengal alluvial soil found that the coefficient of variation, encompassing both genotypic and phenotypic aspects, exceeded 20 for traits such as yield per plant, fruit rind thickness, seed weight, and number of fruits per plant. Additionally, phenotypic coefficient of variation was prominently high for titratable acidity. These results signified significant variability in these traits within the studied germplasm and soil conditions. Ahmed *et al.,* (2018) during the assessment of diversity in grapefruit and tangelo, concluded that the greatest PCV and GCV were found for seed weight, number of seeds per fruit, number of fruits per tree, and acidity in grapefruit. They further added that these characters were also influenced by the environmental factors. Angami *et al.* (2022) conducted varietal assessments and genetic variability analyses of pummelo accessions in mid hill conditions. They found that the character with the highest genetic advance was the number of seeds per fruit, recording a value of 131.40. This was followed by fruit weight at 68.17, peel thickness at 64.79, and titratable acidity at 56.96. These results highlight the significance of these traits in the selection process, emphasizing their potential as essential tools for breeding and improvement efforts. Paudyal (1999) reported that a total of 39 different genotypes observed in 43 accessions of pummel and the cluster analysis of isozyme data produced 7 groups. Farmers inputs were found very useful for the assessment of diversity and identification of superior trees. They preferred fruits with sweet, non-bitter, red colour and high pulp content as the varietal selection criteria. Based on these criteria 6 accessions were identified as superior genotypes for mid-hill and plain areas of Nepal. Dutt *et al.,* (2021) described about the citrus industry in Florida and there is in desperate need of new and improved cultivars in light of recent disease epidemics which have ravaged the citrus industry and threaten all citrus producing regions of the world. The primary diseases at present are Huanglongbing (HLB) and citrus canker. Most cultivated varieties of citrus are hybrids derived from a few ancestral species. Disease tolerance found in the ancestors may be used to develop synthetic new hybrids that approximate the genetic make-up of modern cultivated forms. This study focuses on selecting and utilizing pummelo (Citrus maxima Burm. Merrill) cultivars and accessions that are exhibiting tolerance to citrus canker (*Xanthomonas citri* var. citri), with additional consideration of tolerance to Huanglongbing (presumed causal agent *Candidatus Liberibactor asiaticus*). These pummelo selections will be used to breed new synthetic grapefruit hybrids to replace current susceptible varieties while maintaining the appearance and flavor of consumer-accepted forms. New hybrids will take advantage of parthenocarpy and triploidy to produce seedless fruits. One of the symptoms of HLB is the loss of feeder roots contributing to the decreased nutrient uptake and decline of the tree's health. Discovery of CLas infected trees exhibiting healthy and expansive root systems on standard Swingle rootstocks after being infected for several years led to the question of whether the scion or an interstock could remediate the effects of HLB. To explore this idea, HLB infected Valencia sweet oranges were grafted onto putative HLB tolerant or resistant pummelo and hybrid interstocks, which were grafted onto standard rootstocks in order to determine if their putative resistance to HLB could be conferred to the scion and rootstock. Hybrids using Citropsis gilletiana and Microcitrus species are also discussed as sources of disease resistance or tolerance. The ICAR-CCRI, Nagpur and ICAR-IARI, New Delhi, have released one variety each for sweetness with white pulp background. The ICAR- IIHR has identified and released two sweet pummelo varieties Arka Chandra and Arka Anandha (Anon, 2022).

2.4.2. Hybridization

Hybridization of two distinct parents and raising of progenies for primary evaluation mainly to identify the progenies with dwarfness, regular bearing, seedlessness or less seeds, attractive pulp colour and sweetness. Fan-Qi Rong (2001) documented a cultivar Jingmenjuyou, which was recognized to be a natural hybrid between pummelo and mandarin. The cultivar was dwarf in growth habit and yet was a high-yielding cultivar. Zhou *et al.* (2006) recorded fruit morphological and biochemical data of ‘Guifeihongyou’ fruit, a hybrid between grapefruit and pummelo cultivar. The fruit matures in late September, a little earlier than the existing pummelo cultivars. The fruits were medium-large and weighed around a kilogram. The shape of the fruits ranged from oblate to nearly round in shape, with a smooth bright yellow rind. The pulp was light purplish red, juicy, with a soluble and edible rate of 53.9 percent. The fruits had a lesser seed count of around 30 seeds (much lower than the standard cultivar Shatianyou). The yield of five-year-old trees reached 23.59 t/ha.

2.4.3. Mutation

Mutation breeding is attempted to achieve few qualitative characters like pulp colour, bitterness and seedlessness or less seeds. This method is also followed to break certain tightly linked traits**.** “Chandler”: Hybrid of Siamese pink and Siamese sweet, pink fleshed, early ripening fresh fruit, maturing in December–April; it is seeded, medium oblate to globose, smooth peel, and stores well (Singh *et al*., 2003) where as the “Kao Ponne” and “Kao Phueng” varieties are white fleshed, seeded Thai cultivars. Kao Phueng fruits are pyriform with distinct necks, whereas Kao Ponne fruit is globose. Kao Ponne matures earlier than Kao Phueng and has a good flavored juicy pulp. Liu *et al.* (2005) documented their findings on the Shanghang Miyou pummelo cultivar, which was identified as a mutation of the Taiguo Miyou cultivar. Their research indicated that Shanghang Miyou held great promise as a late-season pummelo selection. The trees of this cultivar demonstrated hardiness, withstanding temperatures as low as -6°C, and exhibited a high level of resistance against citrus canker (*Xanthomonas axonopodis pv*. citri). The Shanghang Miyou pummelo fruits were round in shape and matured in early January. They were characterized by their significant size, with an average weight of 1745 g. The pulp of these fruits was described as yellowish white and possessed a fine, tender, and juicy texture. The presence of a limited number of seeds, ranging from 10 to 15, was notable. Importantly, the pulp's flavor profile was highlighted as pleasantly combining acidity with sweetness, contributing to a very good overall eating experience. Somsri *et al.* (2008) studied the acute and chronic gamma irradiations for mutation induction in tangerine (*C. reliculata*) and pummelo (*C. grandis*) to produce new cultivars with seedless or less seed by using cultured shoot and root from seeds, scions and pot plants. They found that 2 M_1V_4 'Khao Thong Di' pummelo which were treated with gamma rays by chronic irradiation with 9.51 and 32.45 Krad, have fruits with seedless. Also, 6 M_1V_3 and 5 M_1V_4 tangerine plants which were treated with gamma rays by acute irradiation at 4 and 8 Krad, have fruits with less seeds. Sankaran *et al.* (2021) irradiated pummel seeds with different doses of Gamma rays and found that 66.94 Gy could suppress germination close to 5 per cent (LD50) in pummelo. This 60 Gy gamma dose can effectively be used for raising th mutant populations to identify a desirable mutation in pummelo.

2.4.4. Biotechnological approaches

Several biotechnological approaches are available for gene discovery, molecular markers linked to trait of interest, hybridity confirmation and diversity analysis. Liu *et al*.(2007) studied the genetic diversity in 122 accessions of pummelo (*Citrus grandis* Osbeck) and its related varieties using simple sequence repeat (SSR) markers. Thirty-one pairs of SSR informative primers generated a total of 335 alleles. The average number of alleles per locus was 9.85. The value of allelic polymorphism information content (PIC) ranged from 0.1939 to 0.9073, with an average of 0.7085 per primer. The 122 accessions of pummelo and its related varieties could be clustered into seven groups by the unweighted pair-group method arithmetic average (UPGMA), in which the 110 pummelo accessions could be divided into 18 subgroups at similarity coefficient of 0.712. These subgroups were mainly composed of the Shatian pummelo variety group, the Wendan variety group and many of the hybrid pummelo groups. The classification method can be used in targeting many varieties in order to widen the genetic background of pummelo. Ruiz *et al.*,(2000) employed SSR markers to differentiate between zygotic and nucellar seedlings in two distinct citrus populations. One population originated from an interspecific cross, while the other resulted from self-pollination. The study's findings indicated that microsatellite markers (SSR) were more effective than isozymic markers in determining the sexual origin of citrus seedlings. This superiority was attributed to the SSR markers' heightened level of polymorphism compared to the relatively limited number of polymorphic isozymes in certain populations.

Perera *et al.* (2001) thirty-three coconut populations were subjected to microsatellite assay with eight coconut-specific microsatellite primer pairs in order to study the levels and distribution of genetic variation.

A total of 56 alleles were detected ranging from 3 to 10 alleles per primer pair with an average of 7 alleles per locus. Overall a very high level of genetic diversity was detected (0.999) for all the populations studied ranging from 0.526 for population Debarayaya to 0.683 for population Dickwella. Only four introduced coconut populations, i.e. Clovis, Margeret, Dickwella, Mirishena and an embryo-cultured population were clearly separated from the resulting dendrogram. A very high level of within population variation (99%) accounted for native populations suggests a common history and a restricted genetic base for native Sri Lankan tall coconuts. Corazza-Nunes *et al.* (2002) conducted an evaluation of genetic variability within 38 grapefruit and three pummelo accessions. This analysis employed RAPD and SSR markers. Out of the 198 RAPD markers used, approximately 49% were found to be polymorphic. For the SSR loci, 4.6 alleles were identified on average, and Polymorphic Information Content (PIC) values ranged from 0.093 to 0.450. They constructed a UPGMA phenetic tree based on the obtained data. This tree revealed the presence of two primary groups among the grapefruit accessions. Notably, the grapefruit cultivars 'do Cabo' and 'Siamesa-Filipinas' were found to cluster closely to the pummelo accessions in Group A. Group B was composed of three sub-groups, encompassing the remaining grapefruit accessions. These findings highlighted the genetic relationships and diversity within the evaluated grapefruit and pummelo accessions.

Karim and Hashinaga (2002) conducted an isolation and characterization of the enzyme limonoid glucosyltransferase from pummelo (*Citrus grandis* Osbeck) albedo tissue. They concluded that elevating the activity of the enzyme limonoid glucosyltransferase (LGTase) could effectively elevate the glucoside levels, consequently mitigating the issue of bitterness induced by limonin. This enhancement in glucoside levels through enzyme modulation at the molecular level offers potential solutions to address the bitterness problem associated with limonoid compounds. Frydman *et al.* (2004) concluded that the pivotal step in determining the flavor of citrus flavanone-glycoside biosynthesis is facilitated by the enzyme 1,2-rhamnosytransferase, encoded by the Cm1,2RhaT gene. This enzyme leads to the formation of bitter flavanone-7-O-neohesperidosides (Naringin) in pummelo and grapefruit. In contrast, the 1,6-rhamnosytransferase, governed by 1,6RhaT gene, results in the production of the tasteless flavanone-7-O-rutinosides (Narirutin) in mandarin and sweet orange.

Su *et al*. (2010) employed inter-simple sequence repeats (ISSR) markers as a tool to distinguish C. grandis 'Tomentosa' from various other citrus variants. This approach aimed to prevent potential misuse or misidentification of the specific citrus variant. Chai *et al*. (2013) evaluated 212 Pummelo EST-derived SSR markers for their potential applicability across different citrus genera, polymorphism, mapping capacity, and utility in genetic diversity analysis. Among these markers, 136 were successfully amplified, while 99 demonstrated transferability to citrus species including *C. sinensis, C. reticulata, C. lemon, Fortunella sp*. and *Poncirus sp*. with transferability rates ranging from 73% to 76%. Furthermore, 52 markers (53%) exhibited polymorphism and were capable of segregating in a mapping population. These findings suggest that CgEMS markers have promising implications for genetic studies, offering insights into genetic diversity, trait mapping, and broader applications across citrus species. Frydman *et al.* (2013) derived significant conclusions from their study, affirming that the enzyme 1,2-rhamnosytransferase (encoded by the *Cm1,2RhaT* gene) catalyzes the production of the bitter flavanone-7-O-neohesperidosides (naringin), while the enzyme 1,6-rhamnosytransferase (encoded by the *Cs1,6RhaT* gene) results in the formation of the tasteless flavanone-7-O-rutinosides (narirutin). Through phylogenetic analysis of the *Cm1,2RhaT and Cs1,6RhaT* genes, they established that these enzymes are both categorized within the branch-forming glycosyltransferase cluster.

Susandarini *et al.* (2016) examined the genetic variability of 13 *C. maxima* accessions from Yogyakarta and three registered cultivars using two RAPD primers, yielding 222 DNA bands with 174 being polymorphic. Cluster analysis based on the UPGMA method using the simple matching coefficient indicated pronounced genetic diversity among accessions. Ahmed *et al.* (2019) conducted an evaluation of fourteen pummelo (Citrus maxima Merr.) fruit varieties using 60 SSR markers in order to elucidate their genetic diversity. The analysis revealed 26 polymorphic SSR loci encompassing 77 amplified alleles, with allele counts ranging from 1 to 4 and an average of 2.96 alleles per locus. The PIC values spanned from 0.12 (CIBE5720) to 0.73 (CAT01), with an average of 0.53. Notably, CAT01 displayed the highest heterozygosity at 0.73, followed by CS05 (0.72) and AG14 (0.69). Genetic similarity analysis unveiled that Pink Pummelo and White Pummelo exhibited the highest similarity, with an 89% coefficient, indicating a close relationship. Despite notable morphological diversity, the study suggested limited genetic diversity among pummelo varieties, likely stemming from somatic mutations contributing to much of the observed phenotypic variation. Wang *et al.* (2019) studied on fifteen simple sequence repeat (SSR) primers to detected the genetic diversity of 73 pummelo germplasms and rootstocks collected in Sichuan Basin. With an average of 8.2 alleles per locus, 15 SSR loci produced a total of 123 alleles. The detected heterozygosity (Ho), with an average of 0.2090 per locus, varied from 0.0000 to 0.7429. Various groupings of pummelo types showed distinct genetic diversity differences. The following was the average genetic diversity index among the various groups: Na is equal to 1.6935, H is 1.404, I and 0.3363, Ho is 0.2570, and He is 0.2470. Ahmed *et al.* (2019) found that fruit weight, productivity, number of fruits per tree, and number of seeds per fruit recorded the highest levels of phenotypic variance (PV) and genotypic variance (GV) among genotypes during characterization and evaluation of pummelo cultivars using SSR markers and quality parameters. They deduced that genotypic and environmental factors, as well as their interactions, were responsible for the variance in the population. In this study, the phenotypic coefficient of variation (PCV) and genotypic coefficient of variance (GCV) for fruit weight, fruit rind thickness, and fruit number per tree were shown to be the greatest. Susandarini et al. (2020) evaluated eighty accessions of *C. maxima* using microsatellite sequences from genomic DNA amplified using DY296883 primer. Results showed that *C. maxima* microsatellite has high polymorphism in the form of repeat length variation of (GA)n, ranging from (GA)7 to (GA)19. This study proved the existence of high genotypic variability in *C maxima*, and confirmed the role of microsatellite as a useful molecular marker for uncovering variability at intraspecific level. Observation of the microsatellite polymorphisms indicated that variability of (GA)n can be used to distinguish some pomelo cultivars. Liu *et al.* (2021) successfully identified a range of potential biomarkers for characterizing limonoids in various tissues of pummelo fruit. Their findings provided insights into the diverse structures of limonoids and their distribution across different parts of the fruit. This research serves as a crucial stepping stone for future endeavors in harnessing and exploiting limonoid metabolites from citrus species. Similarly, Chen *et al.* (2022) discovered three flavonoid-7-O-di-glucosyltransferase (*dGlcT*) genes that share close relation with the 1,2-rhamnosyltransferase (*1,2RhaT*) in citrus genomes.They demonstrated that when *CitdGlcTs* were over-expressed in transgenic tobacco BY2 cells, flavonoid-7-O-glucosides underwent conversion into non-bitter flavonoid-7-O-di-glucosides, whereas over-expression of *Cit1,2RhaT* led to the formation of bitter-flavored flavonoid-7-O-neohesperidoside (naringin) from the same substrate. Interestingly, during citrus fruit development, *dGlcTs* exhibited an expression pattern contrary to CHS and CHI, two genes encoding rate-limiting enzymes in flavonoid biosynthesis. This divergence in availability of *dGlcTs* and substrates likely resulted in trace levels of flavonoid-7-O-di-glucosides accumulating in *C maxima* (pummelo) fruit.

Future thrust

Pummelo has attained the commercial crop status in the countries like China, USA, Italy and Thailand but this crop is being treated as an "orphan" or underutilized crop. Like any other fruit crops, the collection and evaluation is of utmost important to identify the donors. There is urgent need to do basic research on inheritance of characters which will ease the choice of parents in hybridization programmes. Breeding work should be taken at priority for developing the sweet pummel varieties with seedlessness or few seeds and also there is a need to start the rootstock breeding for biotic and abiotic stress tolerance. The integration of breeding approaches involving molecular methods including the genome editing would yield the varieties with economic traits at a shorter breeding period.

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17. Mainstreaming underutilized fruit species resources for increasing fruit crop diversity

S. Ganeshan

Former Director JNTBGRI, Palode, Trivandrum

Email: ganeshans54@gmail.com

Introduction

Underutilized fruit species are largely known as minor, neglected, new, hitherto unknown or less known, low volume, underdeveloped etc., but promising for their importance, having nutritional value and has a potential for source of income.

Less-known fruit species are neglected even today as far as management of their resources is concerned. From a positive perspective, they represent a wealth of as yet untapped potential for valuable research effort, for accomplishing large scale cultivation. This can be achieved by identification and prioritization of these species for agri-horticultural needs and develop them as crops.

The distribution of less known fruit species are predominantly recorded in natural ecosystems, which points out that either the species diversity is widely distributed or is scattered in small pockets; often several species may be truly endemic. Ecogeographic surveys to assess this diversity and distribution of these fruit species is of cardinal importance. A good deal of data already compiled from national/regional herbaria will be helpful in providing information on the site, terrain, ecology, climate, phenology, uses, etc. Further, published reports, surveys conducted, and information catalogued will be a major input in assessing the overall distribution pattern of diversity in targeted ecosystems, with a major emphasis on wild forms of these fruit species.

There is a need to develop and promote near *in situ* cultivation/conservation of these fruit species, especially after identification of niche ecosystems; field studies will be required with particular species in question. The activity must focus on developing appropriate cultivation practices and optimize the specie specific techniques to be adopted. Suitable socio-economic indicators need to be zeroed upon which provide clues to demarcate the ultimate *in situ* conservation sites for better understanding of the extent of species diversity.

Global examples

There are fruits which are commonly known to all, but some fruits are so bizarre and alien that only a few people are familiar. The reason that such fruits are unheard of to a majority of people in the world is due to their exclusive geographical distribution / growing region. What is common to a country remains unknown to the rest of the world.

Ackee (*Blighia sapida*) is a national fruit of Jamaica and is poisonous if eaten prematurely and can lead to coma. It is safe to eat this fruit only after it opens naturally. This fruit was not a part of Jamaican culture as it was originally native to West Africa, introduced to Jamaica in 1778 and the fruit soon became a major part of Jamaican cuisine. The tree habit grows to ca.10 meters height and is evergreen. The fruit looks like a pear and is green in colour when raw, but changes its colour to orange or red after it ripens, splitting open to reveal 3 black seeds surrounded by spongy white flesh aril which is edible. The fruit weighs 100 to 200 grams.

Synsepalum dulcificum referred as miracle fruit/berry produces red berries, when eaten makes sour food that are eaten after it tastes sweet for the next 30 minutes. The fruit tree originates from West Africa, grown on acidic soil with a small tree habit growing to Ca.18 feet. Because of its ability to turn unsweet food to sweet taste, The species was introduced to the US for commercialization, but failed since it was classified as a food additive. Organoleptic evaluation classified it as an unsweet fruit, binding with taste buds to make acidic fruit taste sweet, effect lasting for nearly two hours.

Pandanus tectorius commonly known as Hala fruit is familiar because of its exotic colourful appearance, extensively grown near the ocean edges. It originates from Australia, Pacific Islands and Philippines. It appears and tastes like pineapple. The fruit is made up of hundreds of wedges or cones innards of which are pulpy yellow or orange, while the outer end of each cone is fibrous and green. The fibrous part is used as dental floss, while the soft end is eaten raw or cooked. The fruit grows ca.25cm in diameter, dioecious in habit, female trees bear fruit when it is 20 years old.

Indian examples

Tropical fruits grown in India, which are lesser known, include many underexploited fruits, which would need exploration and identification of superior types to make them commercially viable. These include barhal *(Artocarpus lakoocha),* chironji *(Buchanania lanzan),* karonda *(Carissa congesta),* dillenia *(Dillenia indica),* rose apple *(Syzygium jambos),* wood apple *(Feronia limonia),* mansari *(Mimusops elengi),* hogplum *(Spondias pinnata),* tropical almond *(Terminalia catappa),* wild lovi lovi (*Flacourtia inermis*), mooti (*Baccaurea courtallensis*) etc.

To study the diversity and distribution of these fruit species in India would need concerted exploration efforts from *in situ* ecosystems to consolidate the available plant species and broaden the collection base. These fruits have also caught the attention of many tribal growers for attempting commercial exploitation. Besides this, there are many hitherto unknown tropical fruit species, which have remained unexploited. Rich diversity of wild fruit species occur in north eastern region and the Western Ghats.

A comprehensive collection of less-known and underutilized fruit species of the Western Ghats are maintained at JNTBGRI. 75 less-known fruit trees were collected and from this 25 species were identified as promising fruit trees for cultivation. An orchard for promising fruit species was developed where 20-25 accessions of each species collected from different localities were grown, to assess the fruit yield and quality. Plus clones among these were identified and saplings were regenerated through vegetative propagation methods (budding, layering and grafting) for distribution. During the last 15 years, over 50,000 saplings of such fruit plants were distributed. The promising species identified during the study include *Alangium salvifolium, Antidesma ghaesembilla, Antidesma menasu, Aporusa acuminata, Aporusa lindleyana, Artocarpus hirsutus, Baccaurea courtallensis, Elaeocarpus serratus, Eleagnus conferta, Emblica officinalis, Ficus auriculata, Ficus racemosa, Flacourtia montana, Garcinia gummi-gutta, Garcinia indica, Garcinia xanthochymus, Madhuca longifolia, Mimusops elengi, Phoenix laureiri, Salacia beddomei, Salacia fruticosa, Syzygium cumini, Spondias pinnata, Syzygium laetum* and *Syzygium zeylanicum.* Besides a few lesser known fruit plants such as Annona *glabra, Annona muricata, Annona reticulata, Averrhoa bilimbi, Averrhoa carambola, Chrysophyllum canito, Citrus grandis, Flacourtia inermis, Morus alba, Persea americana, Phyllanthus acidus, Pouteria campechiana, Psidium guineense, Psidium littorale* and *Syzygium jambos* were also selected for regeneration and popularization.

Another area which needs attention is conservation of the wild relatives of underutilized fruit species. It is estimated that there are ca. 75 wild fruit tree species found distributed throughout the Western Ghats, out of which more than 50 % are endemic and some are very rare and locally restricted to 2 or 3 niche populations. With the funding support of The Botanic Garden Conservation International (BGCI) a project on the cultivation / conservation of arborescent fruit crop relatives was initiated at JNTBGRI in 2005 which resulted in establishment of a full-fledged fruit tree arboretum having tree representations from the Western Ghats, North East and Andamans.

The presentation attempts to provide a road map to mainstream hitherto less known fruit species into the cropping ecosystem.

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18. Crop for future/neglected and underutilized vegetables on FAO perspective for Bharat

Sudhakar Pandey[1*] and Rakesh Kumar Dubey[2]
[1]Indian Council of Agricultural Research, New Delhi
[2]ICAR-Indian Institute of Vegetable Research, Varanasi
*Email: sudhakarpandey.hsd@icar.org.in

Agriculture became the backbone of food systems more than 10,000 years ago, as humans shifted from hunting and gathering to growing and cultivating food. The Green Revolution led to development of high-yielding varieties of maize, wheat, rice that were responsive to additional inputs such as fertilizers and water, resulting in the birth of an agro-industrial food regime. To an extent, India benefited from the Green Revolution, saving them from famine; however, this impacted smallholder agriculture with a shift towards greater dependency on the agro-industrial food system. Inevitably, the successes of the Green Revolution and subsequent emergence of the agro-industrial food system gave birth to 'new' challenges, such as environmental pollution and degradation, loss of biodiversity, and malnutrition. The current food system remains a diverse mixture of localized and industrialized systems of interconnected food chains; however, the majority of these systems are centered on a handful of crop choices. As a result, modern food systems are more vulnerable to economic and climatic shocks, as they may not always have the requisite diversity and redundancy to be able to buffer these risks—i.e., they are not resilient. Underutilized/ indigenous and traditional crops through the introduction of exotic and, now considered "major" crops,that were often higher yielding, but also more input intensive. This led to neglect of underutilized/ indigenous and traditional crop species that had previously formed the basis of local food systems. The erosion of agro-biodiversity, combined with an emphasis on input-intensive cropping systems has, arguably, lowered the resilience of food systems. Underutilized/ traditional crops as "crops that have either originated or those that have become "indigenized" over many years of cultivation as well as natural and farmer selection. Underutilized and traditional crops are often characterized by limited development relative to their potential. Consequently, they have poorly developed and understood value chains; however, this varies across geographic and socio-economic settings. Furthermore, the concerns regarding environmental degradation, loss of biodiversity and vulnerability to climate change, have prompted a call to rethink the current configuration of the food system. The "mainstreaming" refer to the integration/inclusion of underutilized/ traditional crops into the dominant food system. However, such integration or inclusion should occur in a way that allows them to retain the attributes that make them attractive and transformative while benefiting from the support mechanisms that exist within the dominant food system. The underexploited vegetables play an important part of food and nutrition of local/ tribal population across the globe. Since time immemorial, they are traditionally been esteemed for their utilization in terms of medicinal, therapeutic and nutritional values along with providing economic stability. This necessitates the importance of inclusion of underexploited and neglected vegetables which feature promptly in the food and nutritional security, improved socio-economic conditions and health promoting benefits.

Food and nutrition security

Food and nutrition security is the ability to obtain safe, nutritious foods to meet the basic dietary requirements of an individual, in order to perform daily duties, while malnutrition refers to deficiencies (under nutrition), excesses (over nutrition), or imbalances in a person's intake of nutrients. Over-nutrition has been linked to several non-communicable diseases such as diabetes, hypertension and cardiovascular disease. While there is evidence that food production is increasing, this is not enough to feed the growing population and the food insecure. To feed the growing population, and to close the food insecurity gap, food production has to increase by at least 35% of the current production. The gap between achieved food production and the desired food production seems to be increasing compared to previous decades. While agriculture is the main source of livelihood for poor sustain subsistence. In this regard, underutilized indigenous and traditional crops could be an alternative to bridge the food and nutrition security gap, especially in the rural areas. Several underutilized indigenous and traditional crops have been reported to be nutrient-dense with good adaptability to marginal conditions; hence, they are more likely to be a sustainable and nutritious source of food. The recognition of the importance of Indigenous knowledge systems, for instance, through a formalization of the indigenous knowledge base, could be used as an entry point to leverage the incorporation of underutilized indigenous and traditional crops within policy implementation processes, in order to improve access to dietary diversity among the previously disadvantaged.

Agriculture and economic exclusion

Current agricultural activities recognize the need for increased crop productivity to fight poverty, unemployment and food and nutrition insecurity. However, many of them remain modeled on green revolution ideology, that emphasizes efficiency and productivity over resilience. Current policies, funding opportunities, and research interests are still trying to push yield potential of a few major crops, and are not geared towards the development of an indigenous food crop sector. Diversity of diet, founded on diverse farming systems, delivers better nutrition and greater health, with additional benefits for human productivity, livelihoods and wellbeing. Agricultural biodiversity will be essential to cope with malnutrition, and to establish more sustainable food systems. The inclusion of underutilized indigenous and traditional crops and associated alternative food systems into policy frameworks can result in improvements of agro-biodiversity. Supporting local food chains for underutilized indigenous and traditional crops is vital to improve local demand, and improve opportunities for smallholder farmers to increase participation in national and regional food chains.

Impact on environment

The ongoing intensification of agricultural production in the country has had particularly notable effects on the environment through release of greenhouse gases, pollution, loss in species biodiversity and erosion. In general, agricultural production, including indirect emissions associated with land use changes and direct emissions from land clearing, contributes 80-85% of total food system emissions while processing, transporting, storing, cooking and disposing of food contributes the remaining 15–20%. There were no statistics to separate GHG emissions of smallholder and commercial agriculture. However, it is hypothesized that commercial agriculture could possibly contribute to more GHG emissions due to its reliance on external input and energy to drive machinery. Animal production contributes a bigger carbon and water footprint compared to plant production. This higher carbon footprint is associated with their feeding, processing and the release of methane gas by ruminants such as cows. Per ton of product, animal sourced foods have up to a 20 times larger water footprint than crop products. Transitioning toward more plant-based food systems could reduce food-related greenhouse gas emissions by 29 %–70%. In support of this notion and to further diversify current plant-based food systems, we advocate for the inclusion of nutrient-dense underutilized indigenous and traditional crops. Ammonia emissions have an atmospheric lifespan which ranges from days to weeks, and pollute whole regions in the process, affecting both ecosystems and human health. In addition, the application of agrochemicals and fertilizer to increase yield in the dominant food system is associated with possible contamination of soil and water through the wrong application or over-usage of these chemicals. Uncontrolled application of pesticides can kill other non-target and beneficial organisms such as bacteria, fungi, and earthworms. Microbial biomass is a labile component of soil organic matter and has an important role in the soil nutrient element cycle. Agrochemicals can move from agricultural fields into nearby streams, rivers and lakes where their toxicity could pose a risk to aquatic ecosystems. These agrochemicals can vary significantly in their toxicity towards aquatic organisms as well as their mobility in the environment—properties which are influenced by their chemical make-up and other climatic, geographic and land management factors. There is need to moderate and regulate the use of agrochemicals in agriculture to reduce the impacts of food systems to the environment. Underutilized indigenous and traditional crops are less susceptible to pests and diseases and require less fertilizer interventions; hence, they can mitigate the negative environmental impacts of agrochemicals. While underutilized indigenous and traditional crops may offer some reprieve to environmental issues, there is a need to complement efforts to mainstream them into the dominant food system with sound agricultural practices for the system as a whole.

Policy for future vegetable crops

The policies governing the food system reflect a favorable environment for big businesses, and have made it conducive for a few players to dominate the food system. The food system is under pressure to achieve equitable distribution of food produced in the food system, and to feed the growing population using the resources already dedicated to agriculture. Arguments have been made for the inclusion of underutilized indigenous and traditional crops in the existing food system. The first is that there is potential to increase crop diversity and thereby to increase dietary diversity, thus achieving food and nutrition security outcomes. Secondly, advocates for an inclusive food system propose the strengthening of local food systems. These arguments show that there is room for underutilized indigenous and traditional crops in the current food system. The extension system exacerbates these trends, as it is not designed to promote the kind of knowledge that is required to invigorate traditional farming practices that are conducive to cultivating underutilized indigenous and traditional crops. Inorganically processed food has been a major component of diets and has been associated with overweight in both children and adults, as well as chronic diseases. This gave rise to a growing market for organic food, which is often very expensive and is beyond the reach of the majority of the population. Ironically, rural farming systems closely resemble organic farming as a result of minimal use of synthetic inputs; however, while their production systems may resemble organic farming. However, merely getting underutilized indigenous and traditional crops onto the agenda is not enough, the resulting policies should be implemented to bring about inclusivity and equity in the food system, and to strengthen its contribution to the local economy and the GDP.

Health and nutrition through diversity

The current food system has been shown to lack dietary diversity and has exposed people to food and nutrition insecurity. Young children and women of child-bearing age in rural areas are often most vulnerable, as they lack access to a diversified diet which leads to malnutrition. On a global scale, there are approximately 7000 known and documented edible species of plants; however, due to globalization, there is a decline in the consumption of underutilized indigenous and traditional crops. With climate change, and the fluctuation in food prices, it becomes very important to support traditional crops and farming systems. Currently, traditional farming systems are poorly developed and not well-marketed. Including underutilized indigenous and traditional crops into a new food system will increase dietary diversity. Several underutilized indigenous and traditional crops, especially vegetables, have high nutritional value, and could improve the nutritional status of many impoverished individuals. Leafy vegetables such as water spinach, amaranth, Chinese cabbage, *Solanum nigrum*, *Corchorus olitorius*, pumpkin leaves, faba bean, cluster bean, Indian bean, vegetable soybean, lotus, water chestnut, pointed gourd, water melon and sunhemp flower have been reported to be good sources of vitamins, fiber and iron. Water spinach variety Kashi Manu as leafy vegetable could produce leafy biomass throughout the year as upland crop and winged bean variety Kashi Annapurna are other examples of underutilized indigenous and traditional crops that are gaining popularity among growers. Hence, by incorporating underutilized indigenous and traditional crops into the food system there will be an increase in dietary diversity, improvement in nutritional status, and a reduction in household food and nutrition insecurity. However, basic knowledge on the production and preparation of underutilized indigenous and traditional crops should be provided to farmers and impoverished individuals, to improve acceptance. When underutilized indigenous and traditional crops are incorporated into a new food system, there should be a trans-disciplinary approach, so that new technologies can be used to add value to the products.

Strengthening socio-economic and environmental concerns through Agro-biodiversity

The consumption of underutilized indigenous and traditional crops in many communities was adversely affected by their perception as ‘poverty foods’ or food for the elderly. Colonization and globalization contributed to the introduction of foods which were considered ‘modern’ and, therefore, more attractive than traditional foods. However, some of these ‘modern’ foods were not as nutritious as underutilized indigenous and traditional crops, and, subsequently, narrowed dietary diversity. In addition, the consumption of underutilized indigenous and traditional crops declined as they were not included in the dominant food systems and could only be purchased in alternative and informal food systems. These alternative food systems, however, were also slowly displaced with the proliferation of regional supermarket chains in both urban and rural part of the country. The agro-industrial food system has inadvertently disempowered farmers, particularly smallholder farmers, many of whom are female. Thus, any attempts to include underutilized indigenous and traditional crops in the food system should, ideally, begin with imparting skills which will increase farmer agency, and economic and political power. Such initiatives would not only equip farmers to demand services and opportunities, but would position them as equal partners in the exchange of knowledge between themselves and researchers and other stakeholders. This is important because elderly farmers, who are custodians of underutilized indigenous and traditional crops’ conservation and knowledge in most communities, are needed to document the different species of underutilized indigenous and traditional crops and their uses. The endorsing of underutilized indigenous and traditional crops by influential persons and bodies can also improve their demand in the food system, thus creating opportunities for inclusion in the value chain. Medical endorsements of underutilized indigenous and traditional crops, which are positioned as healthy and nutrient-rich foods, have led to increased consumption, particularly by wealthier members of society. Mainstreaming into the diet of wealthier people would, presumably, also make these crops more attractive and aspirational to poor households, thereby overcoming any previous stigma. Cultivating underutilized indigenous and traditional crops in an inclusive food system could contribute significantly to addressing environmental concerns. Agro-ecological practices and other farming systems which mimic nature would be instrumental in reducing impacts. By their nature, such farming systems promote the growth of a multiplicity of edible and medicinal plants which are indigenous to a region. The influence of including a trans-disciplinary approach, recognizing/endorsing underutilized indigenous and traditional crops, developing local food chains, resulting in diverse farming systems and alternative food systems, would create a virtuous cycle of increased household food and nutrition security, improved livelihoods, and reduced malnutrition thereby reducing vulnerability, inequalities, and improving human wellbeing.

Linkage among agriculture, environment and health

There are strong linkages between agriculture, environment and health in the current agro-industrial food system. The three sectors need to work together in order to address common issues such as improved agricultural productivity, food and nutritional security, reduced environmental degradation, improved human health outcomes, and improved human wellbeing in general. It is clear that agriculture is responsible for increasing food production and influencing healthy diets. Consumers are important players in the food system and their demands can influence production, as shown by the increased demand for animal sourced foods in countries experiencing rapid economic growth. It is possible that improving consumer education on the link between certain foods and their carbon footprint can reduce the demand for those foods. However, agriculture is not just about growing food for consumption, there are also aspects of the environment that are key for agriculture. Key inputs in agriculture include water and land, thus, any consideration of increasing food production will need to consider water and land use. Given the challenges of water scarcity and associated challenges in expansive agriculture, there is a need for an agriculture-environment-health nexus approach to address the sustainable provision of enough nutritious food for supporting healthy diets.

Table1. Potential Underexploited vegetables for different food systems

English name	Botanical name	English name	Botanical name
Winged bean	*Psophocarpus tetragonolobus*	Cluster bean	*Cyamopsis tetragonoloba*
Vegetable Soybean	*Glycine max*	Water chestnut	*Trapa bispinosa*
Water spinach	*Ipomoea aquatica*	Jack bean	*Canavalia ensiformis*
Sword bean	*Canavalia gladiata*	Lima bean	*Phaseolus coccineous*
Yam bean	*Pachyrrhizus tuberosa*	Gherkin	*Cucumis anguina*
Spiny Amaranth	*Amaranthus spinosus*	Leaf Amaranth	*Amaranthus viridis*
Bathua	*Chenopodium album*	Sorrel	*Rumex vesicarius*
Moringa	*Moringa oleifera*	Fern	*Dryopteris filix-mas*
Water cress	*Nasturtium officinale*	Tannia	*Xanthosoma atrovirens*
White yam	*Dioscorea alata*	Basella	*Basella alba*
Lotus	*Nelumbo nucifera*	Velvet bean	*Mucuna pruriens*
Cluster bean	*Cyamopsis tetragonoloba*	Long melon	*Cucumis melo* var. utilissimus
Faba bean	*Vicia faba*	Indian bean	*Lablab purpureus*

Mainstreaming of Underexploited/minor vegetables for food and nutrition secure future

Minor *Cucurbitaceous* vegetables

There are several underexploited/ minor cucurbitaceous vegetables, which are grown and consumed by people across the country. These are mainly *Cucumis hystrix*, *Cucumis trigonus, Luffa graveolens, Momordica macrophylla, Momordica subangulata, Trichosanthes cucumerina, Trichosanthes khasiana, Trichosanthes ovata,* and *Trichosanthes truncasa*. In addition, wild relatives of several cucurbits are also found with significant genetic variability, such as *Cucurbit*a *ficifolia*, *Cucumis hardwickii, Momordica cochinchinensis* etc. providing a reservoir of useful genes. Chow Chow (*Sechium edule*), is a very popular vegetable in the NEH region of India commonly called as squash and grows abundantly without much care and attention.

Underexploited *Solanaceous* vegetables

In *Solanaceous* vegetables, India is very rich in diversity for *Solanum melongena,* with several primitive cultivars having excellent quality of soft flesh, less seeds and large fruit size. Additionally,wild species, such as *Solanum gilo*, *Solanum torvum, Solanum indicum, Solanum khasianum*, *Solanum macrocarpon* and *Solanum xanthocarpum. Solanum khasianum* is an important species of medicinal value (solasodine content) and *Solanum torvum,* extensively used in the Ayurvedic medicine system. These species have also been found to possess resistance to shoot and fruit borer and root diseases, respectively. *Solanum pimpinellifolium* has also expressed resistance to late blight and tomato leaf curl virus. *Capsicum annuum, Capsicum frutescens* and *Capsicum Chinense* form important food crop.

Potential minor leguminous vegetables :

Several wild forms and wide variability found in rice bean (*Vigna umbellata*) with profuse branching, higher seeds per pod, higher number of pod per peduncle, bold seeds and high grain yield and higher polymorphism has also been recorded in local landraces for seed colour. Additionally, *Vigna radiata* var. sublobata is known for yellow mosaic virus resistance, whereas *Vigna umbellata* var. radiata is known for resistance to diseases and insect pests. In, French bean pole type is popular among the tribal population, since it is used for mixed cropping with maize. Jack bean (*Canavalia ensiformis*) is also cultivated whereas; winged bean (*Psophocarpus tetragonolobus*) is confined to the humid subtropical parts of the local pockets. Broad bean *(Vicia faba*), *Atylosia geonsis*, *Atylosia scaraboides*, *Canavalia gladiata, Mucuma monosperma, Mucuma nivea, Mucuma utilis, Dolichus bifflorus, Bauhinia purpurea, Vigna vexillata* are the under exploited legume species holds potential for nutritional security. Tree bean (*Parkia roxburghii*), is one of the most common of multipurpose tree species of Manipur.

Underexploited leafy vegetables as potential source nutrition

Important minor leafy vegetables include Lai sag (*Brassica juncea*), lafa (*Malva verticillata*). In addition to these a wide variety of indigenous leafy vegetables are also available. Amaranth (*Amaranthus spp*), poi (*Basella rubra* and *Basella alba*), sorrel (*Rumex rasicarius*), etc. Other indigenous leafy vegetables used occasionally are bathua (*Chenopodium album*) and Kalmi sag (*Ipomea aquatica*), *Amaranthus viridis*, *Amaranthus lividus*, *Amaranthus retroflexus* and *Amaranthus spinosus* are the potential leafy vegetables for addressing malnutrition.

Tree tomato

Tree tomato is a perennial shrub, grown as a backyard crop in Meghalaya and Sikkim. It is 2-3 m tall tree, which bears prolifically egg shaped berries with pointed ends in cluster near the young shoots. The long-stalked, pendent fruit, borne singly, or in clusters of 4 to 12, is smooth, egg-shaped but pointed at both ends and capped with the persistent conical calyx. In size, it ranges from 7-10 cm in length and 5-6 cm in width and in colour may be solid deep-purple, blood-red, orange or yellow, or red-and-yellow and may have faint dark, longitudinal stripes. The inside pulp of the fruit is light orange and the seeds are black in colour. Tree tomato is consumed as delicious chutney when raw or after roasting and peeling off the skin. It is liked by the people due to its unique flavour.

Chow-chow

Chow-chow is a very popular vegetable in the NEH region, commonly called as squash and grows abundantly without much care and attention in high hills of Meghalaya, Manipur, Mizoram, Nagaland and Sikkim. Chow-chow produces large starchy edible roots in addition to fruits. It is a vigorous, scrambling, tuberous-rooted perennial plant, grown for its starchy, edible fruit and seeds. This climber can spread to up to two meter producing huge tubers. It looks like a large, green pear, but having a number of deep folds in the skin. Some varieties have smooth skins, while others have dots of prickly spines on the surface. The flesh is crisp and white with a large white oval seed in the centre.

Kakrol and Kartoli

Both are having high nutritional and medicinal with economic values. Immature tender green fruits are cooked as vegetable. Young leaves, flowers and seeds are also edible. The unripe fruits of both the crops act as appetizer and astringent. The seeds are used in chest problems and stimulate urinary discharge.

Jack bean

It is mostly cultivated in the North Eastern region. It is a bushy, semi-erect, annual herb, 2-3 m tall and the tips of its branches tend to twine under shade. Leaves are trifoliate and shortly hairy. Pods are sword shaped, 10-30 cm long and 2-2.5 cm broad. The pods are pendent, ribbed near suture and 10 to 25 seeded. Young green pods are eaten as a cooked vegetable.

Sword bean

It is used as vegetable and medicinal plants in NEH region. The red and black sword beans have antioxidant capacity compared to the white sword bean and this was attributed to their red and black bean coats, which possessed extremely high phenolic content. Gallic acid and its derivatives, such as, digalloyl hexoside, methyl gallate and digallic acid is the main phenolic compounds in the coats of red and black sword beans. Therefore, the red and black sword beans, especially their bean coats are good sources of antioxidant phenolics and may have potential health benefits.

Winged bean

Winged bean is an underexploited leguminous vegetable crop which finds an important place in traditional diets in several parts of the country. It is climbing short-day plant, cultivated as an annual with indeterminate growth. The tubers, young pods, seeds, leaves, flowers and shoots, are rich in protein, amino acids, oils, vitamins and minerals. Almost all parts of the plant can be eaten and are consumed by incorporating in a variety of cuisines. The leaves contain 5 to 15% protein and high amount of vitamins and the tubers contain 10 to 12% crude protein higher than other tuber crops. The green tender pods also have high protein content (1.9- 2.9%), carbohydrates (3.1- 3.8 %), rich in calcium, iron, phosphorus and vitamins. The mature seeds contain 29.8 to 37.4% protein, 15 to 20% fat and 28 to 31.6% carbohydrates and are also rich in Ca, Mg, P, Fe and vitamins. Like many legumes, the winged bean can be grown as an intercrop with tapioca, banana, sugarcane, sweet potatoes, or other green vegetables. Popularisation of its cultivation techniques and augmenting the potential of this "Wonder Legume Vegetable" can play an important role for sustaining the dietary needs as well as health benefits for a large section of population. ICAR-IIVR, Varanasi has released variety Kashi Annapurna for commercial cultivation.

Cluster bean

Cluster bean is a drought and high temperature tolerant, deep rooted, annual legume of high social and economic significance. The crop holds great potential like high adaptation towards erratic rainfall, multiple industrial uses, importance in cropping system for factors such as soil enrichment properties, low input requirement, etc. Cluster bean is a three-four months crop. From sowing to harvesting it takes about 90 to 110 days. Crop cycle starts with sowing by first to second week of July. In general flowering stage starts after 40 to 60 days of sowing. The pod formation takes place after 50 to 70 days from the date of sowing. Being a legume crop, it has ability to fix extra nitrogen in the soil so that it can perform well even in poor fertile soil and nutrient depleted soil. Cluster bean has the ability to fix nitrogen to the tune of 30 - 40 kg/ha. Several improved varieties of cluster bean have been evolved by Universities and ICAR Institutes in the country. Increasing demand of cluster bean on account of growth in shale gas industry along with other factors has made cluster bean a golden crop.

Tree bean

It is one of the most common multipurpose tree species in the North eastern region, especially in Manipur and Mizoram. Locally called 'Yongchak' in Manipur and 'Yontak' in Assam, its tree commonly grows in every household of hill region. The inflorescence head arise terminally with clusters of yellowish white tiny flowers, hanging at the top of long stalks from the branches. The fruits in early stages are soft, tender and bright green in colour. They turn blackish when fully mature in March-April. Pods are formed in clusters of 10-15, each measuring 25-40 cm in length and 2-4 cm in breadth. Based on local preference, the pods are consumed at different stages of maturity, either fresh or processed.

Yard long bean

Crop is widely grown in every part of NEH region during April-October. Besides immature pods, tender leaves and shoots are very popular as leafy vegetable. The plant is climbing type, branched, 4.0-5.5 m long, 20-35 nodes and flowers are large. Pods are pendent, green and purple in colour, 25-45 cm long, fleshy and inflated.

Lai sag

It is one of the most popular leafy vegetable. This is winter season annual crop, but being grown round the year except heavy rainfall period, having cylindrical taproot system. The crop bears soft, fleshy, broad, green and glabrous/ hairy leaves, fleshy stalk, and reaches a height of 60-70 cm which is being used as green vegetable. The leaves are dried to use during rainy season. Mustard leaves are an excellent source of vitamin E, vitamin C and beta-carotene. They also contain vitamin B6, folic acid, niacin, magnesium, calcium, iron, and are an excellent source of phyto-chemicals.

Water chestnut

Nuts of Singhara form a staple food. West Bengal, Jharkhand and Bihar (Darbhanga, Madhubani and Samastipur) are major growing areas of Singhara. Singhara is one of the submersed plants, used as edible nut. Kernel of Singhara contains protein (up to 20%), starch (52%), tannins (9.4%), fat (up to 1%) and sugar (3%). It is also a good source of fiber and vitamin B along with Ca, K, Fe and Zn. Cultivation of Singhara in combination with Magur-fish could provide good income to the farmers of seasonal water logged areas. Ripe nuts are usually sold in the market at the rate of ₹ 50- 200/kg.

Water spinach

Water spinach is commonly used as a food plant. The leaves are a good source of minerals,vitamins and is considered a possible source of food protein. It also possesses several medicinal properties. Being rich in iron, beneficial for people with anaemia as well as who require iron in their diets. Water spinach is rich in fiber and aids in digestion. All parts of the young plant of water spinach are edible. Water spinach is commonly grown in waterlogged areas. However, such cultivation requires cumbersome practices for plant protection measures and harvesting. This also invites water pollutants harmful for human health. Therefore, an attempt was made for scientific cultivation of water spinach in upland field conditions by ICAR-Indian Institute of Vegetable Research, Varanasi and promising results were obtained for the same. This technology is proved to be simple and can be cultivated round the year which can serve as boon for the socio-economic upliftment of the growers. The advantages of Upland - water spinach are Multiple cuttings, can be grown throughout the year, Can be grown in upland field condition, submerged condition is NOT necessary, Produce may be free from water pollutants, Technology promises "Safe Biomass", Crop can be raised by both seed as well as vegetative mode. Thus, Promotion of this water spinach cultivar Kashi Manu among growers promises socioeconomic prosperity as well as nutritional security.

Conclusion

A sustainable and healthy food system delivers food and nutrition security for all, in a way that is economically, socially and environmentally sound, so as not to compromise food and nutrition security for future generations. Future crops/Underutilized/ Neglected/indigenous and traditional crops can support and strengthen the existing food system, as they in particular are considered as economically, socially, and environmentally sound. Several underutilized indigenous and traditional crops are nutrient dense and adapted to marginal conditions, suggesting that they could be used to champion sustainable and resilient agriculture and food systems for smallholder farmers residing in these environments. The mainstreaming of underutilized indigenous and traditional crops should not seek to transform them into "new major crops" but should recognize their attributes that make them desirable as well as the role played by their current custodians in conserving them. Importantly, the significant role played by women in the production and conservation of underutilized indigenous and traditional crops offers opportunities for women empowerment through their inclusion in the food system. Promoting gender equality and women's empowerment is inextricably linked to the strengthening of sustainable food systems to fight hunger and malnutrition, and improving the lives and livelihoods of rural populations. The mainstreaming of underutilized indigenous and traditional crops into the food system would support women to diversify their landscapes in a sustainable way, feed their own households, and to provide nutritious food at local markets. Concerted efforts are needed to assess the food value of these future vegetable crops for their exploitation at commercial scale. In addition to food and nutritional security, this is also likely to generate on-farm and off-farm transportation, storage, processing marketing for more employment and income generation leading to economic prosperity.

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19 Potentiality for exploring underutilized vegetable crops for nutritional diversity in telangana

B. Neeraja Prabhakar
Vice-Chancellor, Sri Konda Laxman Telangana State Horticultural University,
Mulugu, Siddipet, Telangana India- 502279
Email: vcskltshu@gmail.com

Introduction

Vegetables are the key component of horticultural crops which plays a vital role in balanced human diet and also in achieving global nutritional security by providing nutrients, vitamins and minerals. This spectacular growth in vegetable production has increased and this was possible due to development of improved varieties/hybrids/ production and protection technologies through systematic research coupled with large scale adoption by the farmers. However, this remarkable production was contributed by only few major vegetables.

However, presently only one fourth is utilized as a major vegetable crops and rest are named as minor, underutilized, rare vegetables, wild edible vegetables or so on which are overlooked. The vegetable crops which are neither grown commercially on large scale nor traded widely may be termed as underutilized vegetable crops. The possible reasons for the low utilization of underutilized vegetables, in spite of their recognized importance are due to lack of planting material, lack of awareness on nutritional and medicinal importance and on production techniques of these crops.

Underutilized or wild vegetables may not be widely known outside of a specific area or region, and there is a perception that they are grown mostly in rural areas. In some places consumption of these plants is not socially acceptable by some community sectors because they are considered to be food for the poor (Jaenicke and Hoeschle, 2006). Underutilized vegetables have local or regional importance, but generally lack national recognition and appreciation. The Underutilized vegetable crops are the plant species that are traditionally used for their food, fiber, fodder, oil or medicinal properties. However, those species have under-exploited potential to ensure food security, nutrition, health, income generation and environmental services.

National scenario of underutilized vegetable crops

Underutilized cucurbits are now getting boost because of their nutritive and medicinal value including antioxidant properties. This includes vegetables like sponge gourd, wild cucumber, spine gourd, pointed gourd, ivy gourd, sweet gourd, *etc*. Most of them are important minor vegetables of Northern, Eastern and Southern India. All India Coordinated Research Network (AICRN) on Potential Crops in 2014 embracing the important priority crops, namely, grain amaranth (Amaranthus Spp.), buckwheat (*Fagopyrum* spp.), Bathua/ Pigweed(*Chenopodium album*.), quinoa (*Chenopodium quinova*), Job's tear (*Coix lacryma* Jobi); adzuki bean (*Vigna angularis*), faba bean (*Vicia faba*), rice bean (*Vigna umbellata*), winged bean (*Psophocarpus tetragonolobus*; perilla (*Perilla frutescens*), paradise tree (*Simarouba glauca*), Drumstick (*Moringa olefera)*; kalingada (*Citrullus lanatus*), kankoda or spine gourd (*Momordica dioica*); *Vigna trilobata*, *Vigna glabrescens*; tumba (*Citrullus colocynthus*), *Vigna marina*, Sweet Gourd (*Momordica cochinchinensis*)**.**These species were prioritized for intensive research and development (Anil Kumar *et al*., 2018).

Scenario of underutilized vegetable crops cultivation in Telangana

Horticulture is the growth engine of Telangana State and is one of the chief source of income to the farmers and the State. It contributes up to 40.5% of Agricultural GDP of Telangana. Telangana ranks 3rd in area and 8th in production of fruits and vegetables in India. In Vegetable cultivation, within the country, Telangana stands 15th position in area, 14th position in production and 7th position in productivity in an area of 1,81,184 acres with the production of 16,44,858 metric tonnes in vegetables in the year 2021-22. State vegetable sector registered 25% share in total horticultural area.

About 20+ vegetables are being consumed in Telangana state. Out of which, top 10 vegetables being consumed are Tomato, Onion, Greenchilli, Bhendi, Potato, Leafy vegetables, Ridge Gourd, Brinjal, Bitter Gourd & Beans. Telangana State is Surplus in production of vegetables like Tomato, Brinjal, Cabbage, Cauliflower, Cucumber, Carrot & Radish. Surplus production is to be converted in to value added products like pickles, sauce, ketchup, dehydrated prooducts *etc*. Similarly, Telangana State is Deficit in production of Vegetables like Bhendi, Greenchilli, Gourds, Beans, Capsicum, Potato, Colacasia, Yam, Leafy vegetables & Onion. As per PJTSAU survey, the per capita consumption of vegetables (including onion) is 250 g per day, as against ICMR recommendation of 325 g per day. Thus, Telangana state population is consuming 75 g less vegetables when compared to recommended diet.

It is believed that underutilized vegetables are nutritionally rich and are adapted to low-input agriculture. Few underutilized vegetables contain more Vitamin C and Vitamin A than widely available commercial species and varieties for example, Bathua and Moringa leaves are very rich in various nutrients like proteins, vitamins like vitamin A, vitamin C and also minerals like iron, potassium, phosphorus and calcium

The climate and soil of Telangana are favorable for the production of different underutilized vegetables. Among them, velvet bean, drumstick, Spine gourd and Bathua are gaining importance in different regions of Telangana. Although the underutilized vegetables production will meet the shortage of per capita consumption availability and at the same time it generates the employment and increase the income of rural people and national economy.

In this context, there is an urgent need to take up programme on production, propagation techniques, genetic resources exploration, management, utilization and improvement of underutilized vegetable crops to ensure food and nutritional security for future.

Research/exploration studies on underutilized vegetable crops

Sri Konda Laxman Telangana State Horticultural University (SKLTSHU) has initiated some studies in few underutilized vegetable crops, which were found to be cultivated in some regions of Telangana due to its significance of having nutritional importance. The outcome of the progress of research/exploration conducted in Underutilized vegetable crops in Telangana conditions are briefed below

Leafy vegetables

- Bathua /Quinoa
- Common Purslane
- Gunugu koora

- Purple Amaranthus
- Water spinach
- Ponnanganni Greens

Leguminaceae

- Jack bean
- Velvet Bean
- Yard Long Bean

Cucurbitaceae

- Spine Gourd
- Oriental pickling melon
- Noogu Dosa

Solanaceae

- Cherry Tomato
- Wild brinjal (Perrennial type)

Leafy vegetables

Deccan Development Society, Telangana has conducted an expo on unexploited leafy vegetables on 12th August 2023 where the tribal women of Arjun nayak thanda and Potpalli villages of Zaheerabad district were identified who found cultivating few new unexploited leafy vegetable crops like *Leucas aspera, Portulaca, Cleome gynanadra, Alternanthera sessilis, Celosia argentina* etc which has to be documented.

Bathua (*Chenopodium album* L.) & Quinoa (*Chenopodium quinoa*)

A study was on evaluation of bathua (*Chenopodium album* L.) entries on growth, yield and quality characters and Performance of Quinoa *(Chenopodium quinoa* Willd.) as a leafy vegetable at different plant geometries in Telangana" during *Rabi*, 2016-17 at Horticulture Garden, College of Agriculture, Rajendranagar, Hyderabad. Among the entries evaluated, RCHBA-7 and Pusa Bathua performed well in terms of growth and yield under Telangana conditions. Significantly highest yield of 36.36, 31.68 and 25.56 g plant^{-1} was recorded in RCHBA-7 at 30,45 and 60 DAS whereas, in terms of quality RCHBA-3-rich in carotenoids (845.67 mg kg^{-1}), RCHBA-2-rich in protein (30.76 per cent) and RCHBA-7-rich in vitamin 'C (87.97 mg 100g^{-1}) (Arpitha,K. 2017).

Common Purslane (*Portulaca oleracea*)

A succulent prostrate or erect annual (*Portulaca oleracea*) belonging to the family Portulacaceae . It is found throughout India not only as a weed, ascending up to an altitude of 1500 m in the Himalayas but also cultivated as vegetable.It is rich in β carotene, folic acid, Vitamin C and essential fatty acids. One hundred grams of fresh purslane leaves (one serving) contain about 300-400 mg of omega-3 fatty acids, 12.2 mg of alpha-tocopherol, 26.6 mg of ascorbic acid, 1.9 mg of beta-carotene, and 14.8 mg of glutathione (Simopoulos et al.,1992). It is mainly propagated by seed.

Gunugu koora *(Celosia argentea L*)

Celosia argentea, commonly known as the plumed cockscomb or silver cock's comb, is a herbaceous plant of tropical origin in the Amaranthaceae family from India and Nepal. It is an erect, usually much-branched, annual plant growing 40 - 200cm tall.This species is one of the most promising leafy vegetable for cultivation in poor or variable growing conditions.

It contains essential nutrients required by humans and animals such as calcium, iron and magnesium. Moisture and ash contents were in the range of 73–95 g/100 g and 0.77–3.54 g/100 g respectively. *Celosia argentea* L. was one of the few that had exceptionally high iron (13.5 mg/100g), calcium (188 mg/100g), sodium (240.6 mg/100 g) ascorbic acid (26 mg/100g) and β-carotene (4.42 mg/100g) content. The edible portion of *Celosia argentea* L. was found to be 55 g/100g fresh weight which was one of the highest, while its protein content was found to be 3.2 g/100g respectively (Gupta *et al*., 2005).

University has collected 54 germplasm and evaluation is under progress.

Purple Amaranthus (*Amaranthus blitum*)

Amaranthus blitum, commonly called purple amaranth or Guernsey pigweed is an annual plant species in the economically important plant of family Amaranthaceae. It is an erect or semi-prostrate annual plant. The single or branched stem can grow to one metre (three point three feet) tall. The green or purplish leaves are up to 10 cm long on stalks of a similar length and are arranged spirally. They are simple, roughly triangular in shape and have entire margins. The inflorescence is a spike with the tiny male and female flowers clustered together. The fruits are small globular capsules containing disc-shaped seeds.

Amaranth contains abundant natural antioxidants, such as flavonoids, pigments, phenolics, carotenoids, and vitamin C. These natural antioxidant phytochemicals defend against several diseases, such as cardiovascular diseases, cancer, cataracts, atherosclerosis, retinopathy, arthritis, emphysema, and neurodegenerative diseases. University is maintaining promising superior germplasm (MLT completed). Seven genotypes were evaluated at three locations in Telangana state as a part of MLT. MHAM-01 is characterized with purple stem, leaves and inflorescence. It registered an average plant height of 40cm and comes to flowering at 27.33 days with a yield of 16.11t/ha.

Water spinach (*Ipomoea aquatica*)

Water convolvulus or kangkong is an herbaceous aquatic or semi-aquatic trailing type whose tender twigs with leaves are used as vegetable or added to sauces and soups (Westphal,1994) . It is used as vegetable in Kerala, Telangana and Tamilnadu. It is mainly propagated by seed and herbaceous cutting. In Indonesia, people believe it has calming effect used as a sleeping tablet. Doctors recommend it to anemia patients due to high Fe content. Exploration of germplasm is under progress. (Acclimatization studies completed).

Ponnanganni Greens (*Alternanthera sessilis*)

The leaves are eaten as potherb and used for cool down the body useful in diarrhoea, fever, anaemia etc. In Karnataka, Telangana, Andhra Pradesh and Tamil Nadu, the leaves, flowers and tender stems are consumed as vegetables. Ponnanganni greens are rich in protein, carbohydrate, fat, fibre, carotene, vitamin C, riboflavin, niacin and various minerals. Leaves and tender shoots are used as vegetables. It is mainly propagated by seed. Exploration of germplasm is under progress at University.

Leguminaceae

Jack bean *(Canavalia ensiformis*)

It is a legume which is used for animal fodder and human nutrition, especially in Brazil. *Canavalia gladiata & C. ensiformis* (Sword bean and Jack bean) Young pods and seeds of Sword bean are used as a green vegetable Sword bean (SB) (*Canavalia gladiata* Jacq.). It is a tropical under-utilized food legume, wildly distributed in the Eastern and Western Ghats of South India (Jana, 2007). Jack bean is a good source of protein, 23%to 34%, and carbohydrate 55%. The mature jack bean seeds are consume by tribal groups, after cooking. Both are propagated by seeds. Collection and evaluation of germplasm was done (MLT completed)

Velvet Bean (*Mucuna pruriens* (L.) DC. var. pruriens)

Velvet bean (Mucuna pruriens (L.) DC. var. pruriens) belongs to family Fabaceae, originally from southern China and eastern India where it was economically cultivated as important green vegetable crop due to its pharmaceutical and nutritional properties.

Studies were conducted at SKLTSHU on the baseline study in morphometric traits and genetic barcoding of velvet bean during the period from July, 2019 to January, 2020 at COH, Mojerla. The experimental material consisted of one wild species of velvet bean collected from Nizamabad district of Northern Telangana region.

The observations recorded for growth, phenological, morphometric, yield, biochemical and barcoding characters revealed that matK loci was considered standard plant DNA barcoding marker and was found more suitable to resolve closely related *Mucuna* species and based on phylogenetic trees and genetic distance estimation from matK data it is clearly confirmed that collected Mucuna species was *Mucuna pruriens* (L.) DC. var. pruriens and the *Mucuna poggei* was the immediate perennial ancestor to the annual varieties of *Mucuna pruriens*. Hence, DNA barcode was best molecular tool to resolve taxonomic boundaries of closely related *Mucuna* species, which share close phenotypic features (Vinayak Rudra, 2021).

Cucurbitaceae

Spine Gourd (*Momordica dioica* Roxb. ex Willd.)

Spine gourd is mostly grown as wild form but there is gradual expansion of cultivated area due to its enormous potential as vegetable by supplying plenty of nutrients as well as medicinal compounds for maintaining healthy diet. The vegetable is also low in calories as it contains roughly 17 calories per 100 gm. It also reduces blood sugar levels in diabetic patients since it is rich in plant insulin. Carotenoids, like Lutein, present in this vegetable help in prevention of various eye diseases, cardiovascular diseases and even cancers**.** Being a source of vitamin C, a natural antioxidant, it removes toxic free radicals from the body reducing the chance of cancer.

Spine gourd crop needs lot of improvement in terms of new traits identification and exploitation. There is need to develop new high yielding varieties in spine gourd crop due to its high market value as well as nutritional potential.

A total of 122 germplasm accessions (98 in 2022 & 24 in 2023) from different agro climatic regions of Telangana *viz*., Northern Telangana, Central Telangana and Southern Telangana were collected. During the year 2022, among 98 germplasm collection 40 were sprouted, among 40 only 26 were flowered, among them 20 female and 6 male lines were identified, among 20 female lines only 12 lines fruited. During the year 2023, 24 spine gourd accessions were collected (in addition to previous year collection).

Hence a total of 64 germplasm lines were being maintained (40 sprouted tubers from past season & 24 new collections) 48 were sprouted, among 48 only 33 were flowered, among them 22 female and 11 male lines were identified, among 22 female lines only 14 lines fruited. The experiment, collection and characterization of spine gourd accessions is at initial stage, to assess the stabilized performance of those lines, it will take another 2 or 3 seasons. (Horticultural Research Station, Aswaraopet).

Oriental Pickling melons (*Cucumis melo* var. conomon)

Oriental Pickling melons, botanically classified as Cucumis melo var. conomon, are elongated fruits that belong to the Cucurbitaceae family with 20 to 30 centimeters in length and 8 to 10 centimeters in diameter, and have a cylindrical, elongated shape with rounded ends. The skin is shiny, smooth, thin, and pale green, with some varieties bearing faint green-yellow stripes. Underneath the surface, the flesh is pale green to white and is crisp, aqueous, and firm, encasing many small seeds that are flat, pale yellow, and bitter. Oriental Pickling melons are crunchy with a mild, sweet, and subtly sour flavor. When cooked, the melon retains its firm and crisp consistency and has a neutral taste, often absorbing other flavors.

Oriental Pickling melons are a good source of potassium, which can help regulate fluid levels in the body and contain vitamins A, C, and B. The fruits also provide some iron, magnesium, and phosphorus. Oriental Pickling melons are best suited for pickled and cooked applications such as stir-frying, simmering, and sautéing. The fruits are primarily selected when young and firm and are used similarly to vegetables in stir-fries, curries. Promising selections were maintained at the University. MHOPM-01 is a selection from local variety of Oriental pickling melon collected from Nakerekal mandal, Nalgonda District.

Noogu Dosa (*Mukia maderaspatana)*

Mukia madraspatana (L.) Roem, belonging to the family Cucurbitaceae it is an annual monoecious, prostrate climber with tendrils and is densely covered with hairs and found in deciduous forests and also in the plains of Maharashtra, Kerala, Karnataka,Tamil Nadu and Adilabad region of Telangana. It has been used as a traditional medicine and also as wild edible greens. Leaves, stem, fruits and roots were reported to be used as a functional vegetable and to treat various diseases among various communities. It is an important medicinal plant for its numerous medicinal values in the field of Ayurveda.

M. maderaspatana leaves are rich in protein, fiber, iron, calcium and vitamin C. Plant could be used as a diuretic, anti-anaemic, anti-oxidant etc., to the patients is due to the presence of a significant number of minerals present in them, like calcium (5.13%), magnesium (3.19%), flavonoids (2.56 mg/kg) and manganese (14.20 ppm)

Solanaceous

Cherry Tomato (*Solanum lycopersicum* var. cerasiforme)

Genetic divergence for quantitative and qualitative traits and Pest population dynamics in relation to weather parameters in Cherry tomato (*Solanum lycopersicum* L.)" was undertaken to estimate the genetic divergence and to carry out yield component analysis through correlation, path analysis and pest population dynamics in relation to weather parameters. Twenty three genotypes were sown in a Randomized Block Design to evaluate genetic divergence.

The genotypes with superior quality traits *viz.*, EC-251751 for anti-oxidant content (428.67 %), EC-631349 for ascorbic acid (49.64 mg/100gm), EC-514013 for lycopene content (3.85 mg/100g), Swarnaratan for titrable acidity (0.83%), RHTC-2 for betacarotene (2.39 mg/100gm) and TSS (9.08 ^{0}Brix) and EC-801748 for chlorophyll content (1.64 %) can be included in pedigree selection for further improvement (Sree Keerthana**,** 2019).

Other Underutilized crops grown in Southern states of India

Kasara Kaya (*Momordica cymbalaria*)

Cucurbitaceae

Momordica cymbalaria is a vine of *Momordica* genus found in the states of Karnataka, Madhya Pradesh, Maharashtra, Andhra Pradesh and Tamil Nadu. Medicinal herb also been named Luffa *tuberose* (Roxb) or *Momordica tuberose* (Roxb). *Momordica cymbalaria* is commonly known as Karchikai (Kannada) or Athalakkai (Tamil) or Kasarakayee (Andhra Pradesh) and Kakrol (India). *Momordica cymbalaria* has been used in various Asian traditional medicine systems for a long time.

Momordica plant parts are characterized by wide diversity of bioactive compounds such as phenolic acids, flavonoids, carotenoids, cucurbitane triterpenoid, and phytosterol. In particular, some of the actual trends of the scientific research are strongly focused on obtaining *in vitro* evidence for the biological efficacy of individual constituents such as triterpenoid, carotenoids and phenolics from different parts of *Momordica* species triterpenoid are the main constituents of Cucurbitaceae family.

The potential health benefits of phytochemical found in *Momordica* species have received ample attention in the recent literature, focusing especially on compounds with high diabetes mellitus, cardio protective, ulcer, cancer, and diabetic neuropathy. The herb also has been reported to possess hypoglycaemic, wound healing, infertility, hypolipidemic, hepato-protective, nephro-protective and antioxidant properties. *Momordica cymbalaria* is under threat of extinction.

Hemajeevanthi/ Green wax flower (*Dregea volubilis*)

Apocynaceae

It is distributed in subtropical to tropical regions of southern Asia, and in India it is grown in Western Ghats of Tamil Nadu and Kerala, particularly in Nilgiris and Wyanad Districts. Tender Fruits and flowers are Used as vegetable among tribes. Leaves and stems are antidiabetic. In Adilabad district, it is consumed by tribal people as a vegetable.

constraints for the development of underutilized vegetable crops

- Lack of awareness among the farming community about the nutritional and medicinal value of Underutilized vegetable crops
- Lack of adequate research
- Lack of desirable seeds and planting material
- Limited application of advance on farm agro techniques
- Lack of application of innovative and novel technologies like biotechnological for enhancing productivity.
- Lack of knowledge on utility and post-harvest management and value addition.
- Lack of inadequate marketing support.
- Poor recognition of these crops in horticulture promotion programmes.

Strategies for the development of underutilized vegetable crops

- Domestication of potential wild species through homestead cultivation should be encouraged for avoiding over-exploitation from natural sources.
- Supports are required in terms of multiplication of planting materials and their distribution besides providing market access through marketing network for perishables.
- Underutilized vegetable crops are nutritionally rich and adapted to low input Horticulture. More R & D efforts in these will add substantially to food security and nutrition vis-à-vis human welfare.
- Limited number of species needs to be targeted for detailed research and development in underutilized vegetable crops by national programmes focusing on their conservation
- and use.
- Research needs to be geared up both on species/crops important for subsistence farming and those exhibiting potential to become commodity crops.
- Increased focus to document indigenous knowledge is required such as through ethnobotanical studies.
- Strategies need to be worked out particularly at national and regional levels to develop and make available promising selections/varieties, overcoming constraints of production of good seed material, planting material, in-vitro/tissue cultured material etc. This would boost production, meeting local needs, promoting domestic markets and thereby, enhance income generation of small farming communities.
- Rapid expansion of infrastructure facilities with priority on market development, transport and communication needs to be done.
- The yield and quality of these crops are poor which hamper the productivity. Hence, some criteria need to be developed for commercial exploitation of underutilised vegetable crops. The criteria maybe high productivity, market demand, freedom from serious insect-pest and diseases, easier postharvest management, high nutritive value and availability of production.

Major issues to be address for commercialization of Underutilized vegetable crops:

Underutilized Vegetable crops are mainly grown /managed under traditional farming Systems by diverse ethnic communities. At the very onset, there is a necessity to make the farming community aware about the nutritional importance of unexploited vegetable crops, i.e., fruits, vegetables and medicinal plants

To address this issue, there is an urgent need for a program focused on exploring, managing, utilizing, and improving genetic resources of underutilized vegetable crops to ensure food and nutritional security.

Various improvement activities such as pre-breeding, molecular markers, quantitative trait locus (QTLs), genomics, and genetic engineering are actively applied so far in leguminous vegetable improvement. Underutilized vegetable crops being very hardy having additional benefits of being used as nutraceuticals due to rich nutritional and medicinal value, identification, improvement and exploitation should be facilitated. The inheritance of bioactive compounds present in vegetable crops are complex in nature and controlled by genetic and environmental factors. Traditional breeding and molecular biology are highly useful for developing nutraceutical vegetable varieties for fresh market.

India's climate and soil are favourable for producing various underutilized vegetables, and the government has taken steps to promote their importance. Although, we have attained self-sufficiency in food grains through conventional breeding approach, but now there is a need for second green revolution where not only production/yield alone but quality food is the major breeding objective, this cannot be realized alone with conventional as well as biotechnological approach alone, some have to find a mid-way where we can integrate these two novel approaches for vegetable crop improvement.

Conclusion

Underutilized vegetable crops are considered as valuable component to attain nutritional security because of their high content of vitamins, micronutrients and proteins. Most of underutilized vegetable crops are tolerant to harsh agro-climatic conditions and have got vast potential in cultivation in Telangana Conditions. Hence, focusing attention on neglected and underutilized vegetables is an effective way to help maintain a diverse and healthy diet and to combat micronutrient deficiencies, the so-called ‘hidden hunger’, and other dietary deficiencies particularly among the rural poor.

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20. Underutilized alliums: its importance and utilization

Vijay Mahajan*, Y. Khade, R. B. Kale, A. J. Gupta, R. Dutta, R. S. Puthem, D.Shirsat, K. Gorrepati,
*Dirctor, ICAR-Directorate of Onion and Garlic Research, Rajgurunagar, Pune, Maharashtra, India.
*Email: director.dogr@icar.gov.in; vijay.mahajan@icar.gov.in

Asia is one of the origin centers of the *Allium* genus, especially *Allium sativum* L. (Garlic), *Allium cepa* L. (Onion), and *Allium tuberosum* (Chinese chive) (Zeng et al., 2017). *Alliums* are a globally well-known genus of plants, best known for their edible taxa. In Asia, Africa, and Europe these have been used for the last 5000 years (Ozturk et al., 2012). *Allium* species are one of the remedial herbs with their bioactive compounds act as a medicine to cure diseases, their roots, stem, leaves, and juices have nutraceutical importance in human health (Khan et al., 2017).It is well recognized that plants are the richest source of antioxidants. Antioxidants comprising compounds are tocopherols, glycosides, carotenoids, alkaloids, flavonoids, phenolic compounds, and other acids (Khan et al., 2017), however, the alliums are a good source of important antioxidants (Sidhu et al., 2019). Some epideminological studies reported that an increase consumption of Allium species reduces the risk of the cancers like prostate and gastric cancer, and it is because of the apolarsulphur and polar saponins compounds in the allium species (Lanzotti et al., 2014).

In the mountainous region of Middle and South-West Asia near about 200 different *Allium* species were reported (Keusgen et al., 2006) *Allium* genus is widely cultivated all over the world, particularly garlic, onion, shallot (*Allium ascalonicum*), leek (*Allium ampeloprasum*), and chive (*Allium schoenoprasum*) are common, however, there are many underutilized species of onion which are needed to be focused. After the accomplishment of interspecific crosses between *Allium cepa* L. and *A. roylei* Stearn an Indian wild allium speciesfor the transfer of resistance genes to powdery mildew and leaf blight, the search for potential underutilized wild allium species gene centers got exaggerated (Pandey et al., 2008).

From last 70 years Central Asian wild relatives of onion such as A. altaicum Pall., A. fistulosum L., A. galanthum, A. roylei were used in interspecific crossing with cultivated onion species. From these crosses many useful traits were incorporated in onion such as male sterility, bulbingresponces, and resistance to numerous diseases, including downy mildew, leaf blight, anthracnose and pink root disease (Simon, 2005).

Epidemiological studies have found that an increase of consumptions of Allium spp. reduce the risk of prostate and gastric cancers and this has been mainly related to two main classes of compounds: the apolarsulphur compounds and the polar saponins (Lanzotti *et al.,* 2014).The compound saponins occurs in the range of plant species are the major family of secondry metabolites, also known as phytoanticipins. Because of there antimicrobial activity saponins they seems to be involved in the plant disease resistance mechanisams (Barile *et al.*, 2006). The steroid laxogenin-1 is an active principal compound in the allium species having the anti-tumour activity, that is why it is widly used in the cancer treatment.

Utilization as food through *Allium* species

Field surveys and exploratory studies have confirmed to utilization of wild *Allium* species in the Garhwal and Kumaon regions of Himalaya for edible purposes (Negi and Gaur 1991). Generally, all plant parts have edible value and consumed raw or as cooked vegetables. Young leaves of many wild species are preferred over the mature ones in the form of vegetable, in soups or for raw consumption given in following table. Freshly harvested leaves or bulbs are occasionally sold in village markets. The leaves and tuberous/fibrous roots are rich in carbohydrates, vitamins and minerals. Bulb/pseudostem of *A. clarkei*, *A. griffithianum*, *A. pratii* and *A. victorialis* are consumed raw, cooked or pickled. Cloves or bulbs of *A. ampeloprasum* and *A. chinense* are pickled. In Pithoragarh region of Uttarakhand Himalaya, India, young leaves of *A. stracheyi* are used as potherb or cooked mixed with potato. Fleshy fibrous roots of *A. hookeri* are consumed as vegetable in the north-eastern hill region or in soups and pickles in same way as *A. stracheyi* in the north-western Himalaya. In Bhutan, *A. fasciculatum* is generally used as vegetable (leaves and scape), salad and in soups (young inflorescence).

Several lesser-known wild species of *Allium* as given in following table were reported from the north-western Himalayan region of India (Gohil 1992; Negi and Pant 1992; Sharma *et al*. 1996).

Utilization of wild *Allium* species in Indian gene centre, status of occurrence

Species	Distribution; status of occurrence	Wild (W); occasionally cultivated (OC)
Allium ampeloprasum L. var. *ampeloprasum* L.	Western Himalaya; C	W; OC (vegetable, pickle, condiment)
*Allium atropurpureum*Waldst. et Kit.	Western Himalaya; C	W
Allium atrosanguineum Schrenk	Western Himalaya (Kashmir); C	W
*Allium auriculatum*Kunth*	Western Himalaya (Kumaon); LC	W; OC (condiment)
Allium caesium Schrenk	Lahaul, Himachal Pradesh; LC	W
*Allium carolinianum*DC.* (*A. thomsonii* Baker)	Western Himalaya; C	W; OC (condiment)
Allium chinense G. Don*	North-eastern Himalayan region (Khasi hills); C	W; OC (vegetable, pickle, condiment) (high seed sterility)
*Allium clarkei*Hk. f.*	Uttarakhand (Kashmir) Himalaya; rare species	W
Allium consanguineum Kunth*	Western (Kashmir) and central Himalaya; C	W; OC (minor cultivated species grown for vegetables and condiment in eastern Himalaya)
Allium fasciculatum Rendle	Indian Himalaya, Tibet, Nepal; LC	W
Allium fedschenkoanum Regel	Western Himalaya (Kashmir); rare species	W
*Allium griffithianum*Boiss.*	Western Himalaya; C	W; OC (condiment)
*Allium hookeri*Thw.*	North-eastern Himalaya (Khasi hills); sporadic in upper gengetic plains; C	W
Allium humile Kunth*	Western Himalaya; C; endemic species	W; OC (condiment)
Allium longistylum Baker	Western Himalaya; LC	W
Allium loratum Baker	Western Himalaya, Tibet; rare species	W

Allium macranthum Baker	Bhutan and adjoining region; LC	W
Allium odorum L.	Western Nepal, West Tibet; LC	W
Allium oreoprasum Schrenk	Ladak Himalaya; LC	W
Allium platyspathum Schrenk	Western Tibet; LC	W
Allium prattii Wight	West Nepal and adjoining Himalaya; rare species/sporadic in distribution	W
Allium przewalskianum Regel*	Western Himalaya; C	W; OC (vegetable, condiment)
Allium roylei Stearn* (*A. lilacinum* Royle)	Western Himalaya; rare species	W; OC (condiment)
Allium schoenoprasum L.	Western Himalaya (Kashmir, Drass); C	W; OC (vegetable, salad, condiment)
Allium schrenkii Regel	Himalayan mountains to Siberia; LC	W
Allium semenovii Regel	Western Himalaya, Kashmir to Uttarakhand, Himachal Pradesh, Zanskar; C	W
Allium sikkimense Baker	Ladak, Sikkim Himalaya, Tibet; C	W
Allium stracheyi Baker*	Western Himalaya (Kashmir-Kumaon); narrow endemic species, rare/threatened species	W; OC (vegetable, condiment; recorded in the Red Data Book of Indian Plants)
*Allium tuberosum*Rottl. ex Spreng.	Widely distributed in Himalaya; C	W; OC (vegetable, condiment)
Allium victorialis L.	Temperate Himalaya; C	W
Allium wallichii Kunth	Eastern part of Western Himalaya; C; endemic species	W; OC (vegetable, condiment)

* Commercially important species; C, common; LC, less common; SGB, seed genebank; FGB, field genebank; IV, in vitro repository

There is lot of scope to evaluate systematically for yield and nutritional value and other desirable traits which can be directly used for commercial cultivation and also can be used in breeding programme for widening the genetic base of the cultivated onion. These above-mentioned Allium species are restricted to kitchen garden in Northern Hill region with the tribal population, have great potential for its medicinal use and direct consumption (Mahajan et al. 2016a). These can be substitute to common onion and diversified for year-round availability and will help in regulating the market price. Some of the underutilized and wild *Allium* species viz. *A. ampeloprasum, A. tuberosum, A. chinense, A. ascalonicum, A. hookeri* and *A. cepa. var. aggregatum* collected from different parts of Himalayan ranges are being multiplied and evaluated for utilization as foliage consumption at ICAR-DOGR Rajgurunagar, Pune. Among nile lines evaluated foliage yield of 22.89 t/ha was recorded in *A. tuberosum* All-1587 followed by 20.21 t/ha in *A. tuberosum* CGN-16373 during rainy season at 30 days interval. During summer maximum yield was 19.25 t/ha in *A. tuberosum* All-1587 followed by 19.12 t/ha in *A. tuberosum* line CGN-20779 and 18.75 t/ha in *A. tuberosum* line CGN-16373 at 30 days interval. During winter, maximum yield of 18.16 t/ha was in *A. tuberosum* line CGN-16373 followed by 17.13 t/ha in *A. tuberosum* line CGN-16418 and 15.77 t/ha in *A. tuberosum* line All-1587 at 30 days interval. The added advantage of these species is that only once it has to be planted, gives number of tillers and can take foliate cuttings at every 15 to 30 days interval under plains of India (Mahajan *et al.*, 2016b).

Utilization of Allium species as Condiment/flavor:

Although all *Allium* species have different aroma (strongly pungent to mildly aromatic) and flavour (onion or garlic like odour) but selective use of the species/plant part is based on utilization and preference by local communities. Young leaves and bulbs of *A. humile*, *A. carolinianum* and *A. loratum* have garlic flavour and are used to garnish different food preparations. Similarly, *A. stracheyi*, *A. roylei* and *A. tuberosum* have mild onion flavour and widely used as flavouring agent and for garnishing purpose. For routine domestic use fresh leaves and bulbs are commonly used whereas for off-season requirement, leaves are generally dried and processed for long-term. In Kumaon region of Uttarakhand (Western Himalaya), dried leaves of *A. stracheyi* (jumbo) are primarily used for garnishing or seasoning vegetable/ curries (Negi and Gaur 1991). In areas of abundant availability of these species, Bhotia tribals collect and process (dry) and bring marketable produce for sale at the lower elevations (Chaurasia and Singh 1996–2001; Sanyal *et al.*, 2000). Bulbs of *A. consanguineum* and leaves and flowers of *A. chinense* are commonly used as flavours in various food preparations such as soups, curries, etc.

Utilization of Alliun species as Potential ornamentals:

Use of *Allium* species for ornamental purposes is not very common in India. *Allium* species have gained much popularity as ornamental in rock gardens, herbaceous beds, perennial borders, pot plant, as decorative items and in dry arrangements (Davies 1992; Kamenetsky and Fritsch 2002). Ornamental value of *Allium* is due to wide range of attractive coloured flowers and persistence of floral or long vegetative cycle. Flower colour in wild *Allium* ranges from white, rose, lilac, purple, violet, blue and yellow. Some wild species of *Allium* have been identified for their potential ornamental values are as follows

Wild ornamental *Allium* species in India

Species	Ornamental use
Allium ampeloprasum	Herbaceous bed, cut flower
Allium atropurpureum	Herbaceous bed, border, cut flower
Allium caesium	Borders of gardens, rock garden
Allium macranthum	Border and cool spots
Allium oreoprasum	Rock garden, herbaceous bed
Allium przewalskianum	Rock gardens, flower beds
Allium roylei	Border, flower bed
Allium schoenoprasum	Pot plant, rock garden, herbaceous bed, border, cut flower
Allium semenovii	Herbaceous bed, damp soil, cut flowers
Allium sikkimense	Border, herb bed, cut flowers
Allium tuberosum	Herbaceous bed, border, pot plant
Allium victorialis	Herbaceous bed, damp soil

Commercial wild/ underutilized Allium species

Many wild species of *Allium* (11 species) have their commercial value for food, flavour and medicine from natural population or grown on the small scale in homegardens. In recent years processed products in the form of dried bulbs, leaves, buds and flowers of some wild species of *Allium* (*A. auriculatum*, *A. carolinianum*, *A. griffithianum*, *A. humile*, *A. roylei* and *A. wallichii*) are in great demand and thus these species are occasionally grown in the homegardens. Sun dried/furnaces dried leaf powder has good shelf-life for off-season consumption (Negi 2006a, b) and for sale in the market. Market products are also available in refined forms as processed bricks/cakes or balls, sold in border areas of Himachal Pradesh, Uttarakhand and adjoining regions. Crushed foliage of *A. przewalskianum* prepared as balls and put in string were reportedly sold in market in cold desert region of India (Baker 1874). The dried leaves of different species are sold at the rate of Rs. 150–250 per kg (approximately 3.5–4.0 US Dollars) (Negi 2006a). Ornamental value of wild species in India is yet to be explored for Indian market. Pandey *et al*. (2008), suggested that the genetic resources of *Allium* species representing wild useful/commercial taxa offer great scope for utilization in crop improvement programmes. The genepool needs to be assembled from areas of occurrence and evaluated for biotic and abiotic traits so as to realize their value in National and International programmes. Research and development efforts need to be focus towards management of wild *Allium* species. Evaluation of the decorative characters of wild/potential species is desirable for their commercial ornamental use. Suitable strategies for conservation, assessment of domestication potential for commercialization and value addition would widen the scope of utilization of wild *Allium* species in India. In India onion Allium cepa & garlic Allium sativum is widely cultivated but there are other Allium species like Japanese bunching onion (*A. fistulosum*L.), leek (*A. ampeloprasum porrum* L.), A. tuberousum, A. macaranthum, A. hookeri are restricted to Himalayan hill in small kitchen garden mostly used as condiments, and also have medicinal value have great scope to diversify its cultivation in different parts of the country.

Utilization of Allium species for Medicinal use

Medicinal use varied from domestic/local usage to commercialization. Some wild *Allium* as *A. humile*, *A. carolinianum* and *A. przewalskianum* are collected on large scale and traded to drug and trade industries in Himachal Pradesh (Chauhan 1999). Dried scales of *A. wallichii* are locally used for pectoral complaints; cloves of *A. ampeloprasum* are utilized after dipping in mustard oil for paralytic limb, ear pain and arthritis; bulbs of *A. wallichii* are used for anti-flatulence and digestive disorders and leaves of *A. griffithianum* and *A. tuberosum* as carminative agents. Information was collected about current medical applications of sixteen wild species, nine of which belong to different sections of *Allium* subgenus *Melanocrommyum*from Tajikistan and Uzbekistan region by Keusgen *et al., 2006*. These plants are used against headache, cold, and stomach problems, and are mostly applied fresh or after boiling. Three wild *Allium* species growing in Tajikistan and Uzbekistan (*A. oschaninii*, *A. pskemense*, *A. praemixtum*) are closely related to common onion are traditionally collected and used as spice like common onion, but only *A. oschaninii*and *A. pskemense*are also used for medicinal purpose. Special dishes, which are much esteemed for strong tonic properties, are prepared from the leaves of three species of the subgenus *Melanocrommyum: A. motor*, *A. rosenbachianum*, and *A. rosenorum*.

Allium porrum

Leeks contain excellent amounts of vitamin C and folate, also good amounts of some of the B vitamins, vitamin E, copper, potassium and iron (Hedges and Lister, 2007).*A. porrum*is biennial, hardy and vigorous plant, it is native to the middle east and eastern Mediterranean (Ozturk *et al.,* 2012).

Allium chinense

Allium chinense have narrow, linear basal leaves, clustered bulbs and red-purple flowers. *A. chinense* is commonly used against the cough, cold and vomiting, also used for healing the wounds, while the ash of the bulbs mixed with oil used in the treatment of skin diseases (Devi et al., 2014). In indigenous system of medicines *A. chinense* is used as anti-tumer agent, acid amide an active constituent contained in the ethylacetate soluble fraction give notable inhibitory effect on platelet aggregation in humans (Shah, 2014).

Allium hookeri

Laves structure of *A.hookeri* is slender with prominent midrib, basal linear membranous. It bears white flowers and white fibrous roots (Devi *et al.,* 2014). Edible parts of *A.hookeri* are different from onion, the thick, flat, green leaves with prominent midrib and the white fibrous roots represents its edible parts (Ayam, 2011). The leaf extract and its paste is applied on forehead in reducing excessive body temperature and blood pressure (Devi, 1990). The juice of leaves with salt is used to cure ulcer and stomach ailments in traditional medicines (Ayam, 2011).

Allium macranthum

These plants have many linear leaves, narrow membranous bulb and large dark purple flowers (Devi *et al.,* 2014). In treatment of cold and skin rashes *Allium macranthum* is widely used (Sharif-Rad *et al.,* 2016). *A. macranthum*also called as"small bird's garlic" is used in the folk medicin by the Tibetan people (Boesi, 2014). It have anti-inflammatory properties and useful for gastritis, tuberculosis and rlung (air) disorders (Yeshi *et al.,* 2019).

Allium prattii:

*Allium prattii*have board linear leaves with prominent midrib and bears pink to red flowers.The leaves, bulbs and roots are used to treat a range of common health problems including coughs and colds, skin rashes (Devi *et al.,* 2014).

Allium rubellum:

Flattish leaves, small rosy flowers and small bulbs are the characteristic features of the *Allium rubellum* (Devi *et al.,* 2014).Sharifi-Rad *et al.* (2016) reported that *A. rubellum*, are use in the treatment of the cold and skin rashes.Motamed and Naghibi (2010) reported the high antioxidant content in *A. rubellum*.

Allium tuberosum:

Allium tuberosum leaves are narrow, linear, flat tall compressed. Flowers are of white or pink colour. Cylindric elongated bulbs with white freshy roots (Devi *et al.,* 2014). It have mild onion flavour and commonly used as flavouring agent and for garnishing purpose in food dishes (Pandey *et al.,* 2008). It is used in the treatment of several diseases like asthma, abdominal pains, diabetes, diarrhea in traditional medicines (Jannat *et al.,* 2019). Many of the allium species having healing properties but not get the attention, *Allium tuberosum* is one of them. Grown in asia peoples of China, the Philippines, Korea, and Thailand use it as vegetable in their daily diet (Adamczewska-Sowinska andTurczuk, 2016.). Wang et al. (2015) reported that the extract of *A. tuberosum* leaves extracted with water gave the watersoluble compounds like amino-styreneacrylic acid and their glycosides which have the anticoagulant activity. *A. tuberosum* contains sulfur compounds derived from allicin which activates TRPA1 and TRPV1, temperature-activated ion channel responsible for pain sensation in mouth (Premkumar, 2014). Inspite of healing properties Park *et al.* (2015) reported that the n-butanol extract of *A. tuberosum* leaves shown hair growth promoting activity in mice. Park *et al.* (2007) isolated S-methyl methanethiosulfonate and S-methyl 2-propene-1-thiosulfinate, a thiosulfinate compounds from crude thiosulfinates of *A. tuberosum*, which were investigated against the cancer cells, which were found to induce cell death in MCF-7 cells of human breast cancer.

Allium wallichii:

The bulbs and aerial parts of the *Alliumwallichii* are used for medicinal purposes (Wawrosch *et al.*, 2001). *A.wallichii* leaves are long linear flat, purple flowers and hardly developed bulbs (Devi *et al.*, 2014).The bulbs of *A. wallichii* are used in the treatment of thecholera and dysentery by boiling, then frying in ghee and eaten (Shah, 2014).However the raw bulb is chewed to treat the cough and cold, it also shows antimicrobial activity (Tiwari *et al.*, 2014). Kunth Garlic (*A. wallichii*) have an antimicrobial, antiprotozoal, antimutagenic, antiplatelet and antihyperlipidermic properties (Yee, 2019).

Allium fistulosum:

A. fistulosum is famous in many parts of the world, it have several local names in different languages, Welsh onion, bunching onion, Japanese bunching onion and stone leek in English, cong in Chinese,Ciboulette and ciboulein French, Winterzwiebel in German,negi and nebuka in Japanese, vilayatilahsunin Hindi, and khoratin Marathi, Mizo-purun in Mizo language of India (Singh and Ramakrishna, 2017). *A. fistulosum* leaves contains high levels of quercetin and flavonoid compounds. It has potential benefit to human health that is as protective effects in reducing the risk of cardiovascular disease, anti-inflammatory responses, acts as anti-cancer due to its antiprostanoid and decreases the rate of DNA degradation (Feng. and Liu, 2011). Sung *et al.* (2011) reported that the leaf extract of *A. fistulosum* down-regulate the expression of genes involved in lipogenesis in the adipose tissue of obese mice fed a high-fat diet results in reduction in adipocyte size, fat accumulation and serum lipid concentrations.

Allium ampeloprasum

Thin layer chromatography of *A. roseum* and *A. ampeloprasum* organic and aqueous extracts reveleas the presence of the saponins, tannins, flavonoids, coumarins, steroids, cardiac glycosides, free quinone and iridoids bioactive compounds (Najjaa *et al.*, 2011).

Allium ampeloprasumis hardy, vigorous, biennial plant, native to the eastern Mediterranean and the Middle East having mild, sweet, onion like flavour. The lower part of the plant is usually blanched by planting in trenches, and eaten along with the upper long green leaves also called chives. It is rich source of vitamic C, folate, iron and diatery fibers (Ashalata *et al.*, 2013; Ozturk *et al.*, 2012). A. ampeloprasum mostly called as great-healed garlic, elephant garlic or pearl onion, is a medicinal plant wll known for its pharmaveutical potential, because of its antihelmintic, diuretic, antimicrobial, anti-inflammatory, antihypertensive and antioxidant properties, or digestive properties (Dey and Khaled, 2015; Adawia *et al.*, 2016).

Allium roseum

The fresh young leaves and bulbs of *A. roseum* were consumed in salads and used as spice for preparation of traditional recipies (Najjaa *et al.*, 2017). A. roseum, also known as rosy garlic is characterized by high ash content (7.2% of dry weight) including macro and micro elements. Its fresh leaves are rich in polyphenols, flavonoids, anthocyanidins, vitamin C, carotenoids and allicin (Najjaa *et al.*, 2012). A. roseum is widely used as vegetable and spice, as well as in folk medicine as an herbal remedy for the treatment of headaches, rheumatism, and respiratory problems (Le Floc'h, 1983). Snoussi *et al.* (2016) reported that the polyphenolic extracts of *A. roseum*possessed high activity against gram positive s well as gram negative bacteria, and *Candida* spp. strains, generally recognized as the most important pathogens affecting food dishes, therefore it can also be in food dishes to prevent contamination by the most common bacteria.

Allium schoenoprasum

Epidemiological studies suggest that certain natural origin foods have ability to prevent the different diseases. Allium species are traditionally used as medicine and in spices in daily diet which possess well-defined activites of antioxidant enzymes and other natural plant antioxidants. The bulb, leaf and stalk of *Allium schoenoprasum* are reported to have high antioxidant enzyme content whch shows radical scavenging activities (Stajner *et al.*, 2004). The essential oils isolated from A. schoenoprasum have high activity of anti-tubercular substance, this activity is slightly lower than the antibiotic streptomycin (Shah, 2014).

Medicinaly important compounds of the underutilized Allium species

Medicinal Compound	Allium Species	Used in disease treatment and activity	References
Allicin	*A. tuberosum; A. sativum; A.roseum*	Gastric cancer	Ha and Yuan (2004)
		Colorectal adenocarcinoma	Bat-Chen *et al.* (2010)
		Lymphoma	Wang *et al.* (2012a)
		Leukemia	Arditti *et al.* (2005)
Four spirostanol saponins	*A. schoenoprasum; A. vavilovii; A.ampeloprasum*	Fibrosarcoma	Zolfaghari *et al.* (2013)
		Colorectal carcinoma	Timite *et al.* (2013)
		Reticulum cell sarcoma	Zolfaghari *et al.* (2013)
		Antifungal activity against *Fusarium culmorum*	Carotenuto *et al.* (1999)
One spirostanol saponin	*A. tuberosum; A. ampeloprasum;*	Leukemia	Sang *et al.*. (2002)
Two spirostanol saponins	*A.chinense*	Cervical carcinoma	Baba *et al.* (2000)
2-propenyl propyl disulfide	*A.macranthum*	Anti-inflammatory and useful for gastritis, tuberculosis and rlung (air) disorders	Yeshi *et al.* (2019)
diallyl trisulfide (DATA)	*A. Roseum*	Antiviral; Enhancing Natural killer-cell (NK-cell) activity that destroys virus-infected cells	Zhen *et al.* (2006), Zouari *et al.* (2012)

diallyl disulfide (DADS)	*A. Roseum*	Antifungal; Irreversible ultrastructural changes in the fungal cells, loss of structural integrity and affected the germination ability	Kuda *et al.* (2004), Zouari *et al.* (2012)
Gamma-glutamylcysteine	*A. schoenoprasum; A.ampeloprasum*	Antihypertensive; Inhibiting the angiotensin-converting enzyme	Bayan *et al.* (2014)

Conservation and popularization of wild and underutilized *Alliums* at ICAR-DOGR (Annual Report ICAR-DOGR 2021)

A total of 89 wild and underutilized *Allium* lines of 17 different species are being maintained and evaluated for desirable traits and being utilized for breeding programs at ICAR-DOGR. The bank contains collections from in-country sources from the states like-Leh and Ladakh, Arunachal Pradesh, Assam, Sikkim, Manipur, Himachal Pradesh, Tamil Nadu etc, and also out of country sources such as, United States, Central Asia, and the Netherlands through the NBPGR. Also some of the underutilized lines are being mass cultivated for the popularization. Keeping in mind the importance of flowering character for the further utilization in breeding; we are recording flowering trend of these lines in agro-climatic conditions of ICAR-DOGR.

List of different *Allium* species available at ICAR-DOGR, Pune

A. altaicum Pall	*A. chinensi*	*A. senescence,*
A.cepavar. aggrigatum	*A. hookerii*	*A. cepa* x *A. fistulosum Beltsville bunching*
A. fistulosum	*A. schoenoprasum*	*A. cepa Shakespeare* (bulb onion)
A. tuberosum,	*A. fragrance*	*A. ladeboramun*
A. macranthum	*A. ampeloprasum*	*A. ascalonicum*
A. prszewalskianum	*A. cariolinianum*	*A.* spp.

Flowering status of *Allium* species at ICAR-DOGR

All the identified 26 flowering lines from four *Allium* species recorded similar flowering trend in 2021 as observed in the year 2020. The January-May flowering of two identified lines of *A. altaicum Pall* was constant in January-May of the year 2021. All the 11 flowering lines identified from the *A. fistulosum* flowered in the month of March 2020, but an early flowering starting from February was recorded in 2021. For the two identified flowering lines of the *A. schoenoprasum* flowering in February 2020 was constant for the year 2021 and similarly in *A. tuberosum*, the January to May flowering in 2020 was constant in the year 2021. Hence accordingly it can be utilized in further breeding programme.

Flowering *Allium* species at ICAR-DOGR, Pune

***Allium* Species**	**Number of flowering lines**	**Flowering months observed in 2020**	**Flowering months observed in 2021**
A. altaicum Pall	2	January - May	January-May
A. fistulosum	11	March	February- March
A. schoenoprasum	2	February	February
A. tuberosum	11	January - May	January-May

Underutilized *Allium* species for popularization and commercialization for foliage consumption

Promising results for the foliage production trend in Rajgurunagar condition based on two years of experiments were recorded in three identified *Allium* species viz. *A. tuberosum*kazakhistan*All-1587, A. tuberosum CGN-16418 (NF)* and *A. tuberosum Rott/Ex-sprkucchai CGN-16373* for foliage purpose. All these lines showed character of multiple cuttings and an increase in the number of tillers with the successive harvest cuttings. These lines were mass multiplied for the further evaluation in 2021. The yield trend in the chives (foliage cuttings) was promising. For the year 2021, highest per annum yield of 129.25 t/ha was recorded in *A. tuberosum* kazakhistan *All-1587* which was higher than the previous year (73.57 t/ha). Both the annual yield and the season wise yields recorded for all three lines in the year 2021 were higher than yields recorded in previous year 2020. In summer 2021 the yield ranged between 32.45- 39.54 t/ha and recorded highest (39.54 t/ha) in *A. tuberosum kazakhistan* All-1587. Similarly yields for the rainy season of 2021 and for the winter 2021 ranged between 40.23-58.88 t/ha and 62.47-73.57 t/ha, respectively and too was recorded highest in *A. tuberosum kazakhistan All-1587.*

In June-2021 an MOU was signed between ICAR-DOGR and Kisan Konnect; one of the leading digital platforms in the fresh vegetable supply chain. Platform was used for the popularization of the three identified lines for the table and culinary purpose consumption in the chive forms on pilot basis. A total of 641.2 kg demand was received and supplied during July 2021 to Jan 2022. The demand observed a slight decline in September to November but geared up a steep rise from the December. Secondary objective of the MOU was to study the scope and general trends in commercialization for chive cuttings. As rising trend in demand being observed; it indicated attainable scope of commercialization with current popularization efforts. Also all three lines recorded nil disease and pest incidence, thus demanded no use of pesticides that depicts possible alternative to use residue free foliage for consumption.

High yielding (t/ha) wild *Allium* species for foliage during summer, rainy & winter season

Wild *Allium* species	Summer (t/ha)		Rainy (t/ha)		Winter (t/ha)		Yield/annum (t/ha)	
	2020	2021	2020	2021	2020	2021	2020	2021
Allium tuberosum kazakhistan All-1587	28.74	39.54	30.46	58.88	14.37	30.83	73.57	**129.25**
Allium tuberosum CGN-16418	25.27	34.28	33.83	51.20	13.63	27.26	72.73	112.74
Allium tuberosum Rott/Ex-sprkucchai CGN-16373	27.84	32.45	26.32	40.23	8.31	22.73	62.47	95.41

Phytochemicals and antioxidant potentials of wild Allium species

Wild allium species are reported to have reserves of phytochemical attributing not only to pharmacogenic properties but also provide tolerance to various biotic and abiotic stresses. Extracts of various plant parts contains antimicrobial properties against fungi, bacteria and even viruses. Many pharmacogenic effects are directly or indirectly associated with antioxidant potentials of phytochemicals. Here, Leaf extract of ten wild allium species were used for total phenolic, Anthocyanin, flavonoids and total thiosulfinates determination and evaluated for its total antioxidants potentials. Total phenol content (TPC) was observed maximum of 50.26 ± 2.09 mg/gFW in *A. fragrance* followed by 49.43 ± 1.33 mg/gFW in *A. angulosum*and minimum in *A. altaicum*pall *(*23.22 ± 0.47 mg/gFW). As presented in *table X*, Total flavonoid content (TFC) were also observed maximum in *A. fragrance* and *A. angulosum*. Antioxidant potential of leaf extract were evaluated with three popular methods viz. ABTS, DPPH and FRAP assay and expressed as percentage inhibition and micromole of Trolox equivalence. As presented in table*, A. angulosum* and *A. fragrance* exhibited maximum antioxidant potential in all three methods whereas it was observed lowest in *A. Cepa. aggr. 3 meithei.* Thiosulfinates are relatively stable intermediates of produced in the course of breakdown of storable sulphur metabolites in allium species. Total thiosulfinate content (TTC) was observed maximum in leaf extract of *A. tuberosum* (6.63 ± 0.04 µmol/gFW) and minimum in *A. ladebouramun (*0.53 ± 0.07 µmol/gFW).

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21 Paving the way towards Future-proofing Neglected and Underutilized species (NUS) for Pharmaceutical and Industries

T. K. Behera* and Rakesh K. Dubey
*Dirctor, ICAR-Indian Institute of Vegetable Research, Varanasi-221305
*Email: director.iivr@icar.gov.in

Introduction

The increasing global population, projected to reach 9 billion by 2050, increasing consumer expectations, health related recommendations for a more diverse diet and ambitions to transition to a more sustainable bio-industrial base will result in an ever-increasing demand for food, feed, fibre and other plant-derived products (Aschemann-Witzel *et al.,* 2019; de Boer *et al.,* 2014). Persistent malnutrition can be attributed to low dietary diversity, together with low production diversity. Dietary diversity represents a more healthy, balanced, and diverse diet, which ensures nutrient adequacy. Promising neglected and underutilized species (NUS) that are nutrient-dense, climate-resilient, profitable and locally available/adaptable are fundamental to improving dietary and production diversity. The Future Smart Food Initiative, led by FAO's Regional Initiative on Zero Hunger, aims to harness the enormous benefits of NUS in the fight against hunger and malnutrition. There is a strong call to end hunger and malnutrition by 2030, especially in the second SDG2. Other related SDGs include SDG3 (good health and well-being), SDG12 (responsible consumption and production), and SDG15 (life on land). Although substantial advances have been made, ending hunger and malnutrition remain a major concern in the Asia Pacific region. In India, 19% of women and 16% of men under 50 are undernourished, while 24% of women and 23% of men are victims of obesity. As such, approximately 40% of the humongous population of 1.40 billion is malnourished. Overweight and obesity are significant risk factors for all age groups for many diseases, including non-communicable diseases (NCDs), such as diabetes, hypertension, cardiovascular diseases, certain cancers, obstructive sleep apnea, osteoarthritis, respiratory diseases, and diabetes. Dietary diversity in children is positively correlated with the mean micronutrient adequacy of the diet, that is, adequate nutrients for growth and development. Minimum dietary diversity (MDD) is a measure of the dietary quality and feeding practices of children. The eight food groups are: grains, roots, and tubers; legumes and nuts; dairy products; flesh foods, including meat, poultry, and fish; eggs; vitamin A-rich fruits and vegetables; other fruits and vegetables; breast milk. Low dietary diversity usually comprises a high consumption of cereals, mainly rice, and relatively low consumption of vegetables, fruits, and pulses. Foods rich in proteins and fats, coupled with an overall increase in consumption, will help combat diseases and improve children's health.

Eat a rainbow of vegetables

Agricultural diversification is a formidable tool for achieving Zero Hunger. However, current agriculture and food systems have limited production diversity, resulting in unbalanced diets and, thus, malnutrition. Mostly, only a few staple crops are grown, mainly rice, which form the bulk of people's diets—the lack of dietary diversity fails to deliver wholesome nutrition, as per the recommended nutrition intake. The prevalence of rice cultivation in the country is associated with multiple factors. According to the FAO (10), the reliance on only a few crops negatively affects ecosystems, food diversity, and health. Food monotony increases the risk of micronutrient deficiencies. Dietary diversity is a cost-effective, affordable and sustainable way to minimize hunger and malnutrition, and production diversity facilitates the supply of nutritious and diversified food and addresses the effects of climate change.

Table1. Underexploited/ neglected/traditional food crops of North Eastern Himalayas

S.No	English name	Scientific name	Family	Morphology	Ethno botanical importance
Leafy vegetables					
1	Water cress	*Nasturtium officinale*	Cruciferaceae	Herb	Leaves are cooked and preferred as a side dish. Its soups are traditionally famous for *momo* and *thukpa*. Leaves are found to contain several phenolic compounds that have anti-cancer and anti-tuberculosis properties and are also effective against high blood pressure
2	Stinging nettle	*Urtica dioica*	Urticaceae	Shrub	Cooked leaves are served during the festival, marriage, and have also entered into the food menu of restaurants in the hills. Root and seed decoction is taken to treat diarrhoea and cough.
3	Vegetable fern	*Diplazium esculentum*	Athyraceae	Herb	Young fronds are used as vegetables (from the scrolled tip to about 18 cm towards the base).
4	Snail fern	*Diplazium polypodioides*	Athyraceae	Herb	It is most expensive than any other fern, tastes like meat when cooked. Dry root ground with guava barks is a folk medicine to treat diarrhoea (*masi*).
5	Wood fern	*Dryopteris cochleata*	Dryopteridaceae	Herb	Used as vegetables and pickle.
6	Pig weed	*Amaranthus viridis*	Amaranthaceae	Herb	Leaf and shoot are cooked and eaten as a side dish. It also ameliorates the symptoms of diarrhoea and dysentery.
7	Chenopods	*Chenopodium album*	Chenopodiaceae	Herb	Cooked and eaten as a side dish either with potato or meat. It is used to cure piles intestinal ulcers and burns.
8	Chameleon plant	*Hottuynia cordata*	Saururaceae	Herb	Either cooked as a vegetable or used for garnishing dishes. It has an aromatic smell that has long been used to treat pneumonia, hypertension, and reduction of heat and diuretic action.

9	Buck wheat	*Fagopyrum esculentum*	Polygonaceae	Herb	The leaves are cooked and consumed as a vegetable. It improves heart health and promote weight loss.
10	Garlic chives	*Allium tuberosum*	Liliaceae	Herb	The plant is eaten as vegetable and is believed to aid in indigestion, diarrhoea and in cleaning the digestive tract.
11	Leaf mustard/ Mustard greens	*Brassica juncea*	Brassicaceae	Herb	It is one of the most consumed green vegetables among hill communities. As the mustard plants mature, it starts to form flowering shoots which are locally known as *duku* which is also consumed as a vegetable.
12	Macroponax	*Macroponax undulatus*	Araliaceae	Shrub	Young twigs are pan dried and eaten as vegetable. It is believed to cure kidney stones.
13	Knot weed	*Polygonum molle*	Polygonaceae	Herb	Young shoots consumed as vegetable and is also prescribed in diarrhoeas. This species is highly important for soil stabilization
14	Indrayan	*Trichosanthes tricuspidata*	Cucurbitaceae	Annual Vines	Tender shoots are cooked as vegetable and roasted seeds are consumed or used to make pickle.
15	Polycephalum weed	*Elatostema platyphyllum*	Urticaceae	Herb	Young shoots and leaves are valued as delicacy vegetable eaten as an appetizer, and specially eaten during religious ceremonies. *Limboo* community mainly preserves it.
16	Kumarika	*Smilax zeylanica*	Smilacaceae	Climber	It helps to control blood sugar level, beneficial for diabetic and ulcer patients.
17	Mountain ebony	*Bauhinia variegate*	Fabaceace	Tree	Flowers are boiled and eaten as vegetable. It helps to control blood pressure.
18	Indian trumpet flower	*Oroxylum indicum*	Bignoniaceae	Tree	The flower is boiled, oil fried, and eaten as a vegetable which is bitter in taste. Various parts of the plant are used in Ayurveda and folk medicine for the treatment of different ailments such as cancer,

19	Red Nongmangkha	*Phlogacanthus thrysiflorus*	Acanthaceae	Shrub	The red flowers are boiled, fried in oil and is consumed by the ethnic people of hills. Flowers are an antidote to pox, it has also been used in jaundice. For the control of RKN, *Meloidogyne incognita* (Mohilal and Dhanachand, 2003) found that *P. thyrsiflorus* as a potential nematicide.
20	Nakima	*Tupistra nutans*	Liliaceae	Perennial herb	The inflorescence is eaten as a vegetable and pickle. Powdered root and flower decoction are taken to control diabetes.
21	Banana	*Musa sikkimensis*	Musaceae	Herb	Ripe fruits are edible and flower buds are used as vegetables and also boiled and make *achaar*. Flower buds are a good source of minerals and iron, taken to control diarrhoea and also advised to take in anaemia.
			Tuber crops		
22	Tapioca	*Manihot esculenta*	Euphorbiaceae	Shrub	People of the hills especially consume the boiled tuber during the *Makar Sankranti* festival. Tubers are fortified with iron and copper which is essential for blood health.
23	Greater Yam	*Dioscorea alata*	Dioscoraceae	Perennial vine	Its tuber has good digestive fibre which keeps stomach and digestion problems away.
24	Wild Yam	*Dioscorea hamiltonii*	Dioscoraceae	Perennial vine	*Makar Sankranti* is a harvest festival where ethnic people of hills start their day by putting tika on in their forehead with the crushed paste of *D. bulbifera*.
25	Taro	*Colocasia esculenta*	Araceae	Herb	They are boiled and served with *achaar*. The corm is a good source of starch.
26	Aerial Yam	*Dioscorea bulbifera*	Araceae	Perennial vine	Matured tuber and fruits are boiled in water and consumed. Good source of carbohydrate and good for stomach troubles

Under exploited fruit vegetables					
27	Indian Nightshade	*Solanum indicum*	Solanaceae	Shrub	The ripe fruit is used as *achaar* or oil-fried which is bitter. Its fruits are crushed and applied in the forehead to cure fever and headache.
28	African eggplant	*Solanum macrocarpon*	Solanaceae	Shrub	The matured fruits are sliced, oil fried, and consumed as a side dish.
29	Spine gourd	*Momordica dioica*	Cicurbitaceae	Perennial climber	Fruits are used as a vegetable. The aqueous extract of fruit possesses very good anti-diabetic activity.
30	Chow Chow	*Sechium edule*	Cucurbitaceae	Perennial climber	It is a very versatile vegetable of the hills. The fruit is the most common plant part sold and eaten in the hills but the tuber, young shoot (*munta*), seeds, flowers, and leaves are all edible. The infusions of the leaves are used to dissolve kidney stones.
31	Achocha	*Cyclanthera pedata*	Cucurbitaceae	Herb	Young fruits are mixed with potato and oil fried. It has anti-inflammatory, hypo cholesterol emic, and hypoglycaemic properties. Cycladol is an extract from fruit available in the market.
32	Tree tomato	*Cyphomandra betacea*	Solanaceae	Shrub	*Achaar* prepared from the combination of *C. betaceae*, and *C. annum* (*dalle*) are very well famous and loved by the hills.
33	Wild cherry tomato	*Solanum pimpinellifolium*	Solanaceae	Shrub	Its ripe fruits are used as *achaar* which is very sour in taste. The fruits and cut into pieces, sundried, and kept to consume during the off season.
34	Soyabean	*Glycine max*	Fabaceae	Herb	Its seeds are roasted, grinded and mixed with chops of chilli and onion to serve with local alcohol for paddy thresher as a supplement of protein.
Fermented food products					
35	Fermented mustard green	*Brassica juncea*	Brassicaceae	Leaf	Matured leaves are wilted, shredded, crushed mildly, soaked in hot water and pressed into an earthen jar or container, made airtight and fermented naturally for about 7-10 days. It is consumed as a soup during glut season.

36	Feremented radish root	*Raphanus sativus*	Brassicaceae	Root	Prepared from radish root by fermentation in pit plastered with mud and warmed by burning. *Sinki* has an acidic flavor, mostly used as soup and pickle
37	Fermented soyabean	*Glycine max*	Fabaceae	Seed	It is ammonia flavoured, alkaline-based fermented food product rich in protein. Mainly *Limboo* tribe from the hills produces, consumes, and sells it.
38	Bamboo shoot	*Dendrocalamus hamiltonii*	Poaceae	Herb	Shoots are boiled to make a fermented dish called *mesu* by the people of hills which is commonly used as pickle.
39	Soft churpi	Cow milk	-	-	It is a fermented cow's milk product consumed as a condiment by mixing with the sliced radish or cucumber and is also mixed with meats and vegetables.

Balanced nutrition

Healthy diets have an optimal caloric intake comprising a diversity of plant-based foods, low amounts of animal source foods, unsaturated rather than saturated fats, and limited amounts of refined grains, highly processed foods, and added sugars. Generally, a healthy diet provides the right nutrients (energy, protein, fats, fiber, and essential nutrients such as carbohydrates, amino acids, fatty acids, vitamins, minerals, and fluids) in the right balance, with sufficient diversity for healthy growth and reducing the risk of diet-related diseases. While humans are omnivores, not herbivores, a healthy diet is often largely plant-based and includes modest amounts of fish, meat, and dairy.

Table 2. Total phenolic content, Total Flavonoids (TF) and Antioxidant activity of tree bean

Plant part	TPC mg/g	Flavonoids mg/g	AOA%
Leaves	207.3	40.7	79.9
Pods	311.6	62.5	92.4
Seeds	165.5	42.9	61.5
Flowers	80.1	19.2	50.1
Quercetin	Standard	-	85.1
Fishers Least Significant Difference <0.1	5.1	1.3	3.3

Source: Dubey *et al.* (2020)

Health and well-being

Micronutrient deficiency mostly affects children and women, particularly those of reproductive age. While the most common indicators for malnutrition in children under 5 years of age are stunting, underweight, and wasting, those for women and children (>5 years) are anemia and vitamin A deficiency. Of the world's estimated 7,000 million people, 500 million suffer from protein-energy malnutrition,

>1,600 million suffer from iron deficiency, and >200 million suffer from vitamin A insufficiency. More than 400,000 children under 5 years are estimated to die each year from zinc deficiency. Diet is one of the most important contributors to health but also disease. Inadequate diets have a direct negative impact on the health of individuals, leading to high NCDs and even death. An unhealthy diet is a significant contributor to most NCDs (18). A systematic evaluation of dietary consumption patterns across 195 countries suggested that dietary improvements could prevent one in every five premature deaths globally. The WHO estimates that diets low in fruits and vegetables cause 2.7 million deaths each year and about 19% of gastrointestinal cancer, 31% of ischemic heart disease, and 11% of strokes. That is, diet-related NCDs are a leading preventable cause of death worldwide. Dietary modifications toward healthy diets are expected to result in significant health benefits, including preventing 19–24% of total deaths among adults.

Table 3. Wetlands plants used as vegetables or spices/condiments in traditional dishes

SN	Name of the local dish	Preparation
1	Ironba	It is a special dish prepared from several vegetables, *viz*., Wendlanda (inflorescence), Sagittaria (tuber), Solanum tuberosum, Musa paradasiaca, Amorphophalus sp., Abelmoscus esculentus, etc., boiled together. The fermented fish mash with red chilli and an appropriate amount of salt is mixed with all the other cooked vegetables. Variations include Ipomea aquatica, Oenanthe javanica, Euryale ferox, Trapa natans, Sagittaria sagittifolia, Polygonum barbatum, and others. The finished dish so prepared is garnished with finely chopped Houttuinia cordata (roots, leaves), onion stalks, Elsholtzia blanda (inflorescence), Allium odorum, etc. as condiments to give it a characteristic aroma.
2	Ametpa	It is spicy chutney prepared from boiled, steamed, or fried chilies mixed with fermented fish. Consume the green leaves of Pisum sativum, Brassica campestris, Brassica oleracea, Houttuinia cordata, Polygonum posumba, Polygonum barbatum, Euryale ferox, Ipomea aquatica, Oenanthe javanica, Neptunia oleraceae, etc.
3	Singju	A traditional Meitei salad is prepared from finely chopped raw vegetables like cabbage, onions, lotus stems, tree beans, coriander, Alocasia cuculata, Ipomea aquatic, Oenanthe javanica, etc., mixed with red pepper, sesame seeds, roasted gram flour, salt, boiled seeds of beans or peas, and fermented fish. Dishes can be prepared with raw papaya, cabbage, banana flower, Nelumbo nucifera garnished with Allium odorum, Houttuinia cordata, and so on.
4	Chagem-pomba	A traditional dish prepared for a grand feast Prepare using a combination of various kinds of tender leaves (Neptunia oleraceae, Brassica juncea, Vicia faba, Parkia speciosa, Anethum graveolens, Allium odorum, etc.), ground rice, (chagem), red pepper, dried and fermented fish, fermented soybean, and then cook together.
5	Kangsu	It is a traditional dish similar to singju. It is a side dish made of mashed boiled vegetables and fermented fish with salt and red pepper powder.
6	Ooti	It is a classic traditional dish that is considered a must-have main course at a grand feast. Prepare peas and several green leafy vegetables, with or without grounded rice. It is the only dish prepared with sodium bicarbonate. Amaranthus spinosus, Colocasia esculenta, Clerodendrum Indicum, Brassica oleracea, Marsilea minuta, etc. are used as green leafy vegetables for the preparation, but varieties can be made using bamboo shoots, black gram dhal, Bengal gram dhal, etc.
7	Champhut	It is another traditional dish prepared by boiling several seasonal vegetables with or without sugar or salt.
8	Kanghou	Several finely sliced vegetables (like Zizania latifolia, Ipomea aquatic, Neptunia oleraceae, Amaranthus spinosus, Allium odorum, etc.) are stir-fried together with pulses, potatoes, or prawns.

9	Hentak	It's a side dish made with phabou ngari (dry fish). Phabou ngari is pounded with the petioles of Alocasia macrorrhiza with the help of a pestle and mortar and mixed until it forms a single, uniform texture and is then hand-rolled into balls. It is advised to young mothers who are not allowed to consume fermented fish to use it as a flavour enhancer in the preparation of kangsoi and chamthong.
10	Pakoura thongba	A dish made with bora (pakora) is a cooked curry soup made of dal (Cajanus cajan or vegetable curry). There are many kinds of bora, *viz*., koukha (Sagittaria sagittifolia) bora, potato bora, onion bora, prawn bora, brinjal bora, cauliflower bora, thambou (Nelumbo nucifera) bora, pumpkin bora, etc.
11	Kangsoi	It is a special traditional dish prepared by frying different seasonal vegetables (Polygonum barbatum, Marsilea minuta, Oenanthe javanica, Amaranthus spinosus, potato, green pea, etc.) with coarsely chopped onions, Allium odorum, ginger, garlic cloves, salt, and a little bit of oil. Fermented fish nigari and water are served on top of the dish.
12	Chamthong	It is a healthy vegetable stew that consists of seasonal vegetables that are boiled together with fermented fish or dried fish and flavoured with sliced onions, garlic, salt, Allium odorum, and a bit of ginger. It is somewhat similar to kangsoi but without oil.

Nutrient adequacy

The Mediterranean diet and the Japanese diet are two examples of a healthy diet. The Mediterranean diet—mainly incorporating legumes, cereals, fruits and vegetables, olive oil, fish, and moderate consumption of dairy products (mostly cheese and yogurt)—is the traditional way of eating around the Mediterranean basin. The Mediterranean diet emphasizes the consumption of plant-based foods, including fruits, vegetables, beans, nuts, cereals, and other seeds, olive oil as the main source of dietary fat, red meat in moderation, and herbs and spices instead of salt to flavor food. Compared to the "modern Western" diet, the Mediterranean diet contains much higher quantities of unprocessed foods, uses much less red meat, and has a much higher proportion of unsaturated fats. The Japanese diet emphasizes the consumption of fish as a major source of protein, vegetables (including daikon radish and sea vegetables), rice, soy (tofu, miso, soy sauce), noodles, fruit, and tea (preferably green). Fish features prominently in Japanese cuisine: Japanese account for only 2% of the global population, but they collectively consume 12 % of the world's fish. With its high popularity, Japanese cuisine is often associated with sushi (raw fish and rice served with pickled ginger) and sashimi (fresh raw seafood that is dipped in soy sauce and wasabi). While sushi and sashimi are originally "made in Japan," Japanese cuisine has had strong external influences: around 300 BC, the Japanese learned how to cultivate rice from China, as well as the preparation of soy sauce and tofu (important sources of plant protein). The other external influence was Buddhism: a ban on eating meat was promulgated with the arrival of Buddhismin the seventh century. The popularity of sushi came about as a result of this ban. While not always strictly observed, for many centuries, eating meat, particularly beef, was unthinkable; the beef-eating habit returned to Japan only in the late nineteenth century. These two examples show healthy diets developed in vastly different cultural, climatic, and geographic settings. Both use diverse ingredients linked to people and cultures as much as to their natural environment. Consequently, the Mediterranean and Japanese diets are on UNESCO's World's Intangible Cultural Heritage list. Japan and the Mediterranean countries can demonstrate the health effects of their respective healthy diets. Medical research has shown that the Japanese diet has the lowest prevalence of obesity among developed countries—and other chronic diseases, such as osteoporosis, heart ailments, and some cancers. Following the Mediterranean diet for several years reduces the risk of developing heart disease, cancer, hypertension, Type 2 diabetes, Parkinson's disease, and Alzheimer's disease.

Indeed, the Japanese have one of the longest average life expectancy in the world- 87.45 years for women and 81.41 years for men in 2019—according to the Japanese Ministry of Health, Labor, and Welfare. Japanese women outstrip all competitors in life expectancy, including their American counterparts, who can expect to live up to 81 years (76 years for American men). The same holds for developed countries in the Mediterranean: women in Italy and Spain have a life expectancy of 85 years, while the figure is 83 years in Germany. Both Italian and Japanese men have a life expectancy of 80 years. An average Indian diet is unhealthy. Even rich Indians don't eat right diets. The World Health Organization reported the life expectancy of an Indian 70.8 years in its 2019-20 report.

Fig 1. Spars hair free-velvet bean genotype VRVB-1.

Table 4. Mineral content in selected Underexploited aquatic plant

SN	Botanical name	Parts of the plant used	Iron (ppm)	Magnesium (ppm)	Ca (ppm)	Zinc (ppm)
1	*Zizania latifolia*	Rhizome	3.13	0.62	1.50	1.61
2	*Neptunia oleraceae*	Tender shoot	8.07	18.01	51.45	1.01
3	*Ipomea aquatica*	Tender shoot	8.44	4.64	9.45	1.70
4	*Jussiaea repens*	Tender shoot	22.11	7.10	14.10	1.17
5	*Enhydra fluctuans*	Tender shoot	12.78	7.11	16.11	1.44
6	*Eleocharis dulcis*	Rhizome	11.18	1.03	2.01	0.61
7	*Sagittaria sagittifolia*	Tuber	15.21	0.98	2.13	1.47
8	*Marsilea quadrifolia*	Whole plant	16.44	3.82	7.70	1.03
9	*Trapan natas*	Tender shoot	12.89	21.20	54.01	0.80
10	*Nelumbo nucifera*	Rhizome	5.21	1.72	3.85	0.63

Source: Devi *et al*. (2023)

Healthy eating patterns and choices

A healthy diet is the pillar of well-being throughout a person's life. Policies that aim to prevent malnutrition, primarily by ensuring healthy diets for children to prevent stunting and obesity, are more effective than those aiming to reduce malnutrition. Unfortunately, there is no one-size-fits-all healthy diet. A healthy diet must be affordable, based on locally available foodstuffs, and meet cultural preferences. Since the First International Conference on Nutrition held in 1992, the FAO together with WHO has worked with governments on national food-based dietary guidelines: short, science-based, positive messages on national healthy eating and lifestyles. National governments use similar approaches. For example, the US government regularly publishes Dietary Guidelines for Americans to show how individuals can have a healthy diet following updated scientific evidence. It is the role of governments and public agencies—rather than special interest groups—to provide unbiased information on what constitutes a healthy diet. The WHO Global Strategy on Diet, Physical Activity and Health and the Commission on Ending Childhood Obesity provide strategies for improving diets and physical activity patterns at the population level. The dietary guidelines for Indian are eat plenty of vegetables and fruits. Ensure moderate use of edible oils and animal foods and use a minimum of ghee/butter/vanaspati. Avoid overeating to prevent overweight and obesity. Exercise regularly and be physically active to maintain ideal body weight.

Fig1.Water spinach var Kashi Manu in upland field condition

Neglected underutilized species (NUS) to ensure healthy diets and food security and nutrition

Agro-biodiversity is essential to sustainable agriculture, of which NUS are key elements. About 30,000 edible plant species have been identified worldwide; of these, more than 7,000 crop species have been cultivated for food. Currently, fewer than 150 crop species are commercially cultivated; 103 deliver up to 90% of the calories in the human diet, and only four (rice, wheat, maize, and potato) provide 60% of the human energy supply. Thus, tens of thousands of edible plant species are relatively "underutilized" and could be used to increase the world's food requirements. Crops can be divided into two main categories (staple and underutilized). Underutilized crops (also called neglected, minor, orphan, promising, or little-used) are mostly wild or semi-domesticated species adapted to local environments. These crops were used as traditional foods for centuries but became increasingly neglected when more productive crops became available in farming systems. NUS face multidimensional challenges ranging from agro-technical, socioeconomic, policy, and institutional perspectives that have resulted in their underutilization. Agricultural modernization, widespread monoculture, and the promotion of high-yielding varieties have marginalized NUS, which play a minor role in current farming and food systems. Culturally, NUS has been stigmatized by the perception as "food of the poor," creating a disincentive for their production and consumption. In short, the lack of an environment conducive to the production, processing, marketing, distribution, and consumption of NUS prevented them from being included in current diets.

Neglected and underutilized species offer immense opportunities to fight poverty, hunger, and malnutrition, and their incorporation into farming systems could lead to nutrient dense, climate-resilient, and sustainable agriculture. Neglected and underutilized species have high nutritional value and are a good source of micronutrients, protein, energy, and fiber. Many NUS crops can also be grown on marginal land, intercropped or rotated with staple crops, and easily fit with integrated practices. Many NUS can tolerate various stresses, which will not only make production systems more diverse but more sustainable and climate-resilient.

NUS to reduce malnutrition

"Hidden hunger" - having enough calories but insufficient vitamins and minerals—is a killer factor affecting both developed and developing countries. Hidden hunger is partly due to the reliance on only a few staple crops. Since the Green Revolution in the 1960s, agricultural research has focused on increasing crop yields to deliver sufficient food for growing population. Nutritional quality has been less of a concern, despite many people suffering from hunger. While people's standard of living has improved, the effect of diets deficient in essential vitamins and minerals has become apparent in many parts of the country. Neglected and underutilized species have the potential to reverse the trend in hidden hunger. They are often richer in nutrients than their more popular staple crop cousins, with high levels of essential micronutrients (minerals, vitamins) and phytochemicals (such as flavonoids) and good macronutrient profiles (energy, fat, protein, carbohydrates). For example, quinoa is a highly nutritious NUS that came into the limelight in 2014 when the United Nations General Assembly endorsed the International Year of Quinoa. Quinoa has twice as much protein, five times more dietary fiber, four times more iron, and 23 times more folate than rice. Neglected and underutilized species have outstanding health benefits. For example, water spinach, winged bean, water chestnut are rich in micronutrients, with the potential to provide adequate dietary amounts, especially for iron (Fe), zinc (Zn), and selenium (Se). The Indian government recognized the key role of dietary diversity for preventing nutritional anemia and used food-based approaches to attain adequate dietary iron by encouraging the consumption of micronutrient-rich foods, such as dark green leafy vegetables, lentils, and vitamin-C-rich NUS fruits, which are often available but underutilized by the nutrient-deficient population. Millets also have superior nutritional and health benefits; they are often referred to as "high-energy" cereals, with higher protein, vitamin A and oil contents than maize. Vitamin A is often deficient in staple diets, making millets a suitable crop for tackling the nutritional challenges faced by mountain communities.

Table 5. Total phenolics content, flavonoids and antioxidant activity of winged bean genotypes

Cultivar	TPC (mg GAE/100 g FW)	Total flavonoids (mg CE/100 g FW)	Ferric reducing antioxidant power (µmol /g FW)	Cupric ion antioxidant reducing capacity (µmol /g FW)	DPPH, 2, 2-diphenyl-1-picrylhydrazyl (µmol TE/g FW)	Trolox-equivalent antioxidant Capacity (µmol TE/g FW)
RWB-16	88.17 ± 4.61	22.87 ± 0.09	1.49 ± 0.06	5.43 ± 0.29	3.50 ± 0.24	2.12 ± 0.23
AMBIKA-13-4 B	113.00 ± 2.54	34.22 ± 1.06	5.51 ± 0.13	5.56 ± 0.44	5.02 ± 0.49	3.06 ± 0.36
AMBIKA-11-2	83.50 ± 11.59	19.44 ± 0.37	3.22 ± 0.57	3.77 ± 0.19	2.75 ± 0.07	2.47 ± 0.23
RWB-15	96.12 ± 6.58	20.14 ± 1.66	2.68 ± 0.29	4.54 ± 0.53	2.19 ± 0.45	2.11 ± 0.24
EC-172600	61.50 ± 1.76	9.07 ± 0.61	1.20 ± 0.03	3.14 ± 0.16	0.66 ± 0.34	1.82 ± 0.18

AMBIKAWB-II-I	143.50 ± 9.79	25.88 ± 2.77	5.65 ± 0.37	6.19 ± 0.42	3.71 ± 0.32	2.18 ± 0.14
IC-26945	95.17 ± 4.13	24.49 ± 1.93	1.60 ± 0.28	5.34 ± 0.16	2.99 ± 0.20	2.47 ± 0.08

Source: Singh *et al.* (2019)

NUS to fight against food insecurity

From a food security perspective, the world's current food system is vulnerable as it relies on a limited range of food items. Current farming systems favor monocultures that require high inputs, which facilitate operations but threaten food security. Basing our diet on such a small number of staple crops has serious implications for food security and nutrition. The major cultivated crops lack genetic diversity within their gene pools, which leaves agricultural systems exposed to pests and diseases and abiotic stresses. The Great Irish Potato Famine provides an alarming lesson from history. It began in 1845 and lasted for 6 years, killing about two-fifths of the population (over a million people) in Ireland and causing another million to flee the country. The famine was caused by potato blight, a disease that ravaged potato crops throughout Europe. The impact in Ireland was disproportionate, as one-third of the population depended almost entirely on potato for food. The marginalized Irish smallholders had cultivated the potato as a staple food since the eighteenth century, as potato yields were much higher per acre than cereals. However, potatoes grown in Ireland were mostly of a single variety, the Irish Lumper. When the disease spread, the lack of genetic variability among the potato plants in Ireland led to devastating effects, while elsewhere in Europe, with more diversity in the varieties of potato being cultivated and/or reliance on a broader range of crops, the effects were much less severe. Rediscovering neglected crops could reduce the risk of overreliance on a few major crops. Agricultural sustainability relies on a healthy interaction between agriculture and nature involving three hierarchical levels of genetic diversity: agro-ecosystems, interspecific diversity (among species), and intraspecific diversity (within species). Marginalizing NUS endangers agro biodiversity and threatens food system sustainability. Neglected and underutilized species can increase agricultural sustainability by reducing the need for external inputs, such as inorganic fertilizers and pesticides. Introducing NUS in a farming system can reduce pest and disease buildup when grown in rotation with main crops. Depending on their characteristics, NUS can also increase soil fertility, prevent soil erosion, reduce evaporation, and suppress weed growth. Neglected and underutilized species are often less demanding of the environment, more resilient to climate change, and more resistant to biotic stresses, thus providing more reliable harvests under unfavorable climatic conditions or on depleted soils. For instance, Water spinach variety Kashi Manu, an underutilized leafy vegetable, is remarkably heat, drought and waterlogged tolerant, a key trait of many NUS. Thus, NUS provide a safety net when the weather turns bad, or external inputs become undesirable as they damage the environment, become unavailable during disasters and emergencies, or become unaffordable due to high prices. Neglected and underutilized crops offer more options for building temporal and spatial diversity into cropping systems. Some NUS have considerable commercial value, such as vegetables and fruits, which can improve household income. Being locally available/adaptable, NUS are accessible and affordable for the local population and therefore contribute to food security and nutrition, livelihood improvements, and cultural diversity. In sum, NUS crops offer superior nutritional value for improving micronutrient deficiencies and addressing NCDs for millions of people. Their resistance to climate change implies that NUS can provide food when other crops fail

Fig 3. Performance of winged bean in water logged condition.

Table 6. Important chemical compounds of plant *Amaranthus viridis* L.

Parts	Biochemical Constituents	Antioxidant and antimicrobial constituents		Medicinal usages of distinctive segments	Uses
Leaf	Reducing sugar, Resin, Tannin	Flavonoid contents	18.4 - 5.42 QE, g/100 g	Whole plant	Lessen labor pain
Leaf/seed	Cardiac glycosides, Phlobatannins, Flavonoids, Zinc, Protein, Calcium, Alpha-Linoleic acid, Linoleic acid, Iron, Magnesium	Phenolic contents	1.03 - 3.64 GAE, g/100 g	Bruised Leaves	eczema, rashes, and psoriasis Diuretics, laxatives, respiratory
Root	Amasterol	Minimum inhibitory concentrations (MIC)	179 - 645 µg/ml	Whole plant	problems, eye problems, and asthma
Seed	Triacontane, Saponins, Ecdysteron,Pentatriacontane, Hentriacontane, Hexatriacontane, Pentatriacontane	1-diphenyl-2-picrylhydrazyl (DPPH)	14.25 - 83.43 µg/ml	Whole plant	Pain and fever
Barren palatable plants	Oxalic acid, carotenoids			Leaves	As anti-bacterial
Leaves	Beta-carotene			Leaves and seeds	Fungal and bacterial diseases
				Roots	Edema

Source: Haider *et al.* (2023)

FAO's regional initiative on zero hunger on future smart food

FAO, in collaboration with national and international partners, under its Regional Initiative on Zero Hunger (RI-ZH), launched a Future Smart Food (FSF) Initiative to support countries in the identification of NUS with high potential to be integrated into agricultural and food systems. The FSF initiative's scope does not include invasive plants and weed species and is focused on crops and their products. Future

Smart Food is defined as NUS that are nutrient-dense, climate-resilient, economically viable, and locally available or adaptable. Only NUS that met four criteria qualify as FSF, being: a) nutrient-dense (nutrients), b) climate-resilient (e.g., require low inputs, promote climate change resiliency, environmentally friendly by reducing runoff and erosion), c) economically viable (generate income and reduce female drudgery), d) locally available or adaptable. A regional priority-setting exercise for scoping and prioritizing, led by the FAO, supported countries in identifying and prioritizing NUS that qualify as FSF. The FSF initiative started with an interdisciplinary priority-setting exercise comprising three phases in eight countries in Asia: Bhutan, Bangladesh, Cambodia, India (West Bengal), Lao PDR, Myanmar, Nepal, and Vietnam : 1) Stage 1: Scoping and identification of NUS (prior to Regional Expert Consultation) – Preliminary scoping report on the availability of NUS at the national level, – Circulation of a preliminary scoping report,– Review of a preliminary scoping report by international experts designated independently by partner institutions. 2) Stage 2: Validation and prioritization of NUS (during Regional Expert Consultation) – Joint validation of preliminary scoping reports from the selected countries – Ranking of high-potential NUS according to the four prioritization criteria (i.e., nutrient-dense, climate-resilient, economically viable, and locally available or adaptable) – Prioritization of 5–6 NUS crops per country. 3) Stage 3: Mapping Mapping of selected NUS according to their geographical availability/prominence using geographic information system – Preparation of GIS reports on selected crops by country. The regional priority-setting exercise targeted the food crops groups: (a) cereals, (b) roots and tubers, (c) nuts and pulses, (d) horticulture, and (e) others. Those NUS present in the national gene banks were considered for the exercise. The four FSF prioritization criteria were adapted as (a) nutritional benefits, (b) agricultural sustainability, (c) ecological sustainability, and (d) socioeconomic sustainability, with each criterion further broken down into a series of parameters (e.g., water requirement, drought tolerance, area under cultivation), requiring experts to provide an aggregated dataset on NUS related to each criterion. The FSF initiative also established the principle of country ownership. TheNUS scoping and prioritization results are owned by the participating country. Considering that NUS is contingent on the local context of each country, a species considered as NUS in one country may not be in another country. The NUS scoping and prioritization exercises are entirely country-driven, and the resulting NUS priority lists were determined by a multidisciplinary review of scientific data and specific conditions of the participating country. At the end of the exercise, 39 FSFs were selected and prioritized by the eight countries. All chosen FSFs have the potential to transform current conventional agricultural practices into more sustainable, nutrient-sensitive, and climate resilient agriculture systems.

Way forward

Future smart foods (FSF) can play a key role in transforming agriculture and food systems into diversified, nutrition-sensitive, and climate-resilient if they are mainstreamed into farming systems. Prioritization of NUS as FSFs is the first step. Moving forward, the FSF value chain must be promoted from production, post-harvest and processing, marketing to consumers and all stages of the food system are connected to minimize transaction costs. Future smart foods need to be produced and marketed in large quantities to guarantee economies of scale and access to up market outlets (groceries, supermarkets and export markets). Public policies promoting FSF as components of sustainable diets could encourage their use. Incentives can support farmers to grow and conserve NUS on-farm and ex-situ. Traditional food systems in India have developed over hundreds of years, featuring an abundance of nutritionally dense and climate-resilient foods: promoting these alternative options offers increased yield potential and an opportunity to diversify dietary patterns and generate income for the rural poor. Since, many Neglected Underutilized Species (NUS) can tolerate various stresses, which would not only make production systems more diverse but also more sustainable and climate-resilient. Their resistance to climate change implies that NUS can provide food when other crops fail. Moving forward, future endeavors should promote Future Smart Foods in terms of production, post-harvest and processing, marketing and consumption.

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22. Genetic Improvement of Vegetable Amaranth for High yield, Nutritional Quality and White rust resistance

B. Varalakshmi[1*], V. Keshava Rao[2], Naresh Ponnam[3], Sangeetha G.[4] and Acharya G.C[5]

[1]Principal Scientist, [3]Scientist, Division of Vegetable Crops,
[2]Principal Scientist, Division of Basic Sciences, [4]Principal Scientist, Division of Crop Protection, ICAR-Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru-560 089,
[5]Principal Scientist & Head, Central Horticultural Experiment Station (ICAR-IIHR), Bhubaneswar-750017
*Email: Varalakshmi.B@icar.gov.in

Introduction

Leafy vegetables are very rich source of minerals and vitamins like Vitamin A (Carotene), Vitamin C, Folic acid, Riboflavin, Thiamine, Iron and Calcium (Varalakshmi *et al*., 2009). They are also good sources of fibre, which helps in the proper functioning of the digestive system. Consumption of plenty of leafy vegetables offers protection against the bowl cancer which is one of the most common cancers. ICMR, New Delhi recommends daily intake of 50g of leaf vegetables, 100g root and tubers and 150g other vegetables /day/ adult (Narsinga Rao, 2013). Regular consumption of these leafy vegetables daily can substantially improve the good health of the population. Leafy vegetables are easy to grow and readily fit in any cropping system owing to its short duration. Vegetable amaranth is one such popular leafy vegetable grown extensively in India. Amaranth belongs to the family Amaranthaceae and consists of approximately 70 species. Among them, 17 species are used as edible leaves and 3 are used as food grains. It is a C_4 photosynthesis crop that easily adapts to adverse climatic conditions and is best suitable for sustainable agriculture.

Amaranth is one of the cheapest dietary sources in the tropics and sub-tropics and is highly profitable to small-scale farmers. Leaves are excellent source of dietary fiber, protein with essential amino acids (lysine and methionine) and minerals (calcium, magnesium, potassium, phosphorus, iron, zinc, copper, and manganese). Plant parts are widely used in traditional medicine as antiviral, antimalarial, anti-diabetic, antibacterial, anti-helminthic and snake antidote. Coloured leaves of some genotypes contain a unique source of antioxidant pigments such as betalain, β-xanthin, and β-cyanin. They are rich source of antioxidant phytochemicals such as vitamin C, phenolic acids, and flavonoids. It is mainly grown in kitchen gardens due to its fast growth which supplements the daily requirements of a family. Despite of its immense nutritional qualities, amaranth is considered an 'orphan crop' and still limited work has been done on its genetic improvement (FAO, 2018) for high yield and nutritional quality. Although they can be raised comparatively at lower management costs even on poor marginal lands, they have remained underutilized due to lack of awareness and popularization of technologies for utilization. Further, the production levels of amaranth is very low because of lack of availability of high yielding varieties.

Origin:

They leafy amaranth is said to be the native of India, while the grain types are originated from Central and South America.

Taxonomy:

Amaranth belongs to the genus *Amaranthus* and the family, Amaranthaceae which comprises 65 genera and 250 species. There are 50 to 60 edible species of the genus *Amaranthus*. The important species of leafy amaranth are *Amaranthus tricolor* L, *A. dubius* Mart exThell, *A. lividus, A. blitum, A tristis* L., *A. spinosus* L and *A. viridis*. The most popular grain amaranth species are *A. hypochondriacus* L, *A. cruentus* L and *A. caudatus* L. There are two sections in *Amaranthus* i.e., Amaranthus and Blitopsis with equal numbers of species in each. The species under the section Amaranthus have only terminal flower clusters and includes important grain types while the section Blitopsis has the species which have flower clusters in axils and includes the green types. All amaranth species have diploid chromosome number of either 32 (n=16) or 34 (n=17) except *A. blitum* which has x = n = 8 and *A. dubius* which is a tetraploid (2n=64).

Botany:

Annual, erect or trailing herb with deep tap root system. Stem green to purple with mixed shades of these two colours, glabrous and succulent leaves are simple and alternate, opposite, exstipulate, entire, lanceolate to obovate, with green to purple colours of petiole and lamina. The basic unit of inflorescence is dichasial cyme called glomerule. Flowers are small, mostly unisexual, monoecious, pentamerous, bracteate and bracteiolate, perianth parts are 4-5, stamens 2-5, carpels 2-3, syncarpous, ovary superior with one ovule, style single to 2 or 3 branched, fruit utricle, indehiscent, seed varying in colour, black, brown or white, compressed, smooth, shiny with floury endosperm.

Floral Biology:

The monoecious species of *Amaranthus*, have two types of arrangement of the staminate and pistillate flowers which has relevance to their breeding behaviour. In the first type, the first flower of each flower cluster is staminate, and all the secondary ones are pistillate. All species except *A. spinosus* belong to this group. In the second type, all flowers of each cluster are of same sex but the clusters of pistillate flowers develop only in the axils of the branches and at the base of the terminal inflorescence, while staminate flower clusters are borne terminally on the main axis and lateral branches. The species *A. spinosus* is of this type. Grain type of amaranth favours cross-pollination, while vegetable types are self-pollinated. The percentage of male flowers per glomerule is 0.5 to 1 in grain types and 10 to 25 in leafy types. The vegetable types are predominantly self-pollinated due to the presence of a number of male flowers per glomerule, small non showy terminal inflorescence and greater development of axillary glomerules. The extent of cross pollination in grain amaranth can be detected with the help of dominant green perianth colour employed as a marker gene and it varies from 16 to 35 %. The method of pollen transfer is generally through wind, sometimes by honey bees and bugs. The stigma of pistillate flowers is receptive 2-3 days prior to the opening of staminate flowers. Anthesis starts from the base of the inflorescence and proceeds towards the tip.

Techniques of selfing and crossing:

As vegetable types are predominantly self-pollinated, covering the inflorescence with butter paper bags when the first basal flower starts opening is enough for effective self-pollination. The same method can be followed for selfing grain amaranth also. But, from the breeding point of view, thesmall closely grouped flowers in glomerules make emasculation extremely difficult. For making crosses, the receptive stigmas are heavily pollinated and the staminate flowers are removed. Kauffman (1979) reported in detail the crossing technique. The lower florets which are already fertilized must be trimmed with a razor and similarly the apical portion. Emasculation is done in the middle portion of inflorescence.

Pollen from previously bagged inflorescence of male parent is collected by shaking the stamens into half a size gelatin capsules, which is then placed over the emasculated flower head. High seed set was obtained when pollination was done on three successive days. For covering the pollinated flower heads gelatin capsules were found to be the best. The flower heads are wrapped with a wisp of cotton which keeps the capsule in place until the head swells sufficiently to fill the capsule.

Genetic resources:

A collection of amaranths is kept at the Rodale Organic Gardening and Farming Research Center (OGFRC) at Kutztown, Pennsylvania, United States; South-East Asian accessions are kept at the Asian Vegetable Research and Development Center (AVRDC) at Tainan, Taiwan. African cultivars and introductions from OGFRC are kept at the National Horticultural Research Institute (NHR) in Nigeria and African cultivars at the AVRDC centre at Arusha, Tanzania and also at IBPGR (Grubben, 1981). Indian collections are kept at the National Bureau of Plant Genetic Resources (NBPGR), New Delhi (India). Many national institutes like TNAU, Coimbatore, ICAR-IIHR, Bengaluru, Kerala Agricultural University, Trissur, ICAR-CHES, Bhubaneswa, IARI, New Delhi, NBRI, Lucknow, and VPKVV, Almora have working collections including local cultivars. Evaluation and variability studies are needed of these germplasm holdings to reveal the amount of exploitable genetic variation.

Genetics of different traits:

Very few studies have been made on inheritance pattern in Amaranthus. The presence of 'V' shaped leaf spots is controlled by 2 dominant complementary genes Vm1 and Vm2 and the red seedling colour is controlled by single dominant gene Bd. Red plant pigmentation (RR) is dominant to green (rr). Spineness is dominant to non-spiny. Purple and green stem colours were found to be dominant over white stem colour. Nitrate content was a heritable quantitative character with low heritability in edible amaranth [*Amaranthus tricolor*] and direct selection for the trait had little effect. Amaranth genotypes with low nitrate content were characterized by light leaf colour, short leaf stalk, wide leaf blade and small plant spread (Lin et al., 1994). The pre-dominance of non-additive gene action for plant height, leaf number, leaf length, leaf breadth, stem girth, stem weight, leaf weight and plant weight and additive gene action for leaf stem ratio in Amaranth was reported by Reddy and Varalakshmi (1998). High heritability coupled with high genetic advance for foliage yield, leaf size, leaves/plant, stem diameter, oxalic acid, vitamin C, fibre, potassium and calcium content were reported in Amaranthus tricolor L indicating the predominance of additive gene effects. Thus, foliage yield can be increased substantially in vegetable amaranth through indirect selection based on these characters namely, leaf size, leaves/plant and stem diameter (Sudhir-Shukla and Singh, 2000, 2005; Shukla et al., 2005 and Shukla et al., 2006).

Breeding objectives:

The broad objectives of breeding are collection and evaluation of amaranth types with high yield potential with resistance to pests and diseases. The characters to be looked for in an ideal leaf type are:

- Leaf stem ratio: the leaf stem ratio has negative association with green yield indicating a high yield should always have a low leaf stem ratio and vice-versa.
- Yield of green matter
- late bolting habit
- succulent, non-fibrous stem with broader and more number of medium size leaves,

- low leaf oxalates and nitrates,
- fleshy, larger diameter of stem in pulling types
- medium plant height good regenerating ability in cutting types, quick growing ability immediately after sowing in case of pulling types and
- longer shelf life.
- high antioxidants, low oxalates and nitrates and
- resistance to white rust and leaf spot.

Breeding Approaches

Vegetable amaranth is valued for its nutritious leaves and stems. Despite its merits, so far, it has not received enough attention as it should deserve in its improvement. Critical evaluation of the available types and selection of improved types with high yield potential will certainly be a boon for increasing the production of this highly nutritious vegetable. However, of late amaranth breeding is getting its due importance with sustainable efforts by breeders at various research organizations involving in the development of not only high yielding varieties but also nutritionally rich amaranth varieties (Varalakshmi *et al*., 1998, 2001, 2011)

A. Genetic Improvement of Vegetable Amaranth for high yield:

Selection

Local germplasm exploration, collection and conserving genetic diversity is an important activity for the selection of suitable accessions/ ecotypes which best adapt to such regions and can be explored in genetic improvement programs. Genetic improvement of amaranth in India was carried largely through simple procedures of selection from the local collections of land races available. The varieties released so far are either pure line selections or native introduction from the land races (Varalakshmi *et al.,* 2001). Variability studies in vegetable amaranth showed high genotypic coefficient of variation, heritability and genetic advance for stem weight, leaf stem ratio, leaf weight and yield of greens indicating the scope for selection for the improvement of amaranth. Positive association among these characters also strengthens the scope of improvement through selection. Among the germplasm lines, IIHR-7, IIHR-65 and IIHR-124 were the late bolters, flowering 55 days after sowing, which is a desirable character in leafy vegetables to obtain higher leaf yields. Three germplasm lines, IIHR-4, IIHR-31 and IIHR-38 were found suitable for "stem amaranth" type with thick (>7 cm stem girth) and tender stems each weighing >120g, where as IIHR-47, IIHR-56, IIHR-66, IIHR-100, IIHR-107 and IIHR-114 were found suitable for "multi cut" type of amaranth with very good regeneration after cutting (Varalakshmi, 2004).

List of varieties developed through selection

ICAR-IIHR, Bengaluru

Arka Suguna (*A. tricolor):* It is notified for cultivation in the state of Karnataka. It is a pure line selection from exotic introduction from Taiwan, IIHR Acc. No.13560. It has broad light green foliage, succulent stem, rich in calcium and iron, yielding 30 t/ha. in 6-8 cuts.

Arka Arunima (*A. tricolor):* It is a pure line selection from IIHR Acc. No.18384. It has broad, purple leaves**,** succulent stem and yielding 27 t/ha in 3 cuts. It has low oxalate and nitrate contents and resistant to white rust under field conditions

Arka Suguna　　　　Arka Arunima

ICAR-IARI, New Delhi

Chhoti Chaulai (*A blitum*): It is developed through selection. It is suitable for leafy shoots, plants erect with thin stem, slightly dwarf, leaves small, green in color, responds well to cutting, suitable for early summer and rainy season

Badi Chaulai (*A tricolor*): It is developed through selection. It is suitable for leafy shoots, thick stem, slightly dwarf, leaves large, green in color, responds well to cutting, suitable for summer and long growing period.

Pusa Kiran (*A. tricolor x A. Tristis):* A promising selection from a natural cross between *A. tricolor x A. tristis.* Leaves are glossy green with broad ovate lamina, 70-75 days, yield 35 tonnes/ha. Suitable for kharif and summer seasons.

Vegetable Amaranth varieties developed in the country by different organizations

TNAU, Coimbatore

Co-1 (*A. dubius):* Green leaves, high yield, resistant to leaf spot caused by *Rhizoctonia.* The leaves are broad, thick and dark green in colour, pulling type. High yielding variety tolerant to leaf spot disease. It yields 7-8 t/ha at 25 days after sowing

Co-2 (*A. tricolor):* Green type amaranth. High yielding variety tolerant to leaf spot disease. The plants are erect with moderate branching. Yield 10.75 t/ha. The crude fibre content is less (1.3%) with 19.0 mg of iron and 20.0 mg of calcium per 100g.

Co-3 (*A.tristis):* Green type multi-cut amaranth. Crop duration 3 months. First harvest 20 DAS. 10 cuttings can be taken.Tolerant to leaf spot disease. The leaf to stem ratio is high (2.0). The plants are erect with green nutritious leaves containing 25.2 mg per 100g of vitamin C, 1.74% crude fibre, 0.8% iron and 2.48% Ca. Yield 30.72 t/ha

Co-4 (*A.hypochondriacus) :*Green leaves, Make rapid vegetative growth in 20-25 days, high yield, 7.0-8.0t/ha., dual purpose, grain yield 2-2.5t/ha.

Co-5 (*A. tricolor):* Plants medium tall, stem and leaves are pinkish red, yields 40 t/ha

Co 1

Co 2

Co 3

Co 4

Co 5

ICAR-IARI, New Delhi:

Pusa Kirti (*A. tricolor):* The leaf and stem both are edible. The Leaves are green with broad ovate lamina, stem green, first cut in 30-35 days then at every 10-12 days interval cuttings can be taken, yield 55 tonnes/ha.

Pusa Lal Chaulai (*A. tricolor):* Leaves are purplish-red and stem is deep-red in colour. 33 days, yield is 49 tonnes/ha suitable for both summer and kharif seasons.

KAU, Thrissur:

Arun: It is a red amaranth variety. Crop duration 54-140 days. Purple coloured big leaf. Suitable for cultivation in all seasons. Harvesting can be done many times. Yield 20 t/ha

Kannara Local: It is red coloured season bound variety of amaranth. The plant comes to flower in November-December. The variety is recommended for cultivation in Kerala

Mohini: It is a green amaranth variety developed at College of Horticulture, Vellanikkara (KAU). Crop duration 120 days. Plant height 80-90 cm. Suitable for summer season. Leaf dark green. Medium branching. Yield 13.2 t/ha

KAU Vaika: Local collection from Vellarada, High yielding, late bolting, multi cut variety with red coloured stem and leaves and long vegetative growth period. Productivity Yield 783.18 g/plant.

A. Breeding for high nutritional quality and low anti-nutritional quality

The recent research on the improvement of nutritional and anti-nutritional qualities of amaranth conducted at ICAR-IIHR, Bengaluru has resulted in the identification of amaranth genotypes with high antioxidant capacity namely, IIHR-74 (355 mg/100g AEAC), IIHR-70 (265 mg/100g AEAC) and IIHR-65 (255mg/100g AEAC). IIHR-7 recorded lowest amounts of oxalates and nitrates (108.38 mg/g d.w.b and 24.47 mg/ 10 g d.w.b respectively). Genetical studies indicated that the nitrate content was under the influence of additive gene action, whereas anti-oxidant capacity and oxalate content were controlled by non-additive/dominance gene action in amaranth. Out of 12 advanced breeding lines with high antioxidant capacity and low oxalate and nitrate content, two lines were identified for release with high antioxidant activity and low nitrates and oxalates (Varalakshmi *et al*., 2011 and Varalakshmi, 2011)

ICAR-IIHR, Bengaluru

Arka Samraksha (*A. tricolor):* This variety has been notified for the cultivation in Karnataka state. It has been developed by the modified bulk method of selection from the segregating population of the cross, IIHR-4 x IIHR-70 in F_6 generation. high yielding amaranth variety -with high antioxidant activity of 499 mg (AEAC units) and minimum nitrate content of 27.3 mg and 1.34g of oxalates per 100 g fresh weight of leaves. It is a pulling type amaranth variety with green leaves and stem, yields 10.9 t/ha in 30-35 days duration.

Arka Varna (*A. tricolor):* This variety has been notified for the cultivation in Karnataka state. It has been developed by the modified bulk method of selection from the segregating population of the cross, IIHR-7 x IIHR-30 in F_6 generation. It is a high yielding amaranth variety with high antioxidant activity of 417mg (AEAC units), nitrate content of 37.6 mg and 1.42g of oxalates per 100 g fresh weight of leaves. It is a pulling type amaranth variety with green leaves and pink stem, yields 10.6 t/ha in 30-35 days duration.

Evaluation of advanced breeding lines done at CHES, Bhubaneswar for quality traits indicated significant variability in the ABLs for nutritional components (d.w.b) such as protein content (18.19-27.50 %), total phenols (568.62-1220 mg GAE /100g), FRAP antioxidant activity (559.83-1531.17 mg AAE/100g), total flavonoids (352-1284 mg CA/100g) and DPPH Antioxidant activity (347.00-1397.00 mg/100g). The ABLs also differed in their mineral nutrient content in terms of N (2.91-4.40 %), P (0.41-0.60%), Ca (1.60-2.40%), S (0.25-0.32%), Fe (831.13-1168.48 ppm), Mn (285-1146.96 ppm), and Zn (133.85-206.29 ppm) (Naresh *et al*., 2023, accepted). This variability can be exploited for the development of nutritionally rich amaranth varieties.

Arka Samraksha

Arka Varna

KAU, Thrissur

Renusree: It is a green amaranth variety. Stem red colour and leaf green colour. Can be grown in all areas. Six to eight harvests can be taken. Yield 15.5t/ha. High nutritive value and low anti-nutritional factors.

Krishnasree: It is red amaranth variety. Stem red colour and leaf reddish green colour. Can be grown in all areas. Six to eight harvests can be taken. Yield 14.8t/ha. High nutritive value and low anti-nutritional factor.

C. Breeding for disease resistance against White rust:

The major disease affecting the marketable yield of amaranth in the tropics and sub-tropics is white rust caused by *Wilsoniana bliti* (Biv.) Thines. Genetic improvement for the development of resistant varieties is the most sustainable approach. At ICAR- IIHR, Bengaluru, ten germplasm lines were identified as resistant against white rust namely, IIHR-37, IIHR- 40, IIHR- 49, IIHR-50, IIHR- 70, IIHR- 111, IIHR-112, IIHR-119, IIHR- 122, and IIHR-124 (Varalakshmi and Celia Chalam, 2002). Also the earlier released high yielding varieties, Arka Arunima and Arka Suguna possess the field tolerance/resistance to white rust.

At CHES, (ICAR-IIHR), Bhubaneswar, germplasm has been explored and through individual plant selection and selfings, advanced breeding lines were developed. Through field screening and artificial challenge inoculation, advanced breeding lines (ABLs) with high levels of white rust resistance were identified. Over three years of evaluation three advanced lines viz., Arka Neelachal Ruchitha, Arka Neelachal Vrichitha and Arka Neelachal Bainishi with good local consumer preference in different color segments with high level of resistance of white rust has been identified for commercial cultivation (Naresh *et al*., 2023 accepted).

Arka Neelachal Ruchitha (*Amarnthus blitum*)

This is a pure line selection from the germplasm collection of Amaranthus blitum. It is a multi cut type. Fleshy tender yellowish green stem with obovate green small leaves. Yield potential of 22.59 t/ha. Resistant to white rust.

Arka Neelachal Vrichitha (*A. tricolor):*

This is a pure line selection from the germplasm collection. It is a pulling type, fleshy tender greenish pink stem with ovate green leaves having purple blotches, suitable for rabi and pre-summer season, resistance to white rust. Yield potential of 7.08 t/ha

Arka Neelachal Bainishi (*A. tricolor):*

This is a pure line selection from the germplasm collection. It is a pulling type, fleshy tender pink stem, pink petiole with greenish purple leaves suitable for rabi and pre-summer season. Resistant to white rust having yield potential of 8.58 t/ha.

Arka Neelachal Ruchita

Arka Neelachal Vrichita

Arka Neelachal Bainishi

Hybridization: Planned breeding work through hybridization has not so far been undertaken with the object of developing new varieties. Only recently, attempts have been made in USA and India involving grain and vegetable amaranth types. But the experimental inter specific hybrids indicated the existence of hybrid in viability, weakness, sterility, seedling mortality stunted and deformed plants, leaves, flowers and pollen and ovule sterility.

Male sterility: Male sterility was genic cytoplasmic type and may be with one or two nuclear restorer genes. Male sterility was associated with abnormal tapetal cell functioning and microsporogenesis failure prior to the first metaphase leading to abortive anthers.

Polyploidy breeding: 0.25% aqueous solution applied to the growing points of *A. caudatus* gave 50% increase in seed weight with late flowering and dwarf plant type. Though the initial response to autoploidy is encouraging, much will depend upon how these gigas characters are maintained in subsequent generations, which needs to be still investigated.

Mutation breeding: As the tiny nature of amaranth flowers make the emasculation extremely difficult for crossing and the presence of inter specific hybrid sterility, mutation breeding may be thought of as an alternate method. But unfortunately very little work in this line has been attempted which resulted in the production of fascinated and curled leaf mutants with chemical and physical mutagens. The *gamma* -irradiation caused greater variability in greens yield and component traits like earliness, dwarf stature, broad leaf characters, late flowering, basal branching, high regrowth ability etc., which widened the scope for selection.

Tissue culture Studies: Explants of leaf, hypocotyl and protoplast were cultured using Basal B5 medium supplemented with different combinations of 2,4-D, alpha NAA and Benzyl Adenine. In leaf culture, embryoid formation was successfully induced. It is also established that *A. tricolor* can be successfully grown in tissue culture, having determined the optimum nutrient and hormone levels of prolific callus growth.

Crop notification by PPV&FRA, New Delhi and DUS Testing:

Crop notification for registering vegetable amaranth varieties has been issued during April, 2016 by PPV&FRA, New Delhi. Under this, once the application for registration of new varieties is submitted, they will be tested for two years at the Nodal Centre, ICAR-IIHR, Bengaluru and Co-nodal centre, at ICAR-IARI, New Delhi.

Researchable Issues:

- Organizing specialized and targeted exploration programs for the collection of the genetic variability present in vegetable amaranth and then characterizing and conserving the collected germplasm.
- Evaluation of indigenous and exotic germplasm lines and initiation of hybridization programs for transferring quality traits.
- Developing varieties with high yield potential, high leaf to stem ratio and late bolting habit.
- Developing varieties with enhanced nutritional qualities especially Protein, Calcium, Iron, Vitamin A and Vitamin C rich varieties.

- So far, very limited molecular breeding work has been done. Hence there is a need to identify trait specific molecular markers to hasten the breeding programs.
- Developing disease resistant varieties against white rust and *rhizoctonia* blight
- Developing varieties with low anti-nutrient factors i.e., oxalates and nitrates
- Developing varieties/elite lines with good processing qualities (leaf protein concentrates) to meet the requirement of the processing industry.
- Development of low cost technologies for the preservation of greens (dried leaves/leaf powders) along with the retention of nutritive values.
- Developing integrated pest and disease management schedules

Challenges

- Promotion of kitchen garden/ nutrition gardens for creating awareness to increase the intake of greens.
- Introduction of amaranth leafy vegetable concentrates in the mid-day meal programs of school children will go a long way in combating the nutritional deficiency disorders.
- Promotion of "Micro greens concept" for providing fresh/nutritious amaranth
- Encouraging scientists to take up basic/fundamental research programs to accelerate the work on different aspects of vegetable amaranth by way of providing sufficient financial assistance and manpower.

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23. Lesser-known leafy vegetables for Food and Nutritional Security

G. C. Acharya*, A.V. V. Koundinya, Adamala Anil Kumar and Satyapriya Singh
*Head, IIHR- Central Horticultural Experiment Station, ICAR-Indian Institute of Horticultural Research, Bhubaneswar-750017, Odisha

Introduction

"The plain fact is that every mouthful of food you eat comes from the natural world. There's no food that nourishes you that doesn't come from the natural world. Every lungful of air that you take is refined by the natural world, oxygen breathed out by plants. If you can't breathe and you can't eat, you don't exist."………………………………… David Attenborough

The United Nations Sustainable Development Goals (SDGs) are a universal call to achieve a sustainable future and promote equality, human rights, and justice for all by 2030. Adopted by UN Member States in 2015, the 2030 Agenda for Sustainable Development provides a shared strategy for peace and prosperity for all people and our planet, now and into the future. The SDGs are a collection of 17 interlinked goals designed to guide reflection and action on the most pressing challenges and opportunities facing humanity and the natural world, including; zero hunger (SDG 2), no poverty (SDG 1), good health & well-being (SDG 3), climate change (SDG 13), peace and justice (SDG 16), and global cooperation to meet global targets (SDG 17). These goals and their targets acknowledge that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, social inequalities, and economic disparities–all while tackling climate change and working to preserve our natural surroundings.

The number of people facing hunger and food insecurity has been rising since 2015, with the pandemic, conflict, climate change and growing inequalities aggravating the situation. As of 2021, the number of people suffering from hunger was close to 800 million, still far above pre-pandemic levels. Despite global efforts, in 2022, an estimated 45 million children under the age of 5 suffered from wasting, 148 million had stunted growth and 37 million were overweight. A fundamental shift in trajectory is needed to achieve the 2030 nutrition targets. After remaining relatively unchanged since 2015, the prevalence of undernourishment jumped from 8.0 to 9.3 per cent from 2019 to 2020 and rose at a slower pace in 2021 to 9.8 per cent. Between 702 and 828 million people were affected by hunger in 2021. The number has grown by about 150 million since the outbreak of the COVID-19 pandemic – 103 million more people between 2019 and 2020 and 46 million more in 2021. Projections are that nearly 670 million people will still be facing hunger in 2030 – 8 per cent of the world population, which is the same as in 2015 when the 2030 Agenda was launched. Around 2.3 billion people in the world were moderately or severely food insecure in 2021, or nearly 30 per cent of the global population – more than 350 million more people than in 2019, the year before the COVID-19 pandemic unfolded. Close to 40 per cent of people affected by moderate or severe food insecurity in the world were facing food insecurity at severe levels. The prevalence of severe food insecurity increased from 9.3 per cent in 2019 to 11.7 per cent in 2021 – the equivalent of 207 million more people in two years.

Biodiversity is essential to food and agriculture

Biodiversity is the variety of life at genetic, species and ecosystem levels. It is the range and variety of

Earth's plants, animals and micro-organisms and is vital to food security. Biodiversity's contributions to food security are often made more effective and reliable by the presence, or availability, of a range of different species and of genetically diverse populations within species. Biodiversity, at genetic, species and ecosystem levels, is important for addressing the challenges posed by diverse and changing production systems, promoting resilience, improving livelihoods and supporting food security and nutrition. Many practices and approaches improve diversification – using multiple species, integrating the use of crop, livestock, forest and aquatic resources, and conserving and managing habitat diversity at landscape or seascape scale. Traditional producers and indigenous peoples have a wealth of knowledge on biodiversity and its use in the supply of food. Although indigenous peoples constitute only 5 per cent of the world population, it has been estimated that they manage or have tenure rights over about 40 per cent of the planet's protected areas and a similar proportion of its ecologically intact landscapes.

Biodiversity is in decline

Across the globe, biodiversity is in decline. Key threats to the biodiversity that contributes to food and agriculture include damaging land-use and water-use practices, often including those associated with food production systems, overharvesting, pollution from a variety of sources, invasive species and the effects of climate change. The world's agriculture is heavily dependent on a narrow range of species. Only 9 species supply nearly 66 per cent of our total crop production, and only 8 of the 40 domesticated mammalian and avian species provide more than 95 per cent of the human food supply from livestock. Ten species account for 50 per cent of total aquaculture production (FAO, 2019b). Production is often also based on a narrow range of within-species genetic diversity, for example, dominated by a few crop varieties or livestock breeds. In many cases, domesticated biodiversity is declining as production systems intensify. Biodiversity needs to become central to the way we think about human well-being, food security and health. Our actions today need to change for the sake of tomorrow.

Biodiversity and traditional Leafy vegetables

There exists a vast resource of undermined plants that can help partly alleviate current problems of malnutrition and under-nutrition, especially in rural areas where malnutrition is increasingly being seen as a consequence of enforced dependence on external food resources mostly obtained from large scale commercial agriculture systems. Green leafy vegetables (GLV) are a part of the larger biodiversity and are an integral part of the diets in eastern India in states like Odisha and West Bengal. They play a significant role in our nutrition and diet and are also used as medicine since ancient times. They are also important sources of protective foods.

Traditional leafy vegetables and food and nutrition security

Several studies have reported that indigenous leafy vegetables address gaps in nutrition by providing wholesome, reasonably priced and nutrient-dense food substitutes. Even though traditional leafy vegetables (TLV) have not been fully exploited in the quest to achieve food safety and alleviate malnutrition, many researchers agree that the vitamins, minerals, and phytochemicals with strong antioxidant properties and nutritional (micronutrient) content in TLVs are their most valuable attributes. The capacity of a food to provide nutrients is of great importance in food security. Indigenous leafy vegetables are diverse and include many different species. Globally, over 7000 species of leafy vegetables are either cultivated or harvested from the wild for food. Amongst these, ILVs that vary in shape, size, colour, taste and nutritional value are consumed in nearly all countries. Few of these leafy vegetables are being maintained at CHES, Bhubaneswar (Table-1).

Traditional leafy vegetables offer a higher nutritional value and would ensure an appropriate supply of those nutrients identified to be lacking if they are consumed in suitable proportions. Since they contain significant amounts of vitamins, pro-vitamin A in particular, they are highly beneficial since they maintain health and prevent diseases. As an antioxidant, vitamin A plays an important role in preventing free oxygen radicals from causing damage to cells and, by so doing, reduces the incidence of some cancers, heart attacks, brain strokes, and maintains eyesight and the immune, skeletal, respiratory, reproductive, and integumentary (skin) systems. Traditional leafy vegetables are rich sources of polyphenols, flavonoids, amino acids, minerals, vitamins A and C, β-carotene and dietary fibre. These bioactive components are involved in protection against various conditions including cancer, diabetes mellitus, arthritis and more. These species are also found as rich in phytonutrients. Their leaves contain significant amounts of major and micronutrients. Species like punarnava, carpet weed, small water clover, flame flower, smooth joy weed and watercress have high nitrogen content (>3.00%) while smooth joy weed and Chinese spinach are rich in potassium (>1.50%). Watercress is found to have a high amount of Ca and Mg when compared with the underutilized species. Watercress, dwarf copper leaf, Asiatic pennywort, and carpet weed are rich in Fe and Mn content. Chinese Spinach, Smooth joy weed and flame flower are also found to have high amounts of Manganese. Asiatic Pennywort, buffalo spinach and watercress have high amounts of Zinc in their leaves. Cu is found to be high in buffalo spinach, Chinese fever vine and flame flower leaves on a dry weight basis.

There is a necessity to characterize these important indigenous leafy vegetables for their phytonutrient contents and promote their consumption among rural and tribal communities where malnutrition, hunger and hidden hunger are prevailing problems. They are the cheaper source of nutrients and vitamins. Because of their short-duration nature and low input cultivation, they can easily fit in any cropping or farming system. Some of these vegetables like Amaranthus, Palak and Ipomea species are tolerant to adverse environmental conditions such as soil acidity and salinity. Few of them are aquatic vegetables suitable for waterlogging conditions and flood-prone areas. Therefore, their cultivation in diversified cropping system models not only enhances income and health but also reduces the risk that arises due to climate change. Few of these indigenous leafy vegetables of Odisha are not being cultivated commercially and a detailed package of practices are not available. Hence, there is a need to develop a package of practices for these crops. Besides, there is also a necessity for promoting these indigenous vegetable cultivation and consumption among the farmers by creating awareness programmes and training.

Table 1: Some of the important traditional leafy vegetables being maintained at IIHR RS Bhubaneswar

Sl. No.	Local name	Scientific name	Family	Season of availability
1	Mati Poi	*Talinum portulacifolium*	Portulacaceae	Mostly rainy season,
2	Ghoda Puruni	*Boerhavia diffusa*	Nyctaginaceae	Rainy season
3	Lata saga	*Rivea hypocrateriformis*	Convolvulaceae	Throughout the year
4	Sunsunia	*Marsilea polycarpa*	Marsiliaceae	Rainy
5	Kansiri saga	*Commelina benghalensis*	Commelinaceae	Rainy, post-rainy

6	Pasaruni	*Paederia foetida*	Rubiaceae	Summer, rainy
7	Puruni saga	*Portulaca oleracea*	Portulacaceae	Summer, rainy
8	Madaranga	*Alternanthera sessilis*	Amaranthaceae	rainy
9	Gayasa	*Leucas aspera*	Lamiaceae	Rainy,
10	Pita saga	*Glinus oppositifolius*	Molluginaceae	summer
11	Kalam saga	*Ipomoea aquatica*	Convolvulaceae	Rainy
12	Kansiri saga	*Commelina benghalensis*	Commelinaceae	Rainy
13	Bana dhania	*Eryngium foetidum*	Apiaceae	Mostly rainy, winter (shade)
14	Pancha patri	*Euphorbia spp*	Euphorbiaceae	Winter/rainy
15	Kuler	*Bahunia spp*	Fabaceae	Throughout year
16	Hidmilchi	*Enhydra fuctuans*	Asteraceae	Summer/rainy
17	Khata saga	*Oxalis corniculata*	Oxalidaceae	Rainy
18	Kolkata madaranga	*Alternanathera spp*	Amarathanceae	Summer
20	Bathua saga	*Chenopodium album*	Chenopodiaceae	winter
21	Sunsunia saga	*Marsilea polycarpa*	Marsiliaceae	Rainy
22	Agasti	*Sesbania grandiflora*	Fabaceae	Perennial
24	Muthi saga	*Polygonum plebeium*	Polygonanceae	Rainy/ winter

Indigenous Traditional Knowledge associated with underutilized leafy vegetables

These underutilized leafy vegetables have several medicinal properties. Albeit the medicinal properties associated with these crops are not yet scientifically proven in the majority of these crops, they are being constantly used by the rural/tribal communities based on the traditional knowledge that travelled generation after generation through hearsay. The below table houses the medicinal properties of these species based on Indigenous Traditional Knowledge.

Table-2: Medicinal properties of the underutilized species based on Indigenous Traditional Knowledge

S. No.	Content	ITKs
1	Flame Flower	The leaves are used by the local inhabitants against constipation
2	Asiatic Pennywort	The leaves are used as tonic for improvement of brain power. It is also used against many skin conditions and healing of wounds
3	Small Water Clover	The leaves are used for improving the digestion. It is also used as aphrodisiac. Leaves are also used for increasing eye-sight for greater visibility
4	Chinese Spinach	The plant juice is used as an emetic
5	Dwarf Copperleaf	The stems and leaves are used against eye related ailments. People use it as a cooling agent to decrease the high fever and as an ingredient for hair oil. Decoction with little salt is drunk to check blood vomiting.
6	Midnapore Creeper	The tribal people use the plant for its ethno-medicinal uses in treating cough, headache, and skin disease.
7	Buffalo Spinach	It is used for skin infections by the certain sections of the tribal people. It is also used as a laxative.

8	Water cress	It is used in the traditional medicine system for the treatment of various ailments like leprosy, sore throat, opthalmia, burns, pain and inflammation.
9	Orchid Tree	This plant has been known to possess antibacterial, antidiabetic, analgesic, anti-inflammatory, anti-diarrheal, anti-cancerous, nephroprotective and thyroid hormone regulating activity.
10	Punarnava	The plant is used as an emetic and purgative. The leaves are used against skin disease
11	Cork Swallow-Wort	The aqueous extract of the leaves are used against storage pest of food grains.
12	Horse Purslane	Decoction of the plant are given for fever, rheumatism, and as an antidote for alcohol poisoning
13	Creeping Woodsorrel	It is used as a hyper accumulator of copper. It can also be used for Phytoremediation
14	White Goosefoot	It is very useful in treating kidney stone and reducing the formation of stone. It is also used for inner and external swellings, jaundice, irregular period, curing infections after delivery, anemia and for blood purification.
15	Smooth Joyweed	It is used as a local medicine often in mixtures with other medicinal plants, to treat hepatitis, tight chest, bronchitis, asthma and other lung troubles. The leaves and shoots boiled and drunk as antihypertensive remedy.
16	Water Hyssop	It is now acknowledged as a nootropic, which is a "smart drug" that enhances brain function.
17	Small knotweed	The crushed seeds are cooked and eaten as a remedy against constipation, stomach pain, and diarrhoea.
18	Chinese Fever Vine	Therapeutically, it is considered as an aphrodisiac. It improves strength and immunity, and is also useful in wound and bone healing besides relieving inflammation and stiffness
19	Indian Chestnut Wine	It is having a long history in ethnomedicines for the treatment of many diseases such as menstrual disorders, rheumatic pain, bruises, gastralgia and other related diseases.
20	Headache Tree	It is used to treat inflammation, immune-related diseases, and stomach disorders, wound healing, and skin diseases.
21	Chekurmanis	Leaves are used as an antidiabetic, to treat ulcers, eye disease, and tonsillitis
22	Indian Cherry	Plant is well-known for its medicinal properties against variety of diseases primarily hepatocellular disorders (Liver cancer).

Conclusion

Traditional leafy vegetables are characterized by limited research efforts, breeding efforts, germplasm characterization, knowledge of species distribution and production levels, and representation in *ex-situ* collections. A dearth of information and poor awareness may allow useful species to be overlooked through a vicious cycle of neglect and underutilization. Declining use and eroding knowledge of traditional vegetables have been observed in many places around the world, which threatens their persistence into the future and limits the delivery of their benefits to society. So, there is a need to identify the importance of leafy vegetables in terms of nutrition and food security, to ensure the characterization and conservation of traditional leafy vegetables and to achieve income and production sustainability

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24. Underexploited vegetables: potential source of nutritional and livelihood security

Rajesh Kumar*, Shivam Kumar Rai, Indivar Prasad
ICAR-Indian Institute of Vegetable Research, Varanasi
*Email: rajes74@gmail.com

Introduction

Nutrition has captured the international spotlight in unparalleled way as persistent global hunger and under nutrition has underscored the need for urgent action. One in eight people around the world still suffer from hunger, and more than double of that are victims of hidden hunger. It is estimated that agricultural production has to increase by 70% by 2050 to cope with an estimated 40% increase in world population. Agriculture is under immense pressure to produce greater quantity of food, feed and bio-fuel on limited land resources for the projected nine billion people on the planet by 2050.

In the quest to address India's complex nutritional challenges, including widespread anemia, micronutrient deficiencies, and the emergence of over nutrition in urban areas, it is clear that a holistic approach is required. While the issues of Protein Energy Malnutrition (PEM), Iron Deficiency Anemia (IDA), Iodine Deficiency Disorders (IDD), and inadequate vegetable consumption loom large, there lies a significant opportunity waiting to be explored - the realm of highly nutritious, underexploited vegetables. Furthermore, the Expert Committee of the Indian Council of Medical Research has emphasized the need for increased vegetable consumption, especially green leafy vegetables and other nutritious options. They recommend that every individual should consume at least 300 g of vegetables daily, in addition to regular consumption of fresh fruits. In the face of these nutrition-related adversities, it is imperative to recognize the potential of these lesser-known vegetable crops. The future demand can be fulfilled only by efficiently utilizing the nutritional and medicinal properties of underutilized vegetables. Currently, underutilized food sources includes minor grains and pulses, root and tuber crops and fruits and vegetables and non-timber forest products.

Underutilized crops/vegetables

Underutilized crops/plant species as "those species with underexploited potential for contributing to food security, health (nutritional/medicinal), income generation, and environmental services" (Jaenicke and Hoeschle, 2006). To be considered as an 'underutilized vegetable crops', a plant must have the following features:

- Crop must have a scientific or ethno botanical proof of food value.
- Crop must have been cultivated, either in the past or only being cultivated in a specific geographical area.
- It must be currently cultivated less than other conventional crops.
- Crop must have weak or no formal seed supply system.
- Crops are recognized to have indigenous uses in localized areas.
- Received little attention from research, extension services, farmers, policy and decision makers and technology providers.

- May be highly nutritious and/or have therapeutic medicinal or therapeutic properties or other multiple uses.

Amidst this nutritional shortfall, underexploited vegetables stand as a beacon of hope. These vegetables, though minor and often overlooked, boast a rich nutrient profile, providing vitamins, minerals, carbohydrates, proteins, and fats in abundance. They are a vital source of essential nutrients, such as beta-carotene, folate, calcium, riboflavin, and iron, addressing deficiencies that plague the nation's health. Moreover, underexploited vegetables have the advantage of being hardy and resilient, thriving in adverse climatic and soil conditions. This resilience ensures a consistent supply of these nutrient-rich crops, bolstering the battle against malnutrition and deficiency diseases, particularly among the rural population, including young children under the age of three.

While the nutritional potential of these vegetables is undeniable, their cultivation and promotion remain limited, overshadowed by more popular crops. The prevailing research focus on mainstream vegetables like tomatoes, chili, and cucumbers has left the potential of these underutilized vegetables largely untapped. In the face of climate change, with its unpredictable shifts in rainfall patterns, temperatures, and the ever-present threat of pests and diseases, the importance of underexploited vegetables cannot be overstated. Their adaptability to such changing conditions makes them an invaluable asset in the quest for nutritional security, poverty alleviation, and sustainable agricultural practices.

Therefore, as we explore the intricate relationship between nutrition and health in India, it becomes increasingly evident that underexploited vegetables hold the key to fulfilling the nutritional requirements of the nation's diverse population (table 1). These crops not only offer a solution to current dietary deficiencies but also represent an opportunity to safeguard the health and well-being of future generations. By harnessing the potential of these highly nutritious, underutilized vegetables, India can take significant strides toward a future where optimal nutrition and health outcomes are within reach for all.

Income generation and livelihood Security through underexploited vegetables

Vegetables in general, but also many traditional vegetables such as water spinach (*Ipomoea aquatica*), Chinese kale (*Brassica oleracea* var. *alboglabra*), edible rape (*Brassica napus*), roselle (*Hibiscus sabdariffa*), basella (*Basella alba*), slippery cabbage (*Abelmoschus manihot*), winged bean (*Psophocarpus tetragonolobus*), amaranth (*Amaranthus* spp.), jute mallow (*Corchorus olitorius*), African nightshade (*Solanum scabrum*) and African eggplant (*Solanum aethiopicum*), drumstick tree (*Moringa oleifera*) and many gourd species are of considerable commercial value and thus can make a significant contribution to household income. Value addition by applying appropriate production and postharvest techniques ensures that high quality produce reaches the market and satisfies consumer expectations. Now in the society selected traditional underexploited vegetables are becoming an increasingly attractive food group for the wealthier segments of the population and are slowly moving out of the underexploited category into the commercial mainstream.

Current research priorities of ICAR-IIVR, Varanasi are genetic improvement of winged bean, cluster bean, vegetable soybean, velvet bean, Indian bean, faba bean, baby corn, sweet corn, water spinach, water chestnut, lotus, kale, basella, moringa, round gourd, long melon, summer squash, snap melon, amaranthus, Chinese cabbage, *Vigna spp*., *Luffa spp*, ivy gourd, spine gourd, teasel gourd and *Chenopodes*. In furtherance of these objectives, ICAR-IIVR employs diverse skills including geneticists, crop physiologists, nutritionists, aqua-culturists, food scientists, computer programmers, soil scientists, social scientists and information specialists.

Table 1: Categories and Examples of Underexploited Vegetables in India

Category	Examples of underexploited vegetables
Underutilized Cucurbitaceous Vegetables	Sponge gourd, wild cucumber, spine gourd, pointed gourd, ivy gourd, sweet gourd, etc. Most are important minor vegetables in Northern, Eastern, and Southern India.
Underutilized Legume Vegetables	Broad bean, cluster bean, Indian bean, sword bean, lima bean, etc. Legumes are valuable for fixing nitrogen in the soil and as a source of protein.
Underutilized Leafy Vegetables	Indian spinach, dill, Indian sorrel, water spinach, portulaca, ponnagani keerai, black nightshade, bathua, sag, mint, lettuce, asparagus, leek, kale, parsley, celery, curry leaf, drumstick leaves, etc. Rich in minerals, vitamins, and antioxidants.
Underutilized Tree Vegetables	Agathi, drumstick, curry leaf, moringa, breadfruit, khejiri, tree bean, khemp, etc. Leaves, flowers, and fruits of trees used as vegetables. Highly nutritious and widely distributed.
Under-Exploited Tropical Vegetables	Agathi, ash gourd, basella, canna, chekkurmanis, clove bean, coccinia, coleus, colocasia, xanthosoma, curry leaf, drumstick, elephant foot yam, jack bean, sword bean, ridge gourd, smooth gourd, roaelle, etc. Rich in nutritive value and potential for exploitation.

Examples of potential underexploited vegetables

Not all traditional and underexploited vegetables can simply and easily be turned into commercial success stories. Significant research, breeding and development efforts are needed to convert existing local landraces of carefully selected, promising crops into varieties with wide adaptation and commercial potential. An overview of breeding efforts and application of biotechnology tools such as micro-propagation, molecular marker studies and genetic transformation for the improvement of underexploited vegetable crops has recently been provided by many researchers. Access to genetic diversity of selected crops, either in situ or ex situ, is a pre-condition for success. Following underexploited vegetable crops are highlighted and briefly described. All these crops have the potential to assume a more important role globally in the sustainable supply of diverse and nutritious food if given appropriate attention by plant breeders. The highlighted crops are well represented with substantial inter- and intra-specific genetic diversity with their potential for wider adoption and commercial exploitation.

Tree tomato

Tree tomato is a perennial shrub, grown as a backyard crop in Meghalaya and Sikkim. It is 2-3 meter tall tree, which bears prolifically egg shaped berries with pointed ends in cluster near the young shoots. The long-stalked, pendent fruit, borne singly, or in clusters of 4 to 12, is smooth, egg-shaped but pointed at both ends and capped with the persistent conical calyx. In size, it ranges from 7-10 cm in length and 5-6 cm in width and in colour may be solid deep-purple, blood-red, orange or yellow, or red-and-yellow and may have faint dark, longitudinal stripes. The inside pulp of the fruit is light orange and the seeds are black in colour. Tree tomato is consumed as delicious chutney when raw or after roasting and peeling off the skin. It is liked by the people due to its unique flavour.

Chow-chow

Chow-chow is a very popular vegetable in the NEH region, commonly called as squash and grows abundantly without much care and attention in high hills of Meghalaya, Manipur, Mizoram, Nagaland, Sikkim and Arunachal Pradesh. Chow-chow produces large starchy edible roots in addition to fruits. It is a vigorous, scrambling, tuberous-rooted perennial plant, grown for its starchy, edible fruit and seeds. This climber can spread to up to two meter producing huge tubers. It looks like a large, green pear, but having a number of deep folds in the skin. Some varieties have smooth skins, while others have dots of prickly spines on the surface. The flesh is crisp and white with a large white oval seed in the centre.

Kakrol and Kartoli

Both are having high nutritional and medicinal with economic values. Immature tender green fruits are cooked as vegetable. Young leaves, flowers and seeds are also edible. The unripe fruits of both the crops act as appetizer and astringent. The seeds are used in chest problems and stimulate urinary discharge. Much popular in NE region, UP, Bihar, Gujarat, Odisha and MP.

Jack bean

It is mostly cultivated in the North Eastern region. It is a bushy, semi-erect, annual herb, 2-3 meter tall and the tips of its branches tend to twine under shade. Leaves are trifoliate and shortly hairy. Pods are 10-30 cm long and 2-2.5 cm broad. The pods are pendent, ribbed near suture and 10 to 25 seeded. Young green pods are eaten as a cooked vegetable.

Sword bean

It is used as vegetable and medicinal plants in NEH region. The red and black sword beans have antioxidant capacity compared to the white sword bean and this was attributed to their red and black bean coats, which possessed extremely high phenolic content. Gallic acid and its derivatives, such as, digalloyl hexoside, methyl gallate and digallic acid is the main phenolic compounds in the coats of red and black sword beans. Therefore, the red and black sword beans, especially their bean coats are good sources of antioxidant phenolics and may have potential health benefits.

Winged bean

Winged bean is an underexploited leguminous vegetable crop which finds an important place in traditional diets in several parts of the world. It is climbing short-day plant, cultivated as an annual with indeterminate growth. The tubers, young pods, seeds, leaves, flowers and shoots, are rich in protein, amino acids, oils, vitamins and minerals. Almost all parts of the plant can be eaten and are consumed by incorporating in a variety of cuisines. Like many legumes, the winged bean can be grown as an intercrop with tapioca, banana, sugarcane, sweet potatoes, or other green vegetables. Popularisation of its cultivation techniques and augmenting the potential of this "Wonder Legume Vegetable" can play an important role for sustaining the dietary needs as well as health benefits for a large section of population.

Cluster bean

Cluster bean is a drought and high temperature tolerant, deep rooted, annual legume of high social and economic significance. The crop holds great potential like high adaptation towards erratic rainfall, multiple industrial uses, importance in cropping system for factors such as soil enrichment properties, low input requirement, etc. Cluster bean is a three-four months crop. From sowing to harvesting it takes about 90 to 110 days. Several improved varieties of cluster bean have been evolved by Universities and

ICAR Institutes in the country. Increasing demand of cluster bean on account of growth in shale gas industry along with other factors has made cluster bean a golden crop.

Tree bean

It is one of the most common multipurpose tree species in the North eastern region, especially in Manipur and Mizoram. Locally called 'Yongchak' in Manipur and 'Yontak' in Assam, tree commonly grows in every household of hill region. The inflorescence head arise terminally with clusters of yellowish white tiny flowers, hanging at the top of long stalks from the branches. The fruits in early stages are soft, tender and bright green in colour. They turn blackish when fully mature in March-April. Pods are formed in clusters of 10-15, each measuring 25-40 cm in length and 2-4 cm in breadth. Based on local preference, the pods are consumed at different stages of maturity, either fresh or processed. Per pod cost about ₹ 20.0 in Manipur.

Yard long bean

Crop is widely grown in every part of NEH region during April-October. Besides immature pods, tender leaves and shoots are very popular as leafy vegetable. The plant is climbing type, branched, 4.0-5.5 m long, 20-35 nodes and flowers are large. Pods are pendent, green and purple in colour, 25-45 cm long, fleshy and inflated.

Lai sag

It is one of the most popular leafy vegetable. This is winter season annual crop, but being grown round the year except heavy rainfall period, having cylindrical taproot system. The crop bears soft, fleshy, broad, green and hairy leaves, fleshy stalk, and reaches a height of 60-70 cm which is being used as green vegetable. The leaves are dried to use during rainy season. Mustard leaves are an excellent source of vitamin E, vitamin C and beta-carotene. They also contain vitamin B6, folic acid, niacin, magnesium, calcium, iron, and are an excellent source of phyto-chemicals.

Snake gourd

Snake gourd is a tropical or subtropical vine, grown for its fruit which is used as a vegetable and for medicine. The narrow, soft-skinned fruit can reach 150 cm long. Small fruited (20-40 cm) snake gourd is popular in almost all regions. Its soft, bland, somewhat mucilaginous flesh is similar to that of the *Luffa*.

Rice bean

It is a warm-season annual vine legume with yellow flowers. It is regarded as a minor edible plant and fodder crop and is often grown as cover crop and intercrop or mixed crop with maize, French bean or cowpea as well as a sole crop in the Jhums on a very limited area. It is good source of protein, essential amino acid, essential fatty acid and minerals. Rice bean is a fairly short-lived warm-season annual, grown mainly for dried pulse, fodder and vegetable.

Water chestnut

Nuts of Singhara form a staple food. West Bengal, Jharkhand and Bihar (Darbhanga, Madhubani and Samastipur) are major growing areas of Singhara. Singhara is one of the submersed plants, used as edible nut. Kernel of Singhara contains protein (up to 20%), starch (52%), tannins (9.4%), fat (up to 1%) and sugar (3%). It is also a good source of fiber and vitamin B along with Ca, K, Fe and Zn. Cultivation of Singhara in combination with Magur-fish could provide good income to the farmers of seasonal water logged areas. Ripe nuts are usually sold in the market at the rate of ₹ 50- 200/kg.

Water spinach

Kalmi sag is an aquatic plant, forming dense mats over the surface of water bodies. It is commonly used as a food plant. The leaves are a good source of minerals and vitamins especially carotene. The plant serves as a green fodder of high nutritive value. It is also used as feed of fish and broilers.

Leafy chenopod

Leafy chenopod is a potential food crop for diversification of vegetable crops to the newer areas, environmental sustainability and for combating the nutritional deficiency in human being in many parts of the world. Leafy chenopod is a prospective nutritious and cheaper leafy vegetable, suitable for fortification of food items, and is worth exploration, improvement, commercialization and utilization. Chenopods are very good sources of dietary fibre; protein; minerals such as Ca, Fe, P, K, Mg, Zn, Mn, Se and Na; vitamins i.e. vitamin-C, β-carotene, niacin, folic acid and riboflavin; antioxidatns; and omega-6-fatty acid. In India; four varieties such as Kashi Bathua-2, Kashi Bathua-4, Pusa Green and Pusa Bathua-1 have been developed through Mass selection by ICAR-IIVR, Varanasi, UP, and ICAR-IARI, Pusa, New Delhi.

Agathi

Agathi is a well-known small, loosely branching, legume plant of the tropical Asia. Leaves, seeds, pods and flowers are edible. Flowers are the most widely used part and white flowers are preferred to the red due to less astringent nature. The raw flowers are eaten as salad in Thailand. Young leaves are also eaten, usually chopped fine and steamed, cooked or fried. Tender pods are eaten like string beans. Agathi leaves taste bitter, sour, and mildly tart. The flowers are also bitter and astringent; it is possible to reduce the bitterness by removing the stamen. Leaves are an excellent source of calcium and iron. Parts used are root bark, leaves, flowers and fruits. Leaves, flowers and pods of the agathi are harvested for consumption as vegetables at proper maturity stage.

Globe Artichoke

Globe Artichoke is widely being cultivated for its large immature inflorescences also known as capitula or heads, which include edible fleshy leaves (bracts) and receptacle, and important part of the Mediterranean diet. It is a perennial herb grown for its globular immature flower heads or buds which are used as vegetable. It has thistle like plants. The small heads are eaten raw or cooked, white large heads are eaten only after cooking. The thick receptacle known as heart is used for canning. The above ground portion of the plant dies each year during winters and again emerges in spring. A healthy plant produces more than 12 stems and 40-50 edible buds and harvest continues throughout the winter.

Asparagus

It is a perennial and monocotyledonous plant that is grown for its edible stems (spears). Spears are consumed as a seasonal vegetable and they are highly appreciated for their delicious taste, low energy content, and nutritional quality. Asparagus are divided into two main groups: green asparagus and white asparagus. From a botanical point of view, white and green asparagus are the same plant. The difference between them is the way their spears grow. Edible stems are white while they grow below the soil, but when they emerge and are exposed to direct sunlight, they acquire a green hue through the chlorophyll.

Curry leaf

Curry leaf is versatile plant with multiple benefits and utilities. It is highly rich in minerals, vitamins, antioxidants, amino acids, proteins, and number of bio-active compounds. It possesses wide range of health promoting properties *viz.*, antioxidant. Curry leaves are rich sources of Calcium (Ca) and fair sources of Iron (Fe), Potash (K), Magnesium (Mg), Phosphorous (P), Sulphur (S) and Zinc (Zn). Regular consumption of curry leaf reduces blood sugar level and is useful for persons suffering from diabetes. The leaves are very spicy in nature and have curry flavour. It is used both as leafy vegetable and spice.

Chekurmanis

This is a multi-vitamin and multi-mineral packed perennial leafy vegetable. The succulent tender shoots and leaves are used for culinary purpose. It is a slow growing shrub suited to the warm humid tropics, whose nutritive value has not been realized to the maximum. The leaves and roots of the plant have several medicinal properties. It is still considered as a minor leafy vegetable crop. Chekurmanis is majorly concentrated in Tamil Nadu, Kerala and Sikkim.

Elephant Foot yam

Elephant foot yam is a plant produce underground stem tuber called a corm. It is one of the popular tuber crops of the tropics, cultivated as food security and remunerative cash crop. Elephant foot yam is used extensively as a vegetable and in preparing traditional ayurvedic medicines. Elephant foot yam can produce high dry matter per unit area than most of the other important vegetable crops. In India, it is cultivated on a commercial scale in Andhra Pradesh, Kerala, Karnataka, Tamil Nadu, Gujarat, Maharashtra and West Bengal, Bihar, Uttar Pradesh, Jharkhand and North Eastern states. Elephant foot yam has become a food security crop because of its capacity to grow and yield well on marginal soils, even with low management conditions.

Kachnar

Kachnar is a well-known moderate sized, ornamental tree of legume family in tropical and subtropical regions worldwide. Almost every part of this tree is used in Ayurvedic medicine system. Its leaves, buds and flowers; all are edible and nutritious. Leaves not only provide fodder throughout the year, but also are important source of nutrition for many tribal communities in different parts of India. Its partially opened inflorescences are cooked and eaten as vegetable. These plants are easily identified by rather unusual shape of their leaves, each divided into two identical halves and folded at the midrib vertically. When both of its halves are open, it figures out as the shape of a camel's foot and hence derived the name "Camel's Foot". Its buds are rich in total carbohydrates, crude proteins, crude fats, crude fibre, hemicellulose, neural detergent fibre, acid detergent fibre and also indigestible carbohydrate content.

Lima bean

Lima bean is an underutilized perennial leguminous vegetable crop. In NEH region, it is normally grown as perennial vine crop in the backyard of home without much care but it play the role of food supplement when there is scarcity of vegetables as well as for preparing special dish. Pods are rich in protein, fibre, and other nutrients, making them a super-food and also good source of iron. Fresh shelled beans are consumed after cooking. In Manipur, tender fresh seeds are used for preparation of special food popularly known as chagempomba by mixing with various other vegetables and rice. Tender pods are consumed as chutney by boiling fresh pod and partially smashing to prepare chatni called *Thingshu* which is relished and considered delicious. Lima bean could be consumed as whole beans and it can also be made into flour which can be added to conventional flour for improved nutrient content. Shelled Lima beans are used in soups, salads, stews and as a vegetable.

Oriental pickling melon

Oriental pickling melon is a cucurbitaceous vegetable which is cultivated in hot humid tropics. Traditionally used for pickling. Culinary cucumbers have a special feature that the fruits can be stored up to 8-10 months without losing their freshness. Melons were seen as a cooling food in traditional medicines and are also used to help improve digestion. The fruits possess cooling properties and are used as a skin moisturizer and as a digestive agent.

Sunhemp flower

Sunhemp flowers and leaves are also used for various culinary purposes. Leaves are eaten raw, while their flowers are consumed as vegetable after cooking with meat and fish and are also pickled. In Ayurveda, the leaves are used as an emetic, laxative, abortifacient and analgesic and for treating diarrhoea and bleeding disorders. The flowers are cooked as vegetables during scarcity and considered good for stomach problems whereas, in Mizoram, flowers are cooked with meat and fish. In Manipur, tender leaf are consumed either in raw or cooked with other vegetables. Flowers are used as cooked vegetable. Sometimes buds and flowers are also used for garnishing of local food preparations especially in non-vegetarian recipes.

Snap melon

Snap melon is widely grown in arid and semi-arid regions such as Rajasthan, Gujarat, Punjab, Haryana, Uttar Pradesh, West Bengal and other North Eastern region. In the rainy season, it is grown as a mixed crop with maize, sorghum, and pearl millets, or as a single crop in the summer. Snapmelon is known by the common name ‘phut,' which means ‘to split.' Longitudinal fruit cracking, which begins in the middle of the fruit, is a common feature of snap melon, though only skin peeling (longitudinal or random) can also occur in some cases. Snap melon is also known as ‘Phootkakari' or ‘Kakadia', or ‘Kherla. The colour of the fruit flesh ranges from cream to yellow to orange. The fruits are high in water and dietary fibres, which aid in the relief of constipation and digestive disorders. It is naturally rich in phytonutrients, folic acid, potassium, and vitamin C, all of which are essential nutrients for keeping the skin natural, soft, glowing, healthy, and youthful. The immature and mature fruits are used to make vegetables and deserts, respectively.

Spiny coriander

It is a leafy herb and used as a culinary, spice and medicinal plant. Leaves are tough, but if sliced and then chopped they are quite tasty. This variety of coriander dries well, retaining good color and flavor, making it valuable in the dried herb industry. In NE India, long coriander is used for flavoring pork and beef. In most places saw tooth coriander is collected from the wild or from some plants in the garden, and is used and traded locally. Leaves are the rich source of valuable phytochemicals such as flavonoids and saponins with antioxidant and antidiabetic properties. Volatile oils contain high amount of acyclic aldehydes and aromatic compounds. The oils are a potential source of natural antioxidant as demonstrated by their strong antioxidant activity.

Tree Tomato

Chow-chow

Kakrol and Kartoli

Jack bean

Sword bean

Winged bean

Cluster bean

Tree bean

Yard long bean

Lai sag

Snake gourd

Rice bean

Water chestnut

Water spinach

Leafy chenopod

Agathi

Globe Artichoke

Asparagus

Curry leaf

Chekurmanis

Elephant Foot yam

Kachnar

Lima bean

Oriental pickling melon

Sunhemp flower

Snap melon

Spiny coriander

Constraints for the Development of Underutilized Vegetable Crops

- Lack of awareness among the farming community about the nutritional and medicinal value of underutilized Vegetable crops.
- Lack of researches
- Lack of desirable seeds and planting material.
- Limited application of advance on-farm agro techniques.
- Lack of application of innovative and novel technologies such as biotechnology, plasticulture for enhancement of productivity.
- Lack of about post-harvest management practices.
- Limited and inadequate marketing supports & infrastructure facilities for transportation, storage and processing.
- Poor recognition of these crops in horticulture promotion programmes.
- Improper institutional arrangements and limited role played by financial Institutions in setting up of agro industrial and horticulture based industrial Units.

Strategy for development of underutilized vegetable crops

Strategy development and appropriate policies are limited to a large extent by a lack of documentation on underutilized vegetable crops. Taking into account agro ecosystem diversity there is need to take a dual approach: considering some underutilized crops as commodities and at the same time considering an agro ecosystem approach. It is well to recall lessons of the past where agricultural modernization and increased production was often through changed agricultural practices long before the input from plant breeding. Substitution of one crop by another of identical or equivalent use e.g. small millets replaced by maize or *Lagenaria siceraria* replaced by Cucurbita pepo is normal and is guided by farmer preference. Research planning and priority setting are closely linked and determined crop improvement through biotechnology. Increasing yield potential in major crops has largely been attributed to aggressive breeding and biotechnology programmes. There is also a need to employ such techniques to improve yield potential of underutilized vegetable crops. Advances in plant genomics now provide breeders advanced molecular and bioinformatics tool that allow the study of the whole genome to accelerate breeding efforts such as genome sequencing. Research should focus on sequencing the genomes of priority underutilized and applying advanced translational techniques using model crops. Consistent with the paradigm shift needed in agriculture, the development underutilized vegetables should seek to address the agriculture-environment health nexus as this is where they have the most potential to make impact. Currently, reports of their perceived nutritional value and health benefits are mostly anecdotal. This should include research on nutrient content, nutritional yield and water productivity, and bio-availability of nutrients.

Research issues and opportunities

In identifying research and development issues, which should be addressed, it is essential to approach the problem from this perspective. One key strategic element involves the deliberate attempt to explore how conservation and use can be combined to secure the resource base of such crops. The approaches may differ, depending on whether the crop is seed propagated or clonally propagated, annual or perennial, out breeding or self-pollinated. However the basic questions remain the same. What is the smallest size of ex situ collection that can cover substantial amounts of diversity and how can it be most economically maintained? How much diversity will remain in production systems and how can this be monitored? How can resources be secured through linkages and collaborations, involving producers, consumers, the formal and informal sectors, to ensure that both conservation through use and conservation for use can be sustained? New technologies (e.g. molecular genetics and GIS) will certainly play their part in the process of developing conservation and use strategies. Strengthened community involvement in the management of underutilized crops and a deliberate attention to resourcing their needs for new materials (and securing access to existing ones) will provide a basis for some more work on key production issues.

Conclusion

Special attention is required for popularization of underutilized vegetable crops in order to exploit their potential to treat many lifestyle related diseases. Research for domestication and utilization is of profound importance as far as nutritive value is concerned. The increase in area and production of these vegetable crops will not only provide nutritional security and save money on import but also export of fresh vegetable crops and seed in further expected to boost region economy. Underutilized vegetable crops also provide many fold employment opportunities in agro-based industries, packaging, storage, preservation, canning and transportation.

25. Moringa breeding: International scenario

Raja Shankar*, Supriya Mandal, Keshav Rao and Kalaivanan D.
Principal Scientist, ICAR-IIHR, Bengaluru
*Email: Raja.Shankar@icar.gov.in

ABST RACT

Moringa (*Moringa oleifera* Lam.) is a multipurpose perennial vegetable, which is widely used for medicinal purposes. Moringa is a native crop of Indian subcontinent, and grows widely in many tropical and subtropical countries. India is a leading producer and supplier of moringa products to the world market. It is an ideal remedy for minimizing the world-hidden hunger due to high nutritional value. It has wider applications in the nutraceutical, pharmaceutical, and cosmetics industries. Due to greater demand for its edible leaves as super food in the international market, exploitation of moringa for leaves, pods and also for seeds is imperative. The medicinal and industrial potential of moringa is well known worldwide, the information on genetic basis and regulatory networks associated with pharmacological and industrial properties, and its molecular dissection of traits linked could help in developing crop varieties with enhanced potential. Moringa is now cultivated in several countries in Africa, Asia, Australia/Oceania, Europe, North America, Central America, and South America, and the Caribbean. However, the breeding approaches adopted in several countries and achievement made for exploitation of the crop depends on their domestic need. Hence, it is imperative to understand the genetic potential across the globe, sharing of germplasm and speed breeding of moringa to fulfill the international demand through successfully developing varieties with improved pharmacological and industrial properties.

Keywords: Moringa, nutrition, genetic variability, improvement on pharmacological properties, molecular and omics

1. Introduction

Moringa (*Moringa oleifera* Lam.) is a multipurpose rapidly growing perennial vegetable. It belongs to a single genus family Moringaceae, having 13 known species. Moringa is a native of Indian subcontinent where it is commonly found from sea level to 1,400 m. Though, the tree grows widely in many tropical and subtropical countries. The importance of moringa on health issue is known dates back to 150 B.C., as ancient kings and queens used its leaves and fruits in their diet to maintain a state of mental alertness and healthy skin. Ancient Mauritanian warriors in India drank *M. oleifera* leaf extract on the war front and this drink was believed to be a kind of elixir and these brave soldiers were the ones who defeated Alexander the Great (Sujatah and Patel., 2017). India is a leading producer and supplier of moringa products to the world market. Though every plant part is widely used in traditional medicine, the leaves and immature seeded pods are used as vegetable for culinary purpose. Moringa seeds also had several uses in human health due to its rich fiber content which improves digestive system, regulate blood sugar levels and reduce joint pain. It also contains around 30 antioxidants, vitamins A, B-complex, C, and other free radical buster to act as an antioxidant, anti-inflammatory, and cholesterol-lowering agent, which attracts the health-conscious consumers, and thus, it drives the moringa seed market globally. The export of moringa from India is increasing at >30% annually as it has wide applications in the nutraceutical, pharmaceutical, and cosmetics industries. The programs of United Nations Sustainable Development

Goal 2 (SDG 2) and the African Orphan Crops Consortium (AOCC) emphasized to exploit moringa to achieve food security by shifting towards improved nutrition and healthier diets (Keatinge et al., 2017; Hendre et al., 2019) paved the way to "rediscover" moringa across the world as super food (or) mothers best friend status.

Presently, moringa attained a inevitable crop in hidden hunger eradication in underdeveloped countries. The demand of moringa product is determined by the consumer demand and awareness, which facilitate to breed varieties for yield or quality etc. Hedhili et al. (2022) attempted snowball sampling procedure with 258 respondents who are consumers of Moringa (124 are Indians and 134 are Africans; 54% are Male and 46% are Female) revealed Indian respondents had a better knowledge and more positive and beliefs towards Moringa than African respondents. In addition to fresh leaves, various functional foods and non-food products are prepared from moringa, it offers a wide array of business opportunities to investors. India is the largest producer of MO, contributing 41% of the global production, followed by other tropical countries, i.e., Western Africa (33%), the Philippines (12%), China (8%), and Venezuela (6%) (Zirmire et al., 2018). India meets ~80% demand for various MO products (Zirmire et al., 2018). In 2017, India exported 11, 81,468 tonnes of various MO parts and/or products worth ~Rs 46.24 crores (~6.25 million US$) (Zirmire et al., 2018) where moringa leaves are primary product to be exported. India exports several countries in Asia (20), Africa (15), Australais/Ocenia (4), Europe (23) North (6) and South America (8). Among the European countries, Germany has the largest market for Moringa products, followed by the United Kingdom, France, Netherlands, Italy, and Spain. African countries (Ghana, Kenya, Mozambique, South Africa, and Zambia) have also entered the global export market for various Moringa products. In Zambia, Moringa is organically grown and supplied to both local and international markets by Moringa Initiative.

Moringa being a mixed mating species due to exerted sigma (the pistil grows beyond the anthers), and delayed stigma receptivity favor cross-pollination. It exhibits both geitonogamy and xenogamy, which determines the fruiting potential of trees based on pollen dispersal and pollinators availability. Pollen grains found to show stickier and fail to disperse freely during August-September (cloudy days). These pollens become shriveled and unviable by the time the stigma became receptive. However, spread of pollen is faster due to non-sticky and more powdery during warm/hot weather by the pollinator results non-uniform fruiting among the populations/seasons. Poor germination of seeds, limb cutting and prone to various biotic and abiotic stresses causes poor yield (Ravi et al., 2019). Harnessing the diversity in natural genetic resources for breeding programs to breed high yielding and biotic stress tolerant varieties with nutraceutical and industrial properties is imperative.

1. Flowering physiology and fruit set

In order to enhance fruiting efficiency of genotypes, understanding the flowering phenology of Moringa is very important. Because, there are two forms in moringa (annual and perennials) where two and one flowering peak appears in a year, respectively. The two seasons for Moringa is from April to June (Summer) and July to September with no flowering during December to February strongly indicates the influence of temperature on flowering phenology. Due to which, the peak flowering period starts from February and extends till April (summer) yields heavy fruiting and yield results with poor price of pods (Rs15/kg) and the next crop fetches Rs 100-125/kg on poor yield. Hence, flowering phenology was recorded at across the country with wider variation depends on their temperature peaks. In India, flowering occurs only once (between April to June) in the cooler regions, whereas flowering typically occurs two times each year in warmer areas. In semiarid ecosystem, the seasonal temperatures and rainfall regimes cause flowering to occur more or less continuously throughout the year (Little and Wadsworth, 1964). In low land tropics, the anthesis pattern is region specific such as commencing from 4.30 a.m. to 6.30 a.m. with peak anthesis at 5.30 a.m. at Coimbatore rather than anthesis starting at 2.30 a.m. and continued up to 7.00 a.m. peaking at 5.40 a.m. at Periyakulam. Under humid ecosystem, the tree flowers in two peaks (August to September and December to January), where the latter flowering only set fruits. However, round the year flowering (except during November to December) was observed in Vellayani conditions (Mathew and Rajamony, 2004). The high rainfall ecosystem recorded flowering only in April-May. In Bahamas, the flowering extended from January to June (Correll and Correll, 1982) and throughout the year flowering in Cuba and Florida. Though round the year flowering is registered in humid/ hot arid regions, the fruiting setting is not reported round the year as the pollen viability is disturbed by either very high or very low temperature (Vaknin et al., 2021).

Stigma is receptive at anthesis time in every tree species, except in moringa where stigma receptivity is delayed (Zhang et al., 2018). The older flower recorded with high pollen germination and fruit set as delayed stigma receptivity favors cross-pollination, despite immature stigma supports pollen adhesion and hampered supply of proper hydration substrate (Zhang et al., 2018). Enhanced stigma receptivity is reported to be associated with increased amounts of insoluble polysaccharides, lipids and proteins in the canal cells at later developmental stages. Hence, having both chasmogamous (sterile pollen/delayed stigma receptivity) and cleistogamous flowers (fertile pollen) reasoned for seasonal yield variation. The genotypic differences on fruit set was observed using different methods of pollination such as natural, natural selfing, natural crossing and assisted crossing (42, 16, 32 and 64%) in PKM-1 as compared to PKM-2 (47.2, 24, 36 and 68.0%, respectively) indicated greater scope for breeding varieties with enhanced fruit set.

2. Germplasm and genetic variability

Germplasm is a treasure of genes conserved in a wide array of crop varieties, landraces, and related wild species of a crop to search for specific genetic traits for identifying elite accessions for developing desirable horticultural traits. Worldwide, Moringa germplasm have been collected and conserved by national (ICAR- National Bureau of Plant Genetic Resources New Delhi, ICAR- Indian Institute of Horticultural Research, Bengaluru, ICAR-Indian Institute of Vegetable Research, Varanasi, ICAR- Central Institute for Arid Horticulture, Bikaner, Tamil Nadu Agricultural University, Coimbatore, University of Horticultural Sciences, Bagalkote, University of Agricultural Sciences, Bengaluru, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Keral Agricultural University, Vellanikara) and International (World Vegetable Centre, Taiwan, National Institute of Horticultural and Herbal Science (NIHHS), Korea, Kasetsart University's Kamphaeng Saen Campus at Nakhon Pathom in Thailand, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Campus at Patancheru in India, Samanko Research Station at Bamako in Mali and International Institute of Tropical Agriculture (IITA) at Cotonou in Benin) etc. In India, germplasm exploration started during 1980s and improved varieties have been released for commercial cultivation (KM-1, PKM-1 and PKM-2) during 1990s by TNAU, Coimbatore. In late 20s, ICAR-IIHR intensified germplasm collection and the genetic diversity and distribution map prepared using 155 germplasm collected across the country (Fig.1) showed wider genetic variations for morphological traits and less diversity in cooler regions (Raja Shankar et al., 2020). During 2001, the World Vegetable Centre, Taiwan initiated germplam collection from Africa, Asia, and the USA, and has distributed the germplasm to several countries in Africa (Egypt), Asia (Malaysia, Pakistan, Philippines, Thailand, and Vietnam), and Europe. In China, conserving about 356 accessions covering 13 moringa species (Zhang et al., 2019). The Instituto de Biología, Universidad Nacional Autónoma de México (UNAM), Jalisco, Mexico maintains the germplasm of moringa for both basic and applied scientific research. In USA, efforts are underway at the University of Hawaii, USA to optimize the production of the leaf, pod, and oil. According to Deng et al. (2016), China in collaboration with Cuba initiated work for developing improved varieties of moringa (Xishuangbanna in China's southwestern Yunnan province) and identifying functionally diverse genes associated with important agronomical traits (South China Agricultural University, Guandong). Moringa Philippines Foundation (Philippines), AVDRC (Taiwan), Rural Development Initiative, and Moringa Community (Zambia) are other research centers across the world focused on the improvement of MO.

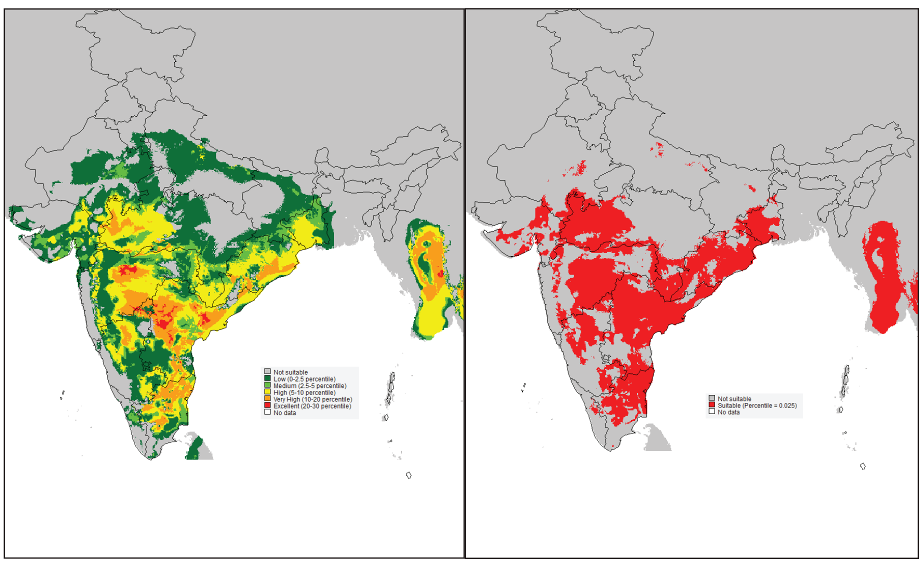

Fig-1: Genetic diversity and distribution map of moringa

3. Genetic diversity in Moringa

2.1.Morphological basis

Being a monogenic family, very remote success in developing of interspecific crosses among the Moring sp., which resulted with very low genetic diversity in the cultivated species. Mgendi et al. (2011) found that wild forms were more diverse than cultivated form in moringa. Diversity pattern observed among *Moringa* species had four clusters, where all *M. oleifera* accessions grouped in cluster-1 and furthermore divided in to three sub groups (Olson, 2002). Entire accessions of Thailand positioned into cluster I-A along with one accession from the Philippines (TOT5474), which clearly indicated both accession may have a common origin. Accessions from India (La-Mu E), Philippines (Davao Malunggay), Taiwan (TOT4100), USA (TOT4880) and Tanzania (RCA *Moringa*) grouped in cluster I-B. Among cluster I, TNAU-1 from India was different from the other *M. oleifera* accessions. Grouping of *M. oleifera* accessions in clusters I-B and I-C might be a reflection of geographical isolation. Accession 97113-971(*M. peregrina*), Mo28 (*M. stenopetala*) and African *Moringa* (unknown species) were very low in similarity compared with *M. oleifera* accessions. Reshmi et al. (2005) found 28 accessions of Moringa collected from central and southern Kerala differed significantly for morphology, yield and quality attributes. Accessions from Thiruvananthapuram (MO 13, 24 and 26) showed three distinct flowering peaks in a year, while others showed one or two peaks. Number of fruits/plant (174 to 612), fruit yield (8.94 to 70.46 kg per tree), leaf vitamin A (8108 to 13216 I.U) and fruit vitamin A (95 to 185 I.U.) also showed considerable variations. Vitamin C content in leaf and fruit was highest for MO 18 (226 mg per 100 g leaf and 129 mg per 100 g fruit). Amoatey et al. (2012) studied intra-specific diversity depending on 18 agro-morphological characteristics of the 14-moringa accessions. All accessions were grouped into different clusters based on phenology, vegetative and pod morphological characteristics using general linear modeling analysis. Popoola et al. (2016) studied intra-specific phenotypic dissimilarity among the 40 accessions of moringa and classified into four clusters such as cluster A (1 accession), cluster B (14 accessions), cluster C (7 accessions) and cluster D (8 accessions). The degree of intra-specific similarity was found high (66.82%) based on Euclidean similarity index. Chan et al. (2018) classified 24 moringa landraces based on 23 quantitative characters into three clusters by using Ward's method. Cluster I had 14 landraces and was characterized with the highest fresh pulp weight and maximum leaf length. Two landraces classified under Cluster II, which exhibited slightly upright flower position, lowest number of seeds per pod, and locules per pod, lowest dry pod diameter and wing diameter. Whereas Cluster III grouped with eight landraces and special characteristic like red colour of young fresh pod, reddish green and greenish red of mature fresh pod color; maximum dry pod length, 10 dry pod weights and 100 seed weight.

3.2. Molecular marker basis

Morphological traits are highly influenced by environmental factors and plant growth stage. Hence, phenotypic traits are not desirable every time rather molecular markers based on DNA sequence polymorphism which are not depend on environmental conditions and also show higher levels of polymorphism are now extensively used by the researchers (Tatineni et al., 1996). Assessment of genetic diversity in *M. oleifera* using AFLP (Muluvi et al., 2004) and RAPD (Mgendi et al., 2011) markers were done with accessions collected from the Kenya and Tanzania, respectively. The genetic diversity assessed between and within cultivated and non-cultivated provenances of *M. oleifera* from coastal regions of Tanzania using 12 RAPD markers found that wild provenances were more diverse than cultivated and produced five clusters with similarity ranging from 54% to 96% (Mgendi et al., 2011). Assessment of genetic diversity in *M. oleifera* has been done using RAPD (Saini et al., 2013), ISSR (Saini et al., 2013) and AFLP markers (Muluvi et al., 1999) in accessions from India as well as Africa. Abubakar et al. (2011) studied genetic variability in 75 accessions of moringa using 24 RAPD primers and obtained high degree of polymorphism (75%). Ojuederie et al. (2012) performed a study of genetic diversity in 10 moringa landraces from Western Nigeria and assessed using 10 RAPD markers. A total of 595 fragments were obtained, out of which 485 (81.5%) were polymorphic primers OPB-3, OPB-6, OPH-2, OPH-5, OPH-6, PT-3, and OPT-4 gave 100% polymorphism. The number of amplified fragments per primer ranged from 44 (OPT-2) to 123 (OPT-5) with a PIC ranging from 0.8301 to 0.9280. Shahzad et al. (2013) evaluated genetic diversity and population structure of *M. olerifera* by using 19 microsatellite or SSR markers along with a partial sequence of chloroplast gene at PB within 161 accessions (131 accessions collected from the wild in Pakistan, 30 accessions collected from ECHO, Florida). Large genetic diversity was present in Pakistan's accessions as compared to accessions obtained from ECHO. Saini *et al.* (2013) studied genetic diversity of eight Indian cultivars collected from various states of India through 17 RAPD, 6 ISSR and 7 pairs of cytochrome P450-based markers and obtained 48.68, 48.57 and 40.00% polymorphisms, respectively. Rufai et al. (2013) analysed genetic relationship among 20 moringa accessions by using 12 RAPD primers, and found heterozygosity and high genetic divergence of 1.80 and 0.13 for Malaysian population and 0.30 and 0.19, respectively for international population.

Robiansyah et al. (2014) used both RAPD (11) and ISSR (15) markers to assess the molecular characterization of a new biotype of moringa found in Al Bahah Region, Saudi Arabia, to compare with *M. oleifera* and *M. peregrina*. ISSR markers recorded higher level of polymorphism (75%) as compared to RAPD (59.7%). RAPD and ISSR primers revealed that the new biotype shared 53 amplicons (43.44%) with both *M. peregrina* and *M. oleifera*, 29 amplicons with *M. peregrina* (23.77%), 22 amplicons (18.03%) with *M. oleifera*, and displayed 18 unshared amplicons (14.75%). Based on RAPD data, genetic distance between *M. oleifera* and *M. peregrina* was 0.59, whereas genetic distance between the new biotype and *M. oleifera* and *M. peregrina* was 0.41 and 0.54, respectively. For ISSR data, genetic distance between *M. oleifera* and *M. peregrina* was 0.98, whereas genetic distance between the new biotype and *M. oleifera* and *M. peregrina* was 0.59 and 0.56, respectively. Ravi et al. (2020) conducted genetic variability study of 23 moringa genotypes collected from Kerala, Tamil Nadu, and Karnataka by using seven cytochrome P450 (CrytP450) markers and reported 88.25% polymorphism. The polymorphic information content (PIC), marker index (MI) and resolving power obtained for seven primers were 0.23, 2.96 and 9.83 respectively. Swati et al. (2020) studied genetic diversity of *M. oleifera* between South-Central and Northern states of India (Himachal Pradesh, Maharashtra and Uttarakhand) using RAPD markers. The genotypes were grouped into 3 different clades at similarity level of 88.5%. The draft genome of *M.oleifera* sequenced on the Illimina platform with 231 MB (~80%) of the total sequence containing more than 19,000 protein-coding genes (Chang et al., 2018). The reference genome sequences of >50 tree species including Moringa, revealed three distinct cluster groups and phylogentic closeness of moringa with *Hevea brasilien- sis* and *Olea europea* belonging to the family Euphorbiaceae and Oleaceae, respectively.

4. Genetic improvement in moringa

The genetic improvement on moringa was initiated through selection method from perennial forms in 80s targeting annual genotypes. Suthanthirapandian et al. (1989) attempted to exploit the genetic variation in the seedling population and identified 20 promising plants for yield from 84 open pollinated seedlings by observing nine characters. The heritability analysis showed non-additive gene action for fruit weight and fruit length and fruit girth (Raja and Bagle, 2008) and involvement of additive gene action for majority of quantitative traits. Different crop improvements strategies have been explored to harness the available genetic diversity using both annual and perennial forms in India and across the world. The breeding approaches such as plant introduction, evaluation, selection, hybridization and use of biotechnological methods have been adopted for the development of varieties with dwarf stature, high biomass production, high seed yield and oil content, better quality, and resistance to pest and diseases.

4.1. Breeding for leaf yield

In moringa, breeding genotypes for high leaf yield is still in budding stage. Due to which none specific varieties are recommended for commercial cultivation and the demand is substituted by superior genotypes identified for pod purpose. Breeding for leaf yield is determined by leaflets per leaf, number of leaves per shoot, node at which first flower initiation take place, leaf weight per shoot and no. of shoots per tree etc. Moringa leaves are double or triple pinnate, with 20-70 cm long. The smaller leaflets are 1-2 cm in length. Abubaker et al. (2011) assessed the genetic variations among the accessions of Sudan and Guinea Savanna in Nigeria. The highest leaf length (58.85-61.75 cm) was found in 16BDZM, highest leaflet length (34.55-37.25 cm) in 5ZRKD, leaflet width (1.85-1.87 mm) in 12BDZM, and leaf area (3.44 mm^2) in 2JHJG. Robiansyah et al. (2014) identified a hybrid between *M. oleifera* and *M. peregrine* developed from spontaneous pollination and fertilization, having round, elliptic or oblanceolate shaped leaflet. The local and exotic accessions of moringa showed variations for leaf colour and petiole pigmentation where dark green colour leaves are preferred over light green as it has high amount of chlorophyll which will enable the plant to produce more photosynthates and preferred for leaf beverage. Supriya et al. (2021) found that foliage density varied from sparse, medium to dense in 52 accessions evaluated and 48.07% and 23,07% gene pool had medium and dense foliage, respectively (Fig-2) and the isolated 14 accessions were superior over comer check PKM-1. As leaf yield is concern, fresh leaf yield of a moringa plant was reported to be 1-5 kg per tree annually. However, leaf yield could be manipulated by plant populations (Sánchez et al., 2006) and its harvest intensity (Isutsa and Mallow, 2013). Unlike improvement for pod types, the leaf types should be fast growing with late flowering and dual types should have both vegetative and flowering shoot concurrently as it is evidenced in amaranth where leaf harvest reduce grain yield by 50% with no compromise on nutrient content (Dinssa et al., 2018). Raja Shankar et al (2021) found significantly difference among 52 accessions for shoot length (89.0- 231.6cm), node to first flower emergence (9.42-24.55), leaf length (36.83-80.67cm). Supriya et al. (2020) found that the highest GCV and PCV value were recorded for whole leaf yield/ha (44.42 and 47.93 respectively), followed by edible leaf yield/ha (42.87 and 46.80), number of shoot/ plant (27.25 and 28.15), whole leaf weight/shoot (26.32 and 31.88), and edible leaf weight/shoot (25.72 and 32.21). Edible leaf weight/shoot had a positive and highly significant correlation with whole leaf weight/shoot (r = 0.97) followed by shoot thickness (r = 0.65), number of leaf/shoot (r = 0.62), leaf width (r = 0.46), shoot length (r = 0.45), leaf length (r = 0.44), and node to flower initiation (r = 0.38). Raja Shankar et al. (2021) estimated stability index for leaf yield related traits and found highly significant differences for whole leaf yield/plant, edible leaf yield/plant and edible percent which indicated the presence of difference in phenotypic expression. The higher edible leaf yield/plant was found in IIHR-D-120, PKM-1 and PKM-2 (X_i= 4.72 kg, 4.52 kg and 3.39 kg respectively) proved its stable and adaptability to wider environments as against IIHR-D-28, IIHR-D-109, IIHR-D-4 (X_i= 8.69 kg, 7.36 kg and 6.72 kg) with suitability for favorable climate. Hence IIHR-D-28 and IIHR-D-4 can be recommended for commercial cultivation (84.5%, 55.9% and 42.3%) due to its greater edible leaf yield increment over the commercial check PKM-1.

Mutation breeding was attempted to overcome the problem of low genetic variation in cultivated species. Gamma rays and EMS were used to induce mutations in Moringa variety PKM-1 and found doses higher than 300 Gy for gamma rays and 0.25% for EMS is ideal to induce variants in PKM-1 (Udayakumar et al., 2019). Among the seven mutants isolated, an apparent phenotypic variation was observed desirable mutant lines generated with 0.25% EMS, which confirms its efficiency in creation of genetic variation and desired mutants. Mutant-22

Fig-2: Genetic variability for edible leaf density of moringa

and Mutant-23 identified possess higher leaf biomass characteristics besides showing genetic variation when compared with the wild type (PKM-1)

Polyploid breeding attempted through *in vitro* tetraploidisation in drumstick tree by treating leaf segments with colchicine and subsequently verifying the ploidy levels (Zhang et al., 2020). Explant survival and regeneration rates were affected more by exposure time than by colchicine concentration, and the highest polyploidisation efficiency was observed at 500 mg/L colchicine for 3 days, which yielded 21% tetraploids. The morphological characteristics and contents of seven fodder-related nutrients observed superior. The tetraploid produced in this study exhibited superior agronomical traits and improved biomass yield than diploids, and may represent excellent raw materials for fodder to enhance biomass and nutrition.

3.1. Breeding genotypes for high pod yield

The first introduced variety for this purpose is Jaffna. The variety is assumed to have been introduced from Sri Lanka and mainly cultivated in Southern India. Pods are of 60-90 cm length having soft flesh and good taste. Chavakacheri Murangai is also assumed to be introduced from Sri Lanka. It is similar to Jaffna type and produces pods having length of 60-120 cm. Selection approach is over exploited as Moringa crop improvement is concern. There are several ecotypes and superior yielding genotypes have been selected from the open pollinated population of a region for its appearance, yield and quality. Perennial ecotypes are propagated by limb cuttings, as seeds take several years to fruit. Chemmurungai is selected for its red-tipped fruits, and said to produce flower year-round and have high fruit yields. Pal muraungai is identified for its thick pulp and better taste. Punamurungai and Kodaikalmurungai have been selected for slender stem with tallness to use as support for betel vine crop, which is most popular in Trichy District of Tamil Nadu. It produces very short fruits of 15 to 23 cm.

Fig-3: Genetic variability for pod length of moringa

In addition, there are some improved genotypes selected for yield and quality with annual in nature. KM-1 (Kudumianmalai-1) is an improved type and designated as seed moringa. Pods are short (32-37 cm and 5.5-6.0 cm girth) and weighing from 65 to 82.5 g. Each tree bears 226-328 pods with high yield potential (14.69 to 26.90 kg). PKM 1 (Periyakulam-1) is improved through pureline selection from the population generated by continuous selfing. The tree comes for harvest at 8-9 months after planting and produces at least 200-350 pods. It bears twice in a year. In Karnataka, GKVK-1, 2, 3 a small stemmed varieties (2-2.5 m) bearing120-200 pods/tree/year have been developed. Dhanaraj is another improved variety characterized with short fruit segments (35-40 cm) producing 150-200 pods/tree have been identified. Bhagya (KDM-1) has been developed for its medium to log pod segment (60-70 cm) bearing 350-400 pods/ tree. In Maharastra, Konkan Ruchira has been selected from Vasai local. It is a bushy type, each tree yields 275 pods with medium long size and yielding 30-35 kg per year. Rohit-1is an early bearing, dark green pods with medium long (45-60 cm) weighing 60-70 g. Each tree bears 400-600 pods per year. In Gujarat, Thar Harsha has been developed from PKM-1, though pureline selection, which is tolerant to drought, densely foliaged, and long pod (100.5 cm) with uniform parrot green colour. Each tree bears 100-125 pods and weighing 120g. Each plant bears 15-20 kg/tree in 2nd year itself and increasing every year subsequently. In addition Amar -32 (Amar seeds

Pvt Ltd), Andipatty (semi dwarf type), Anupama (Kerala Agricultural University, Vellanikara), MOL'E (Advanced Biofuel Centre, India), MOMAX-3 for oil production (Advanced Biofuel Centre, India), MS01 and MS02 (Ancient Green field Pvt Ltd), MX-3 for oil production (Advanced Biofuel Centre, India). In Kenya, Mbololo is a variety developed by the Kenya Forestry Research Institute (KFRI) of Nairobi, Kenya. It grows well without irrigation and is wind resistant and a heavy pod producer. In Malawi, a variety naming Malawi was developed for enhanced oil content. In Texas, STX-1 and STX-2 developed where STX-1 is quite cold-hardy, heat and drought tolerant, fast-growing, and very productive. STX-1 concentrates most of its energy into leaf production, and less on flowering and pod production. Where as STX-2 is a dual type for both leaf and pod production.

In heterosis breeding, the selection of parent is a pivotal factor to have desirable hybrids, considering their *per se* performance and GCA effect. The single parent cannot be a good performer for every quantitative character. Hence, the parents showing high per se and GCA are the good combiners, and the high per se and high SCA for best hybrids. Sadasakthi (1994) identified best lines and tester for improvement of various characters in Moringa and found PKM-1 as the best tester except for fruit length, fruit weight and seed number, whereas land races showed higher value. Ramnad local, Pudukkotai local and Moovarai Vendran local were found to be the best general combiners to improve quality characters (Fe & protein content). Eppodumvendran local (line) and PKM-1 (tester) and their crosses had high yield due to non-additive gene action and positive relative heterosis, which indicated dominance gene action. The parents Tutucorin local and PKM-1 and its hybrid had non-additive gene action for number of fruits per plant. PKM-2 is an hybrid derivative developed from the cross between MP31 and MP28, characterized with medium tall tree, long pod (123 cm) and higher girth (8.5 cm) weighing 280 g.

4.2. Breeding for moringa seeds and seed oil

Pod length is a major determinant of consumer acceptability as the pods with medium length (<60 cm) are more preferred than extra long pods (>1.0 m). The seed yield is determined by no of seeds/pod and its arrangement in pods as its is evidenced that extra long pods had poorly packed seeds as compared to short to medium length pods. There has been no exhaustive research on seed yield and oil content in India, as main focus was given to leaves and biomass production. PKM-2 followed by MO-3 had pods with nearly 3.5 to 4 ft. The short pods are in general packed with seeds and gives uniform fruit thickness and shape as against long podded where seeds are packed distantly. Considering the number of seeds per pod with specific to its pod length, MO-8, MO-2 and MO-5 were found tightly packed as seeds are arranged very closure (<3.0 cm). The popular commercially released varieties such as PKM-1 (4.38 cm) and PKM-2 (5.37 cm) had seeds apart wider. The improvement of moringa for seed and seed oil content needs densely packed seeds with longer pods. Ayerza (2012) found that Arid Chaco had significantly higher oil percent than at Sub-Humid Chaco; however, the seed/tree yields and the oil/tree content among the ecosystems did not differ significantly among four ecosystems of Argentina and Bolivia (Arid Chaco, The Yungas Tropical Forest, Sub-Humid Chaco Lowland, Tropical Forest) to determine the seed yield and oil content of PKM-1. Further, PKM-1 recorded superiority for seeds/tree, oil yield/tree, and seed weight/trees than for the African cultivar, suggesting that the genotype from India would be more economically useful in a subtropical environment. However, oil from the two cultivars had a practically identical fatty acid compositions and oil content ranging 31.8% to 40.8% which depends on the different years and trees. The kernel is constitutes 70-75% of the seed weight. Oil is the main component of the seed and represents

36.7% of the seed weight. However, lesser yield is obtained by cold press extraction over the oil extracted almost entirely by solvent extraction, generally n-hexane.

Worldwide, except improvement for edible pod in moringa, none other exploitation has been made although seeds oil (lubricator in delicate machineries, manufacturing of perfumes and hair dressings), seed powder (a water clarifier) is most valuable products. The seed yield and its oil content are determined by the no. of fruits/plant, average fruit weight, fruit length, number of seeds/fruit and seed weight etc. Pod length is an important character, which decides the consumer preference. The medium pod length (< 60 cm) is preferred for local market, where the lengthiest fruit (> 1.0 m) is suitable for the processing industry. However, the breeding for seed yield demands lengthier or pods with more seeds. Accordingly, the genotype PKM-2 had the lengthiest pods (123.1cm) followed by MO-3. However, the genotypes MO-8, MO-9 and MO-11 had shorter pods (<50.0 cm).

Fig-4: Genetic variability for seed size and seed color of moringa

4.4. Breeding for quality and pharmacological properties

Moringa leaves are rich in nutrients like iron, potassium, calcium, and multivitamins, however the anti-nutritional substances such as tannins (20.7 mg/g), trypsin inhibitor (1.45 TIU mg/g), nitrate (17 mg/g) and oxalic acid (10.5 mg/g) also coexists (Charron et al., 2005). Moringa leaf powder have been reported having higher oxalates at level of 1,600.00 mg/100g, which forms insoluble complexes with some metals, especially calcium and iron, thus leading to reduced calcium and iron bioavailability/ metabolism (Iwuoha and Kalu, 1995). Radeke and Savage (2008) also reported that the ratio of total oxalate to total calcium in moringa was 0.38 mEq which indicated that the calcium bound in oxalate to total oxalate was 40.3% and the available calcium for metabolism was 59.7%. Hence, isolation of genotypes with low oxalate coupled with high calcium makes the later more available to health rather than >40% calcium in unavailable form. Although not much work has been done on quality improvement in moringa, the assessment of 52 accession for quality traits had population in sub cluster III (IIHR-D-5 and IIHR-D-28) showed higher leaf yield (14.81 kg and 7.70 kg, respectively) with higher biochemical values (Fe, I, Cu, TP, FRAP & DPPH antioxidant activity) proved that the genotypes placed in sub cluster III are more suitable for the quality improvement (Supriya et al., 2021). However, the higher total oxalate content (1117.83 mg/100 g DW) of these genotypes is a concern too. The higher Ca and Fe of these genotypes attributed that total oxalate found in insoluble form has less health hazards. The sub cluster V (IIHR-D-5, IIHR-D-40, IIHR-D-80, IIHR-D-123, IIHR-D-38, IIHR-D-103, IIHR-D-46 and IIHR-D-59) had minimum value for leaf yield, however the oxalate content was found least among all groups (770.33 mg/100 g). Hence, this sub cluster can be an ideal parental line for transgressing anti-nutritional factor with high yielding genotypes (Supriya et al., 2021). Supriya et al. (2021) had isolated few stable genotypes for quality traits such as Ca (IIHR-D-55, IIHR-D-120, IIHR-D-69), Fe (IIHR-D-4, IIHR-D-28), total carotenoids (IIHR-D-149), total phenols (IIHR-D-35), FRAP (IIHR-D-128) & DPPH (IIHR-D-33) antioxidant activity, total flavanoids (IIHR-126 and IIHR-D-34) and total oxalate content (IIHR-D-5 and IIHR-D-8) from the leaves sample harvested at 3 different contrasting seasons.

Plantlet development through *in-vitro* approach had an embryogenic callus induction issues. To overcome these issues Yang et al. (2021) sequenced the cDNA libraries of three moringa embryogenic callus leading to identification of 7191 differentially expressed genes (DEGs) responsible for embryogenic callus development, 2325 of these were categorized for plant hormone signal transduction and plant-pathogen interaction of KEGG database (Yang et al., 2021). qRT-PCR based experimental validation of 16 unigenes related to auxin signalling pathways, showed their key involvement during moringa embryogenic callus formation (Yang et al., 2021). Earlier *M. oleifera* genotypes (T-01, T-06, M-01, and M-02) with wider genetic base were identified using twelve RAPD markers to use in future breeding program (Rufai et al., 2013). Fingerprinting and genetic variability of 23 superior moringa genotypes collected from different Indian states were investigated by (Drisya et al, 2022) using 27 RAPD markers and reported that 471 bands (89.61%) were polymorphic out of the total 519 bands obtained (Drisya et al., 2022). The *in-vitro* protocol for the mass propagation of *M. oleifera* was achieved when nodal explants were cultured on 1.0 mg/L 6-Benzylaminopurine (BAP) supplemented Murashige and Skoog (MS) medium followed by rooting on basic MS media (Bharati et al., 2022). Genetic transformation attempted in moringa (Zhang et al., 2017) using a reliable and stable *Agrobacterium tumefaciens*-mediated transformation system for the genetic improvement of drumstick. *A. tumefaciens* strain EHA105, harbouring the plasmid pCAMBIA1301 containing the hygromycin phosphotransferase II and ß-glucuronidase genes driven by the CaMV 35S promoter using vacuum infiltration-assisted *Agrobacterium* infection (excluding a pre-culture step) and co-cultivation for two days significantly increased the transformation frequency. Genomic integration and transgene expression were confirmed by β-glucuronidase (GUS) assays, polymerase chain reaction (PCR), Southern blot analysis and real-time quantitative PCR (RT-qPCR).

3. Molecular and Omics Interventions

High quality reference genome of moringa was reported just few year back (Tian et al., 2015) which has opened the gateway for modern omics based research on moringa tree. 19,465 protein-coding genes representing about 91.78% of the estimated genome size (Tian et al., 2015) was further explored by other researchers for identifying the genes responsible for high protein content, fast growth, stress and heat tolerance of this unique tree. Draft genome information of African moringa (Chang et al., 2018) and *de novo* draft assembly and annotation of genome of Pakistani moringa (Pervez et al., 2022) have also been reported recently. Whole genome sequence of *M. oleifera* var. Bhagya was reported (Shyamli et al. 2021) with 90% of its genome into 915 contigs having 4.7Mb of N50 value and 32,062 putative protein coding genes and 21 heat shock transcription factors (HSFs) which played significant role in defense against different abiotic specifically drought stress. Pasha et al. (2020) sequenced the cDNA libraries prepared from different tissues like root, stem, leaf, flower and seed of Bhagya cultivar of *M. oleifera* and 17,148 gene models were predicted using assembled transcriptome developed using already available *M. oleifera* genome. Genes responsible for biosysthesis of secondary metabolites (like quercetin, kaempferol and benzylamine), vitamins and iron transporters were identified and their expressions were further confirmed using RT-PCR. Extremely high level of expression of enzymes involved in the biosynthesis of vitamins and quercetin and kaempferol like metabolites were reported in leaves, flowers and seeds while in root and leaves higher expression of iron transporters and calcium storage proteins were reported. Relatively higher expression of quercetin along with higher amount of minerals like Fe and Ca (even higher than that reported in spinach leaves) in moringa leaves proved and justify its classification as a “Super Food” (Pasha et al., 2020). The proteomes of *M. oleifera* using mass spectrometry and bioinformatics-based methodologies (Wang et al., 2016) revealed a total of 202 proteins identified from the four vegetative organs (101 proteins from leaves, 51 from stem, 94 from bark and 67 from root) having pI between

5–10 and below 100 kDa of molecular weight. Several heat shock proteins and also those involved with catalytic activities were reported in all four vegetative tissues which used to play significant role in enabling moringa tree surviving under heat stress of tropical and subtropical region (Wang et al., 2016). The 3D structure of the protein ribulose-1,5-bisphosphate carboxylase/oxygenase from *M. oleifera* were model by using Modeller (Kumar et al., 2018). The predicted models were validated and the active sites of ribulose-1,5-bisphosphate carboxylase/oxygenase protein were predicted to be made of Val13, Lys14, Asp15, Tyr16, Thr19, Tyr20, Thr59, Gly60, Thr61, Trp62, Thr63, Thr64, Val65, Asp68, Leu73 residues. Zhang *et al*. (2019) has investigated the WRKY proteins family in moringa, and using genomic data 54 *MoWRKY* genes were reported, and were classified into three groups having five subgroups in second group, and its expression level were associated with the different abiotic stress responses (Wang et al., 2016). Liu et al. (2019) has reported first time the chloroplast genome of *M. oleifera* being 160,599 bp long and having 113 genes (NCBI accession number MH778650). Only one recent report on the molecular docking of bioactive compound 'Quercetin' with p53 protein in the apoptosis pathway of oral squamous cell carcinoma is available in the literature (Rath et al., 2021) leaving behind a broad bioinformatics and molecular biology based unexplored are of research in *M. oleifera* to be taken up by the future researchers.

5. Conclusions and the Way Forward

Moringa is an important perennial vegetable crop grown across the world from arid to temperate ecosystem. It is highly nutritious and has vast potential for pharmocological properties due to its mineral, vitamins and other essential phytochemicals. Hence, moringa has been identified as chief and alternate remedy for the malnutritional issues. The genetic potential and crop improvement in moringa for enhancing its yield and phytochemical properties particularly targeting the present requirements of nutritional and pharmacological industries globally, as the natural products and their structures played a highly significant role in drug discovery and development process which is genotype specific. Natural coagulent protein based on globulin and albumin fraction needs to mined for industrial purposes. Moringa leaf extract suppressing the monoamine and phosphodiesterase type 5 activities favoring aphrodisiac potential needs investigation. Examination of Moringa seed MUFA/PUFA of total fatty acids of brains involving in brain development at embryonic stage for cell proliferation and neuronal differentiation and their deprivation causes apoptosis/ Alzheimer disease in aged people for memory loss. The moringa seed extract contains niazirin having an antitumoural and antioxidant activity which inhibit the proliferation of high glucose induced vascular smooth muscle cells of diabetic by regulating the protein kinase/NADPH oxidase 4/ ROS signalling pathway needs investigation.

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26. Strategies for harnessing the potential of orchids in India

Chandan Gowda H[#], Siddhartha Sankar Biswas[#], L C De[#], Suman Natta, N S Kalaivanan, D. Saha and S P Das*

ICAR-National research centre for Orchids, Pakyong-737106, Sikkim

*Email: Sankar.Das@icar.gov.in , Director.nrco@icar.gov.in

ABSTRACT

Orchids are occupying a prime position in global floriculture owing its explicit diversity in flower shape, size and colour; long shelf life, year-round production of different species. The advancement of orchids to occupy a position in the top 10 flowers in the world was due to the tremendous development in inter-specific and inter-generic hybrids of orchids, advancement of micro-propagation techniques and optimization of controlled growing conditions for economically important genera for year-round production of cut flowers and potted flowering plants. Today global cut flower trade alone generates revenue of US $ 28,891.5 million and expected to grow up to US $ 47,965.5 million at a CAGR of 5.8% by 2030. Orchids represent 10% of the total global cut flower trade, left aside the huge turnover of potted orchids and legal and illegal orchid species trade. India is home to 1256 orchid species belonging to 155 genera, out of which 388 species are endemic to this part of the globe. India, unlike most established orchid growing countries globally such as Thailand, Netherland, Taiwan, etc.; can grow all types of orchids: temperate, sub-tropical and tropical, very successfully owing to its agro ecological diversity. In spite of that India's share in orchids trade is negligible. Considering the scope and potential of Orchids in the country. ICAR-National Research Centre for Orchids, Pakyong, Sikkim was established by ICAR on 5th October, 1996 based on the recommendations of the Planning Commission during VIII Five Year Plan. Keeping the aspiration of the Government and the country as whole, the ICAR-NRCO has the following perspective to put orchids of India in its much deserving and awaited place to harness the potential of this sector. 1. NRCO should act as National custodian of orchid genetic resources, breeding pipelines & economically profitable and sustainable production technologies. 2. To conserve orchid resources of India; collection, characterization and evaluation for economic utilization. 3. To develop marketable hybrids, preferably new inter generic / inter specific combinations of indigenous orchids and production of quality planting material. 4. To develop complete POP of production, protection and post-harvest handling to produce quality flower / potted plants at competitive cost. 5.To work closely with the stake holders to establish viable and sustainable orchid value chains in the country. In the present paper the strategies for harnessing the potential of orchids in India will be discussed.

Orchids: most fascinating among flowering plants

Orchids are one of the most prized flowering plants traded as cut flowers and pot plants. Orchids belong to the second largest family of the flowering plants having more than 29,500 orchid species worldwide. IUCN Global Red List has assessed about 1641 orchid species of which 747 are categorized as "Threatened' with 197 listed as 'Critically Endangered'. India is home of 1256 species belonging to the 155 genera. Of these, 307 species are endemic the country. Experimental evidences suggest that orchids emerged over 80-100 million years ago. They have the smallest seeds amongst the flowering plants in the world and require unique microhabitats to grow. About 8 % of all flowering plants are orchids and many of them have been in use in traditional systems of medicine in several countries including India, in the ancient Indian Ayurvedic system for their medicinal properties.

Ecology and orchids

Orchids are highly sensitive to the climatic changes in their habitat and show extensive interconnected symbiotic relationships with organisms like insects, plants and fungi and their presence is a positive indicator of the healthy ecosystem and the biodiversity of their habitat.

Habitat and distribution

Orchid habitat ranges from tropic to alpine zones in the forests, river banks, bamboo and palm thickets, grassy slopes and rocky areas. They are distributed in the Himalayan Region, the Peninsular Regionm and A& N islands.

Conservation status

- IUCN Red List includes *Paphiopedilum druryi, Paphiopedilum fairieanum, Paphiopedilum charlesworthii, Paphiopedilum venustum, Paphiopedilum spicerianum, Paphiopedilum insigne, Paphiopedilum wardii, Paphiopedilum villosum* and *Paphiopedilum hirsutissimum* and other 154 genera.
- Under wildlife protection Act, 1972 schedule VI, *Vanda coerulea* (Blue Vanda), *Renanthera imschootiana* (Red Vanda) and all 9 species of Paphiopedilum.
- Conservation on International Trade in Endangered Species of Wild Flora and Fauna (CITES) envisages *Dendrobium cruentum* (Pigeon Orchid), *Paphiopedilum* spp., and *Renanthera imschootiana* (Red Vanda) of Appendix-I and all species of orchidaceae excluding the species included in the Appendix I.
- Export of plants and plant parts of the wild origin, of species specified in the Export Licensing Note 1 is prohibited.
- A special exemption can be granted for research, education and life saving drugs in case basis.

Threats

- Habitat destruction and degradation are the most serious threats to orchids today. In addition, climate change is also harming the species which has a significant impact on pollination services and affects the plant communities where orchids exist.
- Illegal harvesting and over-exploitation cause a serious threat with species like *Cypripedium, Paphiopedilum* and *Renanthera imschootiana*.
- Orchids are illegally collected and traded for ornamental plants, traditional medicine and food. Due to increasing demand orchids like *Eulophia dabia*, and *Dactylorhzia hatagirea* are succumbing due to unsustainable harvesting practices.
- Orchid species used in Chawanprash preparation such as Cr*epidium acuminatum, Crepidium muscifera, Habenaria edgeworthii* and *Habenaria intermedia* are collected from the wild for their medicinal properties.

Conservation status

About 70% of the world's orchids are epiphytic and/or lithophytic; 25% are terrestrial and 5% of the world's orchids grow in mixed substrates (lithophytic, epiphytic and terrestrial). These also occur as saprophytes. There is the close link between collection based research and conservation. Approaches addressing conservation of process (rather than individual species) may be appropriate in groups which are relatively undergoing evolution due to hybridization and/or polyploidization.

There are three prominent methods of conservation of genetic resources of orchid species namely Legislative measures, in-situ conservation in sanctuaries, NATIONAL PARKS, Secred Groves Reserves and Ex-situ conservation in Orchidaria, Field Gene Banks, in-vitro conservation, cryo-preservation and Botanic gardens.

Production status

The total orchid cut flower trade of the world mostly consists of 85% *Dendrobium* species and 15% *Phalaenopsis* and *Cymbidium* species and Asia is the main source of orchid to enter the world. Globally, trade on artificially propagated live plants are dominated by Orchidaceae hybrids (28.7%), Cymbidium species (26.9%), Orchidaceae species (18.9), Phalaenopsis hybrids (10.1%), Phalaenopsis species (4.4%), Dendrobium species (3.4%), Cymbidium hybrids (3.3%), Dendrobium hybrids (2.3%), Cattleya species (0.4%) and Oncidium species (0.2%).

Temperate orchids: *Cymbidium*, the temperate orchid, is now grown in the Sikkim, Arunachal Pradesh and Darjeeling Hills of India. The flower spikes are erect, arching or drooping and display a wide variety of colours. Some of the hybrids of importance cultivated in India are 'Levis Duke Bella Vista', 'Madrid Forest King', 'Sparkle Late Green', 'Angelica December Gold', 'Sleeping Nymph', 'Pine Clash Moon Venus', 'Soul Hunt', 'Dr. H. C. Aurora', 'Susan Highes', 'Tia Gaig Suther Land', 'Miss Sanders', 'Amesbury', 'Kenny Wine', 'Red Star', 'Red Princess', 'Show Girl , Jungfrau 'Snow Queen', Jungfrau 'Dos Pueblos', Lilian Stewart 'Coronation', Lilian Stewart 'Party Dress', Orkney 'Pink Heather', Ensikhan 'Alpha Orient', 'Winter Beach Sea Green', 'Fire Storm Ruby','Angelica Adven't, Dingwall 'Lenes' and Peter pan 'Green Leaves'.

Tropical orchids: Tropical orchids are mainly cultivated in Kerala and some parts of Tamil Nadu, Karnataka and Maharashtra. Since *Dendrobium* consists of a large number of species (over 1,500), several hybrids have been produced and released for commercial cultivation. Those popular in Kerala are 'Sonia 17', 'Sonia 17 Mutant', 'Sonia 28 Mutant', 'Hieng Beauty', 'Dorine White', 'Ekapol Panda', 'Sakura Pink', 'Pramot Sabine', 'Emma White', 'Kasem White', 'Mme Vipar', 'Kasem Gold', 'PM 11', 'Waiphu Beauty', 'Sarifa Fatimah' and 'Jiad Gold'. In north-eastern states, popular varieties are 'Abraham','Madam Pompadour', 'Triple Pink', 'Thongchai Gold', 'Bangkok Blue', 'Erika', 'Lervia', 'Kating Dang', 'Emma White' and 'Dang Saard'.

Salient features and common varieties of other popular genera are as follows:

***Arachnis* (Scorpion orchid):**

It is monopodial, requires good sunlight and temperature for growth and flowering. *Renanthera* is a related genus. Common varieties are 'Maggie Oei Red Ribbon',Maggie Oei Yellow Ribbon', 'Maroon Magie' and 'Merry Maggie'.

Vanda: Its habit is that of *Arachnis*. Based on shape of leaf, terete (cylindrical leaved, pencil Vanda), semi-terete and strap leaved vanda. *Aerides* and *Rhyncostylis* are related genera. Varieties: 'Roberts

Delight', 'Dr. Anek', 'Pakchong Blue', 'Miss Joaquim', 'Fuch's Delight', 'Lumpini Red', 'Motes Indigo Blue', 'Pat Delight', 'Rasri Gold', 'Samsai Blue', 'Adisak Smile', 'Robert Sorenson', 'Kasems Delight', 'Richard Brandon', Kultana Delight', 'John Clubb;, ;Josephine Van Brero', 'Norbert Alphonso', 'Wirat Uchida' and 'Ruby Prince' are important.

***Phalaenopsis* (Moth orchid):**

Monopodial, requires partially shaded conditions. *Doritis* is a related genus. Varieties: 'Strawberry', 'Manchester', 'Detroit', 'ChianXen Magpie', 'Shih Hua Long First Love', 'Taida Salu Red', 'Hsin Yang Fortune', 'Kaleidoscope', 'Rose Parade', 'Keith Shaffer', 'Temple Cloud', 'Hennessy' and 'Diana Pinky' are important.

***Oncidium* (Dancing Girl):**

Sympodial, with or without pseudobulb, loves partially shaded conditions. Varieties: 'Goldiana', 'Sharry Baby Sweet Fragrance', 'Taka Yellow', 'Sweet Sugar', 'Wild Cat Bob Cat', 'Dark Tower', 'Ruby Frost' and 'Gower Ramsay' are important.

***Cattleya*:**

Sympodial, loves partially shaded conditions. *Brassovola, Laelia, Sophronitis, Encyclia* etc. are related genera. Varieties: 'Queen Sirikhit', 'Ahmad Sheikhi', 'Chinese Beauty Orchid Queen', 'Brazilian Star', 'Amazon Blue', 'Black Wonder', 'Little Bell', 'Suzzanne Hye' and 'Edithe Bow Bells' are important.

***Paphiopedilum* (Lady's Slippers Orchid):**

A pseudobulbless, sympodial terrestrial or lithophytic orchid is grown in cool and shady conditions. Common varieties are 'Joyce Hasegawa', 'Lynleigh Koopowitz', 'Magic Lantern', 'Harold Koopowitz', 'Magic Lantern', 'Armeni White', 'Red Glory', 'Black Pepper'.

***Aranda* (*Arachnis* x *Vanda*):**

'Christine', 'Thailand Sunspot', 'Millenium Dawn', 'Broga Giant', 'Salaya Red', 'Prapin White', 'Prapin Spot', 'Lueng Cholburi', 'Ishbel Manisaki', 'Baytown', 'Chao Praya Blue', 'Chao PrayaDotCom', 'Chao Praya Beauty'.

***Mokara* (*Arachnis*x *Ascocentrum* x *Vanda*):**

'Madam Panne', 'Bangkok Gold', 'Chao Praya Gold', 'Chark Kuan Orange', 'Chark Kuan Pink', 'Kelvin Red', 'Kelvin Orange', 'Walter Ouame', 'Jitti Orange', 'Happy Beauty', 'Chark Kuan Red'.

A humidity range of 75-85% in summer season and 50-55% in winter season is ideal for orchids. Most orchids generally prefer indirect or filtered light. Although it varies species to species, growth habit and habitat, as the rule of the thumb, 50% shading is always advised for most of the commercial orchids. Warm orchids like *Aerides, Vanda, Rhyncostylis* and some Dendrobium species grow at day temperature upto 32.2^{o}C and 15.5^{o}C for a minimum night temperature; intermediate species like *Cattleya, Laelia, Brassovola, Oncidium, Miltonia* etc prefer 26.6^{o}C days and 12.8^{o}C nights. Cool species such as *Cymbidium, Odontoglossum, Cypripedium* etc prefer 24^{o}C days and 10^{o}C nights. Most orchids require a lower night temperature for both robust growth and to initiate blooms. A night temperature of 10-13^{o}C is ideal for initiation of flowering in *Cymbidium*. Fresh air and good circulation are essential for orchid production. Monopodial orchids like *Vanda, Aerides*, *Arachnis* and *Mokara* can be propagated by top cuttings. In *Phalaenopsis*, *Phaius*, *Calanthe* and *Thunia*, flower stalks give rise to plants. Sympodial orchids like *Dendrobium, Cattleya, Oncidium, Miltonia, Paphiopedilum* and *Cymbidium* can be propagated by division. The shoots growing on the plants which are called 'keikis' can also be used. Keikis are common in *Dendrobium, Epidendrum* and *Ascocenda*. Backbulbs (already flowered bulbs) can also be used as propagules in case of *Cymbidium*, *Cattleya* and *Coelogyne*. Earthen pots, plastic pots, baskets, tree fern block, wooden trays and whole husk of coconut are common containers used for planting orchids.

Terrestrial and semi-terrestrial plants like *Paphiopedilum* and *Cymbidium* perform better in deep pots. Basket culture is useful for those orchids like *Vanda*, *Rhyncostylis*, *Arachnis* with pendent flower spikes and long dangling roots. Orchids in hanging pot or baskets are grown with lighter media like charcoal, coconut husk and tree fern fibre. Clay pots are best suitable for terrestrial orchids. Plastic pots are used for epiphytes. Slabs or logs of tree fern are effective for cool growing orchids. A potting medium consisting of wood chips, brick pieces and leaf mould in equal proportions is ideal for vegetative growth and flowering of epiphytic orchids. In *Cymbidium*,the pots should be placed at spacing of 60 cm x 60 cm, which will accommodate about 3 pots / m^2 (gross). The total number of plants will be about 30,000 / ha. In *Dendrobium*, the planting density should be 100,000-1,50,000 plants/ha. During flower initiation and inflorescence development plant are fed with less nitrogen, more phosphorus and potassium. During the blooming time, a small level of nitrogen and phosphorus and high levels of potassium are maintained. In orchids, foliar feeding is found to be ideal. Frequent application of fertilizers in low concentrations is the best way of feeding orchids. A concentration of 0.2 to 0.3 % of 30:10:10 (N:P: K) at vegetative stage and 10:20:20 (N:P:K) at blooming stage are applied for quality flower production. The chemical fertilizers are to be properly balanced with organic manures-cowdung, cows urine, groundnut cake, fish emulsion and neem oil cake. They are to be diluted before application. Since urine contains high level of salts, a dilution of 1: 25 is necessary. For others, 1:10 dilution is ideal. One spray a week with organic manure is enough. In *Dendrobium*, the spikes of orchids are harvested when a few buds on the top remain unopen whereas in *Cymbidium* two buds open stage or 70% bloom stage. Pricing of spikes depends upon the type of orchid and the grade of spikes. The cost of one *Dendrobium* spike ranges from Rs. 10 to Rs. 25 depending upon the grade. For *Oncidium* and *Vanda*, the usual pricing in between Rs. 10 and Rs. 20 and in *Cymbidium*, the cost of one spike ranges from Rs.100/- to Rs.200/-. A *Cymbidium* grower can earn Rs. 40 lakhs in 10 years from an area of 500 m^2 accommodating 1500 plants after investing 10 lakhs and selling of 55000-60,000 cut spikes. From an area of 500m^2 containing 3000 plants, a *Dendrobium* grower can earn 5 lakhs in three years after selling of 3000 number of cut spikes and 3000 mother plants.

Export and import status

Orchids are consistently ranked among the best sellers in the global potted plant trade and also comprise 10% of all fresh cut flowers traded internationally. Thailand is the largest exporter of orchid cut flowers to India devoting 80.67% of total import followed by Netherlands 15.54%, New Zealand 2.29% and China 1.5%, respectively. Highest import of orchids was recorded in 2013-2014 (Rs. 3425.76 Lacs) followed by 2015-2016 (Rs. 2985.19 Lacs) and 2018-2019 (Rs. 2321.84 Lacs). Maximum export of orchids was found in 2016-2017 (Rs. 5.23 Lacs) followed by 2017-2018 (Rs. 4.89 Lacs).

Prospects of orchids in India

The commercial potential of orchids in India or its strength in orchid development and trade lies in the following areas: i) Rich orchid diversity/germplasm; ii) Varying an ideal agro climate from tropical to temperate regions to grow varieties of orchids; iii) Technical know-how of orchid growing, propagation technique, biotechnological backing, green house technology; iv) Affordable labour; and v) Ever-growing high end consumer market. Our shortcomings include: The production of planting material is lacking due to the following reasons: i) Lack of high-quality planting materials in sufficient quantities; ii) Lack of a market-driven approach to the production of plants and flowers that incorporates modern technologies; iii) Lack of production of our own hybrids that can compete in the global market; iv) Lack of consistent R and D support with new hybrid varieties and technical innovations; and v) a lack of planting material production.

Urban involvement

Urban areas serves as major flower markets for both loose and cut flower spikes used for a variety of occasions and purposes, such as bouquets, hotel flower arrangements, wedding decorations, and other events. Even flower-filled potted plants are used for landscaping and décor. Others who cultivate orchids for fun, relaxation, and house and garden decorating are hobbyists. In addition, metropolitan women, young people without jobs, and business owners are interested in growing orchids to augment their income. To meet the demand for orchids, such people must receive training in plant production, marketing, and cultivation. Another area is the establishment of export-oriented orchid farms with cutting-edge greenhouse equipment connected to tissue culture facilities to increase quality production of cut flowers for export as well as planting materials. In order to promote the floriculture sector based on orchids, both NGOs and the various governments have a significant role to play.

Rural involvement

The production and marketing of various agricultural, horticultural, plantation, and floricultural goods and commodities are essential to rural living. After receiving training in how to grow and seeing that the things they produce are in demand on the market, they have the knack for doing it flawlessly. As a result, every business will be successful if there is a market for its high-quality goods in both quantity and regularity. The Flori-tech village concept will need to be implemented with the full infrastructure in order to accomplish the same. Governmental bodies like NHB, APEDA, state horticulture departments, research centres, financial institutions, and banks will need to work together in this area, enlisting the aid of the local rural people or organisations.

Involving the local populations in growing Cymbidium cut flower variations is another admirable thing Sikkim has done, and this has helped the Indian orchid business. For our country to have a significant impact on the global market, more examples like this are required across the country. Thailand's model for the growth of the orchid business should be used as a guide. Encouragement and Growth of Subsidiary Industries Similar to how hardware engineering supports software, other industries must assist the development of orchids in order for it to be successful and have a positive impact on society. The production of high-quality planting materials from the newest hybrid clones in large enough quantities to satisfy growers' or farmers' needs at a competitive price is based on plant biotechnology. To produce high-quality flowers that are in demand in the market, farmers or business owners also need poly house constructions, foggers, humidifiers, temperature controllers, timers, agrochemicals, poly pots, compost, benches, tools and equipment, etc. In order to get fresh flowers to market with value addition, post-harvest mechanisms include packing supplies, transportation systems, etc. Of course, trained and competent labour is necessary for quality output that is cost-effective and adds value.

A number of variables, including as economic, environmental, and cultural issues, have an impact on the future of orchids in India.

Strategies to promote orchid in India

- Exploration and identification of unique orchid germplasms having aesthetic values in terms of genetic resources as parental materials, cut flowers, potted ornamentals, hanging baskets, medicinal and aromatic plants.
- Development of market driven hybrids of Cymbidium, Dendrobium, Vanda, Phalaenopsis, Cattleya, Oncidium and Paphiopedilum with attractive blooms of various colors, forms, shapes, sizes and long keeping quality.
- Production of planting materials of commercial hybrids and valuable species at mass scale through micropropagation and other propagation techniques.
- Round the year production technology of orchids through growing of selected hybrids and species.
- Area expansion of production in Cymbidium and Paphiopedilum in temperate regions, Oncidium, Cattleya, Zygopetalum in subtropical regions and Dendrobium, Vanda, Phalaenopsis and Mokara in tropical region.
- Improved post-harvest technologies and value addition, through dry flower production of unmarketable species and hybrids, single Floret packaging and wealth from waste.
- Domestication, multiplication and popularization of lesser known but high value orchids such as *Dendrobium nobile, Renanthera imschootiana, Rhyncostylis retusa, Aerides spp., native Paphiopedilum species, Vanda coerulea, Cymbidium whiteae, Malaxis spp., Habenaria* spp.
- Vertical gardening with suitable orchid genera such as Phalaenopsis, Coelogyne, Dendrobium, Bulbophyllum, Aerides, etc.
- Development of epiphytic orchid based farming system, including other ornamentals like Anthurium, Alstroeneria, gerbera and terrestrial orchids.

Future strategies

Conservation

- To create awareness among local people to encourage them to preserve the wild species in their area.
- Promote sustainable and measurable use of threatened orchids in legally permitted areas through village level biodiversity management committees.
- Greater emphasis on medicinally and ornamentally important valuable orchids threatened by illegal trade and over-exploitation the various Schedules of Wildlife Act 1972 of India for protection and to restrain their over-harvesting from the wild.

Genetic improvement

- Genera and species wise cataloguing of all germplasm collection using IPGRI descriptors.
- The rich diversity of orchids in the country requires a strong concerted Network Approach mode. The NRC for Orchids have to work on a network mode and also to work as an National Active Germplasm site with the various active cen- tres working on specific group of orchids. In view of the IPR regulations, it is the paramount importance to protect our germplasm using modern tools of bar coding. A network project involving groups with identical interest between universities and ICAR. These germplasm should be conserved with the duplicate sets grown in at least two locations, properly catalogued and characterized with national number obtained from NBPGR avoiding duplication. Cryopreservation to conserve germplasm can be taken up in collaboration with NBPGR
- At present, orchid trade is solely based on the hybrids derived from varietals, interspecies and inter-generic crosses. Building up a strong crop improvement programme based on sound breeding methodologies that will yield into development of hybrids/varieties of internationally acceptable quality traits. It is essential to develop own hybrids suitable for varied agroclimate for our country fulfilling the basic requirements of market demands.
- Evaluation of newly evolved genotypes to suit specific agro- ecological conditions
- Locating sources of resistance for biotic an abiotic stresses using conventional and biotechnological tools and developing varieties with high yield, quality and specific traits.

Production improvement

- Characterization of rhizosphere microbial community struc-ture and effect of engineered nanoparticles on microorganisms in the rhizosphere and phyllosphere.
- Commercialization of orchids through bioreactors covering micropropagation technology to industry in network mode.
- Cost effective agroclimatic management through optimization of a number of factors like light, temperature, humidity, water, air, growing media and nutrition for quality flower pro- duction. The standardization of growing media using cheap and indigenous materials such as leaf ferns, leaf moulds, green moss etc. may be explored and this must be used in consonance with cropping system to develop an orchid based farming systems.
- Development and popularization of cost-effective agricultural practices (INM/IPM) for increasing productivity.
- Quantification of water use efficiency and water requirements in orchids based on growth habit.
- Carbon sequestration potential in orchid based cropping systems.

Post harvest and value addition

- Development of location specific complete protocols starting from pre-harvest, harvesting, post-harvest techniques upto domestic and international markets for each genera of commercial orchids.
- Developing a comprehensive approach on value added products from wild orchids including species trade, drying, flower arrangements, herbal medicines, edible products and other aesthetic and aromatic products.
- Bio-prospecting using bioinformatics tools.

Bio-risk management

- Surveillance, identification and characterization of new invasive insects pests and pathogens.
- Pest-risk analysis.
- Development of rapid and reliable diagnostics kits against pests and pathogens including invasive species.
- Management alert and control of new invasive insect pests and pathogens.

Policies

- Commercialization of the new upgraded technologies.
- Genetic finger printing of rare, endangered and threatened species and their registration.
- Finger printing and registration of newly released varieties or hybrids.
- Patenting technologies related to orchids.
- Confirmation and Documentation of ITK's.

Transfer of Technology

- Constraint analysis and impact assessment of new technologies
- Production of quality planting materials, distribution and commercialization
- Large scale demonstration of proven technologies through training, demonstration, advisory services, social media etc.
- Participatory planting material production of commercial use.

Action points

Augmenting production area

- Awareness about orchid cultivation
- Mobilization of youth in orchid cultivation
- Developing production clusters
- Encouraging contract farming
- Promotion of export oriented units
- Database development

Economising production cost

- Demarcating suitable production zones
- Developing indigenous commercial varieties
- Greenhouse technology
- Production and post-harvest technology

Ensuring availability of quality planting material

- Setting up tissue culture laboratories
- Introduction of orchid varieties

Controlling product quality

- Certified quality planting material
- Sanitary and phytosanitary measures

- Adoption of good agricultural practices (GAP)
- Development of post-harvest management infrastructure

Skilling Human Resource

- Providing proper trainings

Marketing

- Strengthening supply chain linkages
- Encouraging direct sale
- Branding and brand promotion
- Boosting domestic consumption

Conclusion

The global orchid sector is extremely developed and competitive in different countries worldwide. With regard to the colour, form, and size of flowers, as well as other factors, market trends and tastes are constantly evolving. Similar to this, novel planting materials are constantly in demand. Therefore, there is a need for a robust and concentrated R&D effort to create novel hybrid strains using local species and exotics that are suitable for our country's different agroclimatic conditions. The availability of rare orchid species and natural hybrids through tissue culture would appeal to hobbyists everywhere.

The idea of integrating village and urban clusters engaged commercial orchid growing and production with a market-driven approach—one for the domestic market and the other for export—would aid in the growth of a thriving orchid industry in India. To grow the orchid business and benefit communities across the nation, corporate sector's involvement is also essential, particularly in the areas of production of high-quality planting materials and providing the market avenues and access for the small growers.

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27. Medicinal and Aromatic Plant Conservation and Cultivation for livelihood security and Human Wellness: Role of Botanic Gardens

N. Anil Kumar
Senior Consultant, M. S. Swaminathan Research Foundation, Wayanad 673 5707, Kerala
Email: anilmaruthur@gmail.com

I. Introduction

The WHO- Traditional Medicine Global Summit held on 17-18 August 2023 in Gujarat has resulted in bringing out an ambitious action agenda that is rooted in the WHO global framework for realising human well-being for achieving health-related Sustainable Development Goals. The accomplishment of the action agenda is advocated mainly by unlocking the potential of traditional, complementary and integrative medicine (TCIM) and through conservation and sustainable use of biodiversity. The Gujarat Declaration also calls for support and implementation of the Kunming-Montreal Global Biodiversity Framework (KMGBF) in full participation of and in consultation with Indigenous Peoples. The KMGBF targets 4 & 5, under the theme of reducing threats to biodiversity, and targets 9 to 13 under the theme of sustainable use and benefit-sharing ropes on urgent management actions required from the part of the member countries.

In the context of the growing interest in TCIM, a major management action that requires attention is the renewed and collaborative approach in conservation and cultivation of Medicinal and Aromatic Plants (MAPs). The renewed interest has to be with an aim of addressing the primary healthcare needs and wellness of senior citizens as well as providing livelihood security to the resource-poor communities. According to WHO (2020), for the first time in human history, people aged over 60 years or above will outnumber children under 5 by the end of 2020. By 2030, this age group will increase to 1.4 billion from the current 1 billion and in 2050 it will be over 2 billion. In India by this period the elderly population will be 194 million from the 2021 figure of 138 million. By that time the 60 year and above population will be twice as many children under 5, and outnumber adolescents and young people aged 15-24 years in the world.

Healthcare and wellness measures for this growing aged population will exert much pressure on all life on this planet. U N has declared 2020- 2030 as the Healthy Ageing Decade to achieve the goal of a long, healthy and happy life for all. This is an achievable goal, if there is the right policy environment, enough commitment, preparedness and action at multiple levels and in multiple sectors (Healthy Ageing Decade 2020-2030). Wider health promotion targeting this age group should be a high-priority action for India by providing a healthy environment and resources to practice a healthy lifestyle.

This paper examines the role of Botanic Gardens of a 2030-2040 India in the promotion of conservation and cultivation of MAPs for the use and benefit of elderly people and farmers, in particular those who hail from indigenous and local communities.

II. MAP's Conservation: Role of Botanic Gardens

Where can we find the lesser-known or lost or underutilized medicinal or aromatic plant species of this country? Some of the indigenous and local community habitations and botanical/horticultural gardens have region-specific collections of India's known medicinal and aromatic plant species. For example, India with over 4500 inhabitant ethnic communities, has developed a multitude of foods, drinks and medicines out of every possible plant genetic resource, and still conserved many of such culinary and curative diversities. However, there are not many gardens in India working with the objective of protecting the long history of medicinal herbs, folk medicine and cuisine, crop husbandry and agricultural practices. Fast erosion of the belief systems, traditional knowledge, cultural practices, art forms, and music associated with bioresource production and enhancement is visible in many parts of India.

The need for preserving and promoting traditional culinary and curative diversities in order to conserve the rich biodiversity in the flora and fauna of the place where the gardens are located thus becomes very important and urgent. See Tables 1-3 for some suggested strategies. The flora employed by each socio-cultural group of a region in meeting their food, health and nutrition needs will have to be demonstrated by every Garden in partnership with the men and women members of the local community.

III. Botanic Gardens for Health and Wellness Promotion

A 2030-2040 India Botanic Garden needs to transform into a Health and Wellness Garden that is meant for people of 60 and above age group who have an inclination towards the resumption of their physical and mental health by exposing themselves to the purity of nature. Many Gardens of India have documented knowledge about the rich culinary and curative diversity of their surrounding region. For instance, the MSS botanical garden in the Wayanad district of Kerala has over 400 species of medicinal plants and 120 species of wild food that signify the food habit of the tribal and rural communities of Wayanad, apart from the collections of many underutilized food plants. This garden promotes the cultivation of a variety of crop varieties in rice, tubers, vegetables, bananas, mango, jack fruits etc. in partnership with local farmers.

Botanical Gardens that are augmented with a variety of designed elements for collections of horticultural, medicinal or aromatic and wild food plants and facilities/spaces for recreation and physical exercise are the ideal settings for promoting health and wellness (Krishnan & Novy 2016). A Wellness Botanical Garden can provide age-friendly environments with a life course approach benefitting old age groups to children with better health and nutrition, skills/knowledge, and social connectivity (Box)

Box

Components of the Wellness Garden

1) Common Facility Centre (CFC): CFC will be a pentagonal/hexagonal mud building having the following facilities
    a) Yoga/Meditation square will be a silent place for the inmates to perform yoga and meditation.
    b) Reading place
    c) Meadow for basking around the 5-meter radius of the CFC with bushy plants here and there.
2) Huts: Five mud houses at equidistance around the CFC outside the meadow with two double rooms, kitchen and attached/non-attached bathroom. The floor of each house will be panelled with medicinal wood and tile roof.
3) Trekking/cycling path of 3-meter wide along the periphery, medicinal trees planted on either side along the path
4) Radiating paths of 1.5 meters connecting the CFC, huts and peripheral path
5) Vine huts (3 numbers)
6) *Nakshathra vanam*
7) Herbal garden outside the meadow till the peripheral trekking path
8) Bicycles
9) Wheelchairs
10) Seating facilities
11) Solar lighting systems
12) Health dishes according to the needs of inmates as prescribed by a health expert
13) Health Caretakers for inmates
14) Battery car facility
15) Music (Instrumental)
16) Badminton court & other such sports facilities
17) Swings

IV. MAP's Cultivation: Role of Botanic Gardens

The current international market of herbal medicine is estimated to be US $ 151.91 billion and is expected to grow 347.50 billion by 2030. India's share in it is less than 1%. This shows, that India has to go a long way in the herbal market though this country is endowed with over 7000 species of Medicinal Plants and has nearly 5000 years of herbal health care traditions.

The National Medicinal Plant Board has recommended large- scale cultivation of over 100 species of medicinal plants (See Annexure). The Botanic Gardens need to mobilise farmers and women SHGs to form their groups and cultivate these species. Good quality planting material of all these species should be raised in the nursery and supplied to farmers at a nominal cost. A raw drug collection centre also needs to be established with the guidance of experts with taking help of the district marketing authority. Apart from this, preparation of simple training manuals in conventional and CD forms on various aspects of medicinal plants could be prepared.

The recent price crash of several cultivated crops has made farmers to go for cultivation of Medicinal Plants. It is becoming more popular among farmers of many hilly districts of India, especially among the planters. Institutional Support in areas like Quality assurance, quality standards, value addition, processing, post-harvest handling, marketing and for awareness & training need to be sought from appropriate agencies. Setting up of following facilities would boost this industry and it can set a fine example for the sustainable utilisation of our genetic resources for economic prosperity.

- Decentralised Nursery Centres for Medicinal & Aromatic Plants
- Research & Development Centre for Medicinal Plants
- Medicinal Plant Information Centre
- Processing Units (Collection and Packing units) & Value addition Centres
- Promotion of Herbal Tourism
- Herbal/Ayurvedic Parks for Herbal Manufacturing Units.

Considering the unique strengths of the hill districts with reference to moisture and soil health, such areas should be given high importance to develop them as the epi-centres of the herbal industry. This could be possible, if there is a political will to translate the ideas and natural potential into action

Conclusion

The need for re-orienting the Botanic Garden's functions towards primary health care services focusing the elderly and creating livelihood for the resource poor farming and indigenous community becomes urgent to act upon. WHO recognizes Traditional medicine as an integral part of Local Health Traditions, and as the "sum total of the knowledge, skill, and practices based on the theories, beliefs, and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health as well as in the prevention, diagnosis, improvement or treatment of physical and mental illness". The approach should be treating synergistically the Human-animal -environmental health as 'one health' to fight against any human health problems. The twin goal of improving the human immune system and the environmental health system must be the foremost priority to safeguard the most vulnerable people against the killer pathogens in the future.

Table 1

Priority Area	The Know-How	The Do-How
In-situ on-farm conservation	Preserve wild habitats of outside forest areas to keep the Ecosystem complexity/diversity on	Awareness to leaders of PRIs, and NGOs to integrate this into the action plan
	Augment Sacred groves and Establish new Tree Groves	Awareness of the religious leaders, astrologers, and temple priests leads to action. Large-scale multiplication of priority species. Networking of Peoples' BD groups
	Protect Paddy Fields and such Wetland habitats	Promotion of profitable rice cultivation Strict Enforcement of the law
	Keep Homesteads	Awareness to the public especially women and retired public servants

Table 2

Priority Area	The Know-How	The Do-How
Community Participation	Build Self Help Groups and ensure their sustainability	Issue-based group formation through proper credit linkage and project support Educate the families -men first and then the women
	Incentivize the contribution and participation	Sustainable Income generation opportunities through appropriate intervention and market linkages
	Accord Recognition and Rewarding	Involve the knowledgeable, enthusiastic women in the project management Generate a Community Herbal Health Fund (with contributions from industries)
	Give Education and Awareness	Use effective mediums and **people** to educate the masses

Table 3:

Priority Area	The Know-How	The Do-How
Sustainable Use	First to know what to use and why to Use	Survey & documentation of the Herbal diversity and the Knowledge and practices across the local communities in a gendered manner coupled with mass awareness generation- An improved form of PBR approach Bio-prospecting for new *in situ* sources of chemical compounds, genes, proteins, micro-organisms
	Promote Sustainable Utilization by mainstreaming herbal traditions	Develop basic health care products for low-income groups Develop skills in sustainable harvesting and cultivation Validate and upscale the best practices
	Educate the Industry and Suppliers	Incentives to the industry and suppliers that follow good collection and supply practices
	Protect Traditional Knowledge and Practices	Strict Law enforcement and Good Governance (E.g. PPVFR and BD Act)

Annexure

NATIONAL AYUSH MISSION (NAM)

List of prioritized plants for cultivation under NMPB Scheme

PLANTS ELIGIBLE FOR 75% SUBSIDY

	Botanical Name	Common Name	Cost per acre for 2016-17
1.	*Aconitum ferox* Wall. / *Aconitum balfouri* Stapf.	Vatsnabh	47101.67
2.	*Aconitum heterophyllum* Wall. exRoyle	Atees	64420.4
3.	*Aquilaria agallocha* Roxb.	Agar	19530.61
4.	*Berberis aristata* DC.	Daruhaldi	36602.5
5.	*Commiphora wightii*(Arn.) Bhandari	Guggal	93702.4
6.	*Nardostachys jatamansi* DC.	Jatamansi	118592.1
7.	*Oroxylum indicum* Vent.	Syonaka	26353.8
8.	*Picrorhiza kurroa* Benth. exRoyle	Kutki	65884.5
9.	*Podophyllum hexandrum* (Royle) T.S. Ying)	Bankakri, Indian podophyllum	58564
10.	*Pterocarpus santalinus* Linn. f.	Raktachandan,Red sanders	33088.66
11.	*Santalum album* Linn.	Chandan	28519.7
12.	*Saussurea costus*C.B. Clarke	Kuth, Kustha	51243.5
13.	*Swertia chirata* Buch-Ham	Chirata, Charayatah	48315.3

PLANTS ELIGIBLE FOR 50% SUBSIDY

	Botanical Name	Common Name	Cost per acre for 2016-17
1.	*Acacia catechu* Willd.	Katha	10424.15
2.	*Aegle marmelos* (Linn) Corr.	Beal	23425.6
3.	*Albizzia lebbeck* Benth.	Shirish	21961.5
4.	*Alstonia scholaris* R.Br.	Satvin, Saptaparna	19530.61
5.	*Atropa belledona* Linn.	Atropa	36602.5
6.	*Crataeva nurvala* Buch – Ham.	Varun	10424.15
7.	*Desmodium gangeticum* (Linn.)DC.	Sarivan	26353.8
8.	*Gloriosa superb* Linn.	Kalihari	80525.5
9.	*Glycyrrhiza glabra* Linn.	Licorice Roots,Mulethi	58564
10.	*Gmelina arborea* Linn.	Gambhari	26353.8
11.	*Hippophae rhamnoides* Linn.	Seabuckthorn	29282
12.	*Inula racemosa* Hk. f.	Pushkarmool	22136.95
13.	*Leptadenia reticulate* (Retz) Wt.&Arn.	Jivanti	36602.5

14.	*Mesua ferrea* Linn.	Nagakeshar	10424.15
15.	*Plumbago zeylanica* Linn.	Chitrak	17569.2
16.	*Pueraria tuberose* DC.	Vidarikand	29282
17.	*Premna integrifolia* Linn.	Agnimanth	14641
18.	*Pterocarpus marsupium* Roxb.	Beejasar	32210.2
19.	*Rauwolfia serpentina* Benth. exKurz	Sarpgandha	36602.5
20.	*Rheum emodi* Wall.	Archa	118592.1
21.	*Saraca asoca (*Roxb.) De Wilde	Ashok	36602.5
22.	*Smilax china* Linn.	Hrddhatri (Madhu snuhi), Chob ChiniLokhandi	29282
23.	*Stereospermum suaveolens DC.*	Patala	10775.05
24.	*Tacomella undulata (Sm.) Seem.*	Rohitak	10424.15
25.	*Urarea picta(Jacq.) Desv.*	Prishnaparni	24304.06
26.	*Valeriana wallichi DC.*	Indian Valerian	35138.4
27.	*Zanthoxylum alatum Roxb.*	Timoor	17569.2

PLANTS ELIGIBLE FOR 30% SUBSIDY

#	Botanical Name	Common Name	Cost per acre for 2016-17
1.	*Abrus precatorius* Linn.	Chirmati,Gudumani Chinnoti	26880.15
2.	*Acorus calamus* Linn.	Vach	36602.5
3.	*Adhatoda zeylanica* Linn.	Adusa	10424.15
4.	*Aloe vera* (Linn.) Burn.	Ghritkumari	24889.7
5.	*Alpinia calcarata* Roxb.	Smaller Galangal	33146.74
6.	*Alpinia galanga* (Linn.) Willd.	Greater Galanga	28589.88
7.	*Andrographis paniculate* (Linn.) Burn	Kalmegh	14641
8.	*Artemisia annua* Linn.	Artemisia	19496.73
9.	*Asparagus racemosus* Willd.	Shatavari	36602.5
10.	*Azadirachta indica* A. Juss	Neem	21961.5
11.	*Bacopa monnieri* (L.) Pennell	Brahmi	23425.6
12.	*Bergenia ciliata* Stern.	Pashnabheda	40073.99
13.	*Boerhaavia diffusa* Linn.	Punarnava	17569.2
14.	*Cassia angustifolia* Vahl.	Senna	14641
15.	*Caesalpinia sappan* Linn.	Patang	31360.78
16.	*Catharanthus roseus*(Linn.) G.Don	Sadabahar	14641

17.	*Celastrus paniculatus* Willd.	Malkangani Jyothismati, Bavanthi Beeja	13000.24
18.	*Centella asiatica* (Linn.) Urban	Mandookparni	23425.6
19.	*Chlorophytum borivillianum* Sant.	Shwet Musali	183012.5
20.(a) (b) (c)	*Cinnamomum verum* Presl *Cinnamomum tamala* (Buch.-Ham.) Nees et Eberm. *Cinnamomumcamphora*(Linn.)J.Presl.	Dalchini, Tejpat, Kapoor	45387.1 26018.63 0
21.	*Clerodendrum phlomoidis* Linn.f	Arni	18827.6
22.	*Clitoria ternatea* Linn. (Blue & White veriety)	Aparajita	18827.6
23.	*Coleus barbatus* Benth.	PatherChur	25182.52
24.	*Convolvulus microphyllus* Sieb. ex Spreng.	Shankhpushpi	19496.73
25.	*Cryptolepisbuchanani* Roem&schult	Krsnasariva	24923.58
26.	*Dioscorea bulbifera* Linn.	Rotalu, Gethi	36602.5
27.	*Eclipta alba* Hassk.	Kesuria, Bhangru, Bhangra, Kesuti, Ajagara, Bringaraj, Kesar raja, Sumilaka, Suparna, Weed yam	14113.44
28.	*Embelia ribes* Burm. f.	VaiVidang	24889.7
29.	*Emblica officinalis* Gaertn.	Amla	38066.6
30.	*Garcinia indica* Choisy	Kokum	36602.5
31.	*Gymnema sylvestre* R. Br.	Gudmar	14641
32.	*Hedychium spicatum* Buch-Ham. ex Smuth	Kapurkachari	23425.6
33.	*Hemidesmus indicus* R.Br.	Anantmool, Indian Sarsaparilla	20497.4
34.	*Holarrhena antidysenterica* Wall.	Kurchi/Kutaj	10775.05
35.	*Ipomoea turpethum* R. Br.	Trivrit	15606.58
36.	*Kaempferia galanga* Linn.	Indian crocus	26704.7
37.	*Lepidum sativum* Linn.	Chandrasur	14406.26
38.	*Mucuna prurita* Linn.	Konch	11712.8
39.	*Ocimum sanctum* Linn.	Tulsi	17569.2
40.	*Phyllanthus amarus*Schum&Thonn.	Bhumiamlaki	16105.1
41.	*Piper longum* Linn.	Pippali	36602.5

42.	*Plantago ovata* Forssk.	Isabgol	14113.44
43.	*Psoralea corylifolia* Linn.	Bakuchi	8784.6
44.	*Rubia cordifolia* Linn.	Manjishtha	58564
45.	*Sida cordifolia* Linn.	Flannel weed	14055.36
46.	*Solanum anguivi* Lam.	Katheli-badhi	1422.96
47.	*Solanum nigrum* Linn.	Makoy	14641
48.	*Stevia rebaudiana* (Bert.) Bertoni	Madhukari	183012.5
49.	*Tephrosia purpurea* Pers	Pawad,Dhamasia, Kalika,Plihari, Purple TephrosiaSharapunkha, ,Wild Indigo, Empali	14523.63
50.	*Terminalia arjuna (*Roxb.) Wt.&Arn.	Arjuna	26353.8
51.	*Terminalia bellirica* Gaertn.	Behera	23425.6
52.	*Terminalia chebula* Retz.	Harad	23425.6
53.	*Tinospora cordifolia* Miers	Giloe	16105.1
54.	*Vitex nigundo* Linn.	Nirgundi	14641
55.	*Withania somnifera* (Linn.) Dunal	Ashwagandha	14641

28. Untapped opportunities: unveiling the potential of flowers

Tejaswini P., Labdhi Dedhia, Chandana B.R., Mahantesh Biradar and Veeresh
Division of Flower and Medicinal Crops
ICAR-Indian Institute of Horticultural Research,
Hesaraghatta lake PO, Bengaluru 560089
Email: Tejaswini.Smt@icar.gov.in

Flowers are always considered for their aesthetic appeal and as crops of commercial importance. When we discuss flowers in the context of Floriculture and ornamental crops, they are primarily categorized into cut flower, loose flower, potted plant and ornamental bedding /garden plants.

Cut flowers

Cut flowers are specifically cultivated for floral arrangements and bouquets. Cultivars of flowers like Rose (*Rosa × hybrida*), Chrysanthemum (*Dendrathema grandiflora*), Carnation (*Dianthus caryophyllus*), Gerbera (*Gerbera × hybrida*) are the most common that top the global trade in terms of volume and are produced under protected cultivation aiming at long stalks. Certain cut flowers are temperature sensitive and more suitable in colder climate such as Tulip (*Tuilpa spp.*), Lily (*Lilium spp.*), Anthurium (*Anthurium andraeanum*), Alstroemeria (*Alstroemeria spp.*), Clematis L., Lisianthus (*Eustoma grandiflorum*) and Hydrangea (*Hydrangea macrophylla*). Crops like Gladiolus (*Gladiolus spp.*) and Tuberose (*Agave amica*) are easy to cultivate and are widely adapted to tropical conditions. Cut flowers are blamed for higher water requirements, but it's important to note that, there are species that can sustain in scarce water resources such as *Heliconia* spp., Birds of Paradise (*Strelitzia reginae*) etc. Numerous other species are market specific and traded in small quantity such as Antirrhinums (*Antirrhinum majus*), Larkspur (*Delphinium spp.*), Hollyhocks (*Alcea rosea*), Cornflower (*Centaurea cyanus*) and Dahlia (*Dahlia variabilis*). Not necessarily all cut flowers have to be of very long stalk. The market and the arrangement have a greater influence on stalk length. Flowers including Gypsophila (*Gypsophila spp.*), Aster (*Callistephus chinensis*), Statice (*Limonium sinuatum*), Cornflower (*Centaurea cyanus*), Sweet William (*Dianthus barbatus)*, Cocks comb (*Celosia cristata*) and Marigold (*Tagetes spp.*) are often used in floral arrangements but aren't always appropriate for long-distance shipping. Umpteen new species like Sunflower (*Helianthus spp.*), Lupins (*Lupinus perennis*), Thistles (*Cirsium* spp.) have niche markets and also can be traded to bring in novelty and vibrance to break the routine and monotony of the floral arrangements.

Loose flowers

These are typical of Eastern culture where flowers are sold by weight and volume. Rose (*Rosa spp.*), Marigold (*Tagetes spp.*), Chrysanthemum (*Dendrathema grandiflora*), Jasmine (*Jasminum spp.*), Crossandra (*Crossandra infundibuliformis*), Tuberose (*Agave amica*), Aster (*Callistephus chinensis*) are the major flowers traded. Nerium (*Nerium oleander*), Gomphrena (*Gomphrena globosa*), Lotus (*Nelumbo nucifera*), Dahlia (*Dahlia variabilis*) and Gaillardia (*Gaillardia pulchella*) are some of the flowers that are gaining popularity over the years.

Pot plants and bedding plants

These include flowering pot plants and indoor foliage plants. The most important potted flowering plants include Orchid species such as *Phalaenopsis* spp. and *Dendrobium* spp. Other widely grown pot and bedding plants are Zinnia (*Zinnia elegans*), Portulaca (*Portulaca oleracea*), Geraniums (*Pelargonium spp.*), Gazania (*Gazania linearis*), Pansy (*Viola tricolor* var. *hortensis*), Torenia (*Torenia fournieri*), Cyclamen (*Cyclamen persicum*), Chrysanthemum (*c*), Salvia (*Salvia officinalis*), Easter lily (*Lilium longiflorum*), Azalea (*Rhododendron spp.*), Rose (*Rosa spp.*), African violet (*Saintpaulia ionantha*), Petunia (*Petunia × hybrida*), Balsam (*Impatiens balsamina*), Begonia (*Begonia spp.*) etc..

Untapped opportunities

Flowers offer a wide range of potential that extend far beyond their aesthetic appeal.

Therapeutic and pharmaceutical uses

Flowers with their color and aroma are stress busters and activities involving either culturing flower plants or arrangement of flowers are considered as therapy for physical and psychological well-being. Flowers are opening up innovative healthcare solutions such as aromatherapy and Bach flower therapy where flower power is used for healing.

Many flowers possess medicinal properties as immunity enhancers. Several flower species are known to have analgesic, anti-inflammatory, antioxidant and anti-anxiety properties. Exploring these properties further can lead to the development of new pharmaceuticals. Certain flowers have antibacterial and antifungal properties that can be used in topical applications for wound healing and skin care. Phytochemical research and identification of bioactive compounds can lead to potential drug candidates.

Floral extracts and essential oils

Floral pigments such as flavonoids, carotenoids and betalains are extracted and used as food colorants and feed additives. Floral extracts and essential oils have immense potential in the cosmetic, aromatic and perfumery industries. Cultivars with unique fragrances and properties can create new opportunities for product development. Even similar species and cultivars can radically differ in the biomolecules that make them up. For instance, the most common compounds in rose oil include citronellol, geraniol, nerol, and linalool which constitute 60% of rose oil. Other compounds such as damascenone, β-ionone, and rose oxides are present in trace amounts although they are the key components that contribute to the distinctive scent of the rose oil. Content and ratios between different compositions are valued for the utilization of different cultivars and species for commercial exploitation.

Culinary applications

The use of flowers in the food industry is getting popular because of their distinct color, flavor, and nutraceutical values with expected health advantages. Flowers are used to enhance the flavour and aesthetic appeal of food and beverages. Due to their vibrant color and nutraceutical values flowers are widely consumed in the form of herbal tea. Petals are used in garnishing snacks, salads, cookies, bakery goods and desserts. Flowers are used to add diverse color to rice, smoothies, soups, cocktails and mocktails beverages. Incorporating flowers into culinary practices not only adds a touch of elegance and uniqueness to dishes but also provides an opportunity to explore new flavors and potential health benefits. Flowers with their rich pigments provide umpteen opportunities to develop natural food colors.

Sustainable environment

Diverse pollinators can be attracted by flowers benefitting agriculture and horticulture production. Some flowers can act as a trap crop, as natural pest repellents and help to control agricultural pests. Utilizing specific flower crops in management can reduce the need for chemical pesticides, leading to environmentally sustainable crop cultivation.

Flowers also offer us a diverse range of colours for the extraction of natural dye which can be used in small- and large-scale textile industries. As a part of the green initiative, people are using flowers for eco-printing where the flowers are directly used to dye the clothes.

Certain flower species have the ability to absorb heavy metals and pollutants from the soil. Using such species for phytoremediation in polluted areas can help to remediate contaminated soil. These flowers also provide opportunities for developing biosorbents.

Flowers can be integrated into urban landscapes to improve air quality, beautify neighborhoods and create space for relaxation and recreation. Flowers as part of biophilic architecture are aesthetically pleasing and add positive impact on human well-being, both physically and psychologically.

Unveiling alternate potential

Bougainvillea (*Bougainvillea glabra*): Bougainvilleas are drought as well as salt-tolerant, making it widely adaptable ornamental plant. Betalains in bracts of Bougainvillea are of great application potential as natural food colorants and antioxidants.

Butterfly pea/Asian pigeon wings (*Clitoria ternatea*) : The flowers are highly packed with secondary metabolites like anthocyanins, flavonoids and fatty acids. It is widely used as a traditional medicine for health benefits and heat coping mechanism.

Carnations (*Dianthus spp.*): The flowers are also edible and with their clove flavor, the petals are used in adorning cakes, salads, and soups. Antioxidant, anti-inflammatory, and anticancer properties are the added benefit of these petals. It has long been used to cure wounds and gastrointestinal disorders. Flowers are also used in the extraction of natural dyes.

Champak (*Magnolia champaca***)**: Its aromatic flowers are used in perfumery industry. Flowers are widely used for the preparation of herbal decoctions for fever, colic and post-partum protection.

Chamomile (*Matricaria chamomilla* L.): This is rich in flavonoids, coumarins, terpenoids and cinnamic acid derivatives which can be used for relaxation, mood upliftment, anti-inflammatory, body aches, antibacterial and antimicrobial, skin, hair and stomach problems.

Chrysanthemum (*Dendrathema grandiflora*): Chrysanthemums are used in the form of healthy tea or beverage due to their unique flavour, colour and health benefits. Along with herbal teas, the flower also finds utility in culinary as garnishing and flavoring agent. The flowers have sedative, antipyretic, anti-inflammatory, anti-arthritic and anti-hypertensive properties.

Elder flowers (*Sambucus nigra*): A flowering shrub commonly seen in temperate regions. Flowers are used in the preparation of food items and beverages. These flowers gained popularity during the pandemic of covid-19 for treatment against respiratory illness. They are rich in bioactive compounds such as flavonoids and phenolic acids which are used in the treatment of cold and flu.

Geraniums (*Pelargonium spp.*): Widely used in aromatherapy and traditional medicine. It is known for its antimicrobial, anti-inflammatory and antioxidant properties.

Gladiolus (*Galdiolus spp.*): Aqueous extracts of corms has antimicrobial effects on *Pseudomonas aeruginosa* and *Aspergillus niger*.

Hibiscus (*Hibiscus rosa-sinensis*): The plant has a wide variety of pharmacological applications such as anti-fertility, anti-microbial, anti-inflammatory, anti-diabetic, anti-microbial and antipyretic activities.

Honeysuckles (*Lonicera japonica*): These arching shrubs or twining vines in gardens have sweet honey-flavoured flowers and are used in the preparation of multiple food items and beverages.

Jasmine (*Jasminum spp.*): The flowers are reported to have antimicrobial, analgesic, antipyretic, anticancer, antioxidant, anti-diabetic, anti-obesity as well as cardio-protective and gastroprotective effects. Jasmine flowers are valued for aromatic, cosmetic, pharmaceutical and food industries.

Lotus: (*Nelumbo nucifera* Gaertn.): Lotus seed is an important part of the lotus plant due to its nutritional and bioactive components. The presence of phenolic compounds imparts numerous bioactivities to the seed extracts. Seeds are used for anti-cancer, anti-proliferation, anti-diabetic, anti-inflammatory, neuroprotective, antioxidant and immunomodulatory action. The stem of the lotus is rich in iron, calcium, dietary fiber and constituents like starch, protein, asparagines, vitamins B and C. It is used for curing fever, diarrhea, hemorrhages, dysentery, high BP and excessive menstruation.

Marigold (*Tagetes spp.*): It is known to have good tolerance and accumulation capabilities to heavy metals like arsenic and thus can be used in phytoremediation. Marigold is used as an intercrop for pest and nematode management. Besides its popularity as a flower crop, marigold is also cultivated for the extraction of carotenoids that goes for the pharmaceutical and nutraceutical industry. Carotenoids are valued as therapeutic due to its enormous potential to prevent age-related macular degeneration, neuroprotective effects, antioxidant, anti-ageing and anti-inflammatory properties. Flowers are used in poultry feed for enriching colour in broilers and egg yolk in layers.

Nasturtium (*Tropaeolum majus*): Highly regarded for its possible health advantages and is mixed into salads, sauces, meats, pasta meals, soups, paste spreads, and pancake batter. It is also known to be used in the production of herbal vinegar. The leaves and blooms are commonly used in herbal medicine formulations due to the presence of carotenoids, phenols and glucosinolate compounds. These compounds are widely used for their antiviral, anti-microbial and anti-inflammatory properties.

Nerium (*Nerium oleander*): The crude flower extract of *N. oleander* is a potent antimicrobial and anti-inflammatory agent with no toxicity potential at therapeutic doses. Oleander leaves have the potential to provide a repellent effect against rice-field rats. The plants of nerium are utilized for their phytoremediation properties and are drought and salt tolerant.

Pansies (*Viola tricolor*): Commonly known to be a garden and bedding plant. The flower petals are used as an edible garnish for salads, desserts, infusion and tea blends and beverages.

Parijat/ Night Jasmine *(Nyctanthes arbortristis L.)***:** Different parts of this plant have been used as local and traditional medicines in Ayurveda, Siddha and Yunani systems of medicines as a laxative, diuretic, anti-venoms, digestives, mild bitter tonic and expectorant. It is a drought and salt tolerant plant and has excellent phytoremediation property.

Peonies (*Paeonia lactiflora*): Flowers are a rich source of flavonoids, anthocyanins and gallic acid derivatives. It can block chemicals that can cause pain and swelling. It might also prevent blood clotting, kill cancer cells and act as an antioxidant.

Protea (*Protea spp.*): Flowers are frequently used in floral arrangements, bouquets and other decorative displays. The flower is also widely known for its nutraceutical properties. For the treatment of diarrhea, bleeding stomach ulcers and enemas, aqueous infusions of the root and stem bark are employed. *P. cynaroides* is used to treat cancer, bladder and kidney ailments.

Rose (*Rosa spp*.): Beside being popular as queen of flowers, the flower petals are also edible. Rose petals are used in preparation of gulkand, Jam, jelly and syrups. Flower petals are infused in beverages to add color and flavor along with health benefits.

Sunflower (*Helianthus spp.***)**: Sunflower seeds are a rich source of phenolic compounds, flavonoids, polyunsaturated fatty acids, and vitamins. Petals can be used as a food ingredient in soups and salads or as a garnish for cakes and cookies to add colour and flavour to recipes. Moreover, dried sunflower petals are a great ingredient for herbal tea blending. Petal decoction is used as a remedy for pulmonary affections to heal wounds, accelerate childbirth, lower blood pressure and strengthen the stomach.

Tuberose (*Agave amica*): Formerly *Polianthes tuberose,* extracts of which are used in perfume industry. In Indonesia, tuberose flowers are also used in cooking.

Tulips (*Tulipa spp.*): Tulip petals are edible, taste varies by variety and season, and is roughly similar to lettuce or other salad greens. Tulip sap also has diuretic and antiseptic properties and has been used to treat coughs and colds. Cosmetic uses of tulips include using the essential oil as a skin moisturizer.

Underutilized species of flowers

Bougainvillea (*Bougainvillea glabra*): The species *B. buttiana, B. glabra*, and *B. spectabilis* are indicated for the treatment of coughing and pertussis. *B. glabra* is recommended for asthma, bronchitis and dysentery. *B glabra* and *B. buttiana* are good phytoremediators for heavy metals.

Chrysanthemum: *Chrysanthemum cinerariaefolium* is economically important as a natural source of insecticide. *C. japonense* is used in the preparation of a unique alcohol. *C. indicum, C. lavandulifolium* and *C. zawadskii* are reported to have multiple medicinal properties.

Gerbera: Coumarins from *G. anandria* were found to have broad spectrum anti-tumor and antibacterial activities and are considered to be potential new cancer chemoprevention agents. *G. piloselloides* are used to make distillers' yeast and is used as a traditional herbal medicine to treat colds, fever and acute conjunctivitis.

Gypsophila: The genus is a source of saponins that can be used for many purposes, including the production of photographic film and hemolytic laboratory reagents. Their detergent qualities make them useful in soap and shampoo. *G. rokejeka* is used as ingredients in liqueur, cheese, and ice cream, providing flavour, aroma, and crispness to foods. *G. sphaerocephala* is used for phytoremediation measure.

Lily: *L. brownii* var. *viridulumis* is one of the most prominent edible lilies. Its bulbs are large in size and not bitter. *L. davidii* var. *unicolor* bulbs are valued for sweetness and are commonly used to flavor soup or processed to extract starch. *L. polyphyllum, L. lancifolium., L. candidum* L. are considered to be beneficial for their medicinal properties.

Marigold: Essential oil of *T. minuta* has a strong, sweet, fruity and slight citrus-like aroma. It possesses excellent acaricidal properties. In addition, oils extracted from *T.minuta* plants cause nematode (*Meloidogyne incognita*) egg mortality. Leaves and flowers infusions of *T. lucida* are used as a folk remedy for gastrointestinal, respiratory, and inflammatory ailments.

Orchids: The underground tubers of terrestrial orchids mainly *Orchis mascula* are ground to a powder and used for cooking. *Gastrodia elata, Spiranthus mauritianum, Galeola foliate, Cypripedium macranthos* var. *rebunense* and *Vanilla* are reported to have anti-microbial properties; while *Anoectochilus formosanus* Hayata, *Cremastra appendiculata, Bulbophyllum odoratissimum, Anoectochilus formosanus, Dendrobium* spp. have anti-oxidant properties.

Rose: Several of rose species and cultivars are popular for their importance in perfumery, cosmetic and pharmaceutical industry. Cultivars of *Rosa x damascene* and *Rosa x centifolia* are most popular for their signature aromatic components and are a known to have medicinal and nutraceutical properties. Rose hips are rich in vitamin C, cultivars of *R.canina* are essentially cultivated for the production of hips that can be made into jam, jelly, marmalade and soup. *R.gallica, R.alba, R.banksiae, R.moschata* are reported to have medicinal values.

Pinwheel Flower (*Tabernae montana* spp.): A crop known to replace the jasmine flowers. *T. divaricata, T. catharinensis, T. crassa* and *T. elegans* have been exploited in traditional and folk medicine for the treatment of illnesses and the prevention of ailments.

Strategies for utilisation

1. **Exploration and conservation:** There are several species in the wild across the globe that needs to be explored. It is important to collect the indigenous and local knowledge associated with the crops that may be helpful for tapping the unexplored potential of the crops. Understanding the ecological region of collection may provide opportunities for strategizing climatic resilient approaches.
2. **Introgression of genes:** Apart from increasing productivity, creating wide variation in colour, shape and fragrance are the objectives of genetic improvement in flower crops. Most of the species are allopolyploids and are vegetatively propagated. This basic nature of flower crops allows them to withstand the addition or deletion of genes into their genomic constitution hence introgression of genes across the species and genus is quite possible by both conventional and non-conventional breeding approaches.
3. **Chemotypes for aromatic and pharmaceutical industry**: Every biochemical component and their proportions creates alternate opportunities for industrial approaches. Unraveling the biochemical pathways and altering the expression levels of genes or metabolic engineering could lead to different chemotypes.

4. **Models for basic research:** With allopolyploidy, sterility, and sexual polymorphism, many of the flower crops can be interesting models for unraveling the botanical puzzles of nature.
5. **Associating with multiple stake holders:** Research in flowers crops can be benefited by association with industrial partners from multiple sectors of aromatic, cosmetic, pharmaceutical and health. Innovative ways of incorporating flowers can add a unique dining experience in the culinary industry.

Flowers offer a wide range of untapped opportunities and potential that extends far beyond their aesthetic appeal. They play significant roles in various aspects of human life, ecology and industry. Exploring the untapped potential of flowers could lead to new business opportunities and economic growth.

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29. Potential and prospects of native orchids for their commercial utility

Ram Pal*, D.V.S. Raju and K.V. Prasad
ICAR-Directorate of Floricultural Research, RS, Vemagiri, Andhra Pradesh
*Email: rampal@icar.gov.in, rampal_nrco@yahoo.com

ABSTRACT

Orchidaceae is the second largest family of flowering plants and the members of this family are valued for their ornamental and therapeutic value. According to recent estimates, there are 26,567 species belonging to nearly 1000 genera. India contributes about 1300 species to this gene pool. Most Indian orchids are showy and bear attractive flowers. They have the potential to be used as parents for structuring new cultivars and restructuring existing varieties according to market demand. Orchids are known to occur here from the coastal plains to an altitude of 4300 m, suggesting that these genetic resources can be used to develop varieties suitable for the tropical to temperate regions of the country. In addition, there are about 150 orchid species that have medicinal importance and offer the possibility of obtaining biomolecules to combat various diseases. Although the country has extensive genetic resources of orchids, very little use has been made of them for the ornamental and medicinal plant industry. Due to various natural and man-made causes, the diversity of orchids in natural habitats is declining very fast and certain species have not been found in their natural habitats for more than 50-100 years. Orchids are among the most vulnerable groups of plants and their vulnerability is due to their specialised life cycle and diverse way of life. Therefore, the conservation and economic use of orchids should go hand in hand.

Introduction

The Orchidaceae is one of the largest families of flowering plants and accounts for about 7% of all flowering plants in the world. Orchids are known for their pretty flowers of various sizes, fascinating shapes and beautiful colours, which have outcompeted other families of flowering plants through the evolution of higher specialization of their vegetative and reproductive characteristics. The first mention of an orchid in the world dates back to 10-6th century BC, when Ni, a Chinese name for orchids, was first mentioned in the Book of Songs (in Chinese). The Greek philosopher Theophrastus (370-285 BC), known as the 'father of botany', referred to these strange plants as Orchis in his "Enquiry into Plants" and coined the name 'orchid'. Taxonomic work on orchids began after Linnaeus (1707-1778). A.L. de Jussieu described a family for orchids for the first time in 1789. The name of the orchids is derived from the root tubers, which resemble testicles. According to mode of living, orchids are divided into epiphytic, lithophytic, terrestrial and saprophytic (holomycoroph) life forms. Epiphytic orchids grow on the trunk or branches of trees without internal connections. The roots of these orchids have a special absorbent tissue called 'velamen' to absorb moisture from the atmosphere. However, the roots of terrestrial and saprophytic orchids form a symbiotic mycorrhizal association with certain species of fungi. The most visible manifestation of orchid diversity is their floral complexity: orchids uniquely fuse their gynoecia and androecia, and one of the three petals is modified into a landing platform or attractant structure, the labellum or lip. It has long been assumed that in orchids the primary control mechanisms for flower morphology that operates in other monocotyledonous plants must be altered. The orchid flower exhibits several variations in shape, size, colour and posture with a prominent labellum or lip formed by a posterior petal, the formation of a gynostegium or column, pollen united as pollinia, and non-endospermic micro-seeds. Orchids are used as cut flowers, bouquets, loose flowers, dried flowers, single flowers, potted plants, by-products in handicrafts and in the perfume industry. Some orchids are demanding in their requirements and removing and transplanting them to a completely new environment might not be so successful. Understanding of the prospects, horticultural and medicinal value and family is gaining much attention worldwide to unfold biology, evolution, taxonomy, cytology, chemistry, hybridization and cultivation etc. In Northeast India, many orchids are used for various purposes such as ornamental, medicinal, food and socio-cultural events (Deb 2009; Medhi and Chakrabarti, 2009).

World orchid diversity

The family Orchidaceae is divided into five subfamilies: Apostasioideae, Vanilloideae, Cypripedioideae, Orchidoideae and Epidendroideae. The world estimates of orchid species generally range between 17,000 and 35,000 (Dressler 1993). More recent estimates are of 26,567 species belonging to ~1000 genera (Chase et al. 2015; Willis 2017; Michael 2018). The largest genera are *Bulbophyllum* (2000 species), *Epidendrum* (1500 species), *Dendrobium* (1400 species) and *Pleurothallis* (1000 species) (IPNI, 2012; World Checklist of Selected Families, 2013). The distribution of orchids extends over all continents, with the exception of Antarctica. Orchids are most common in the humid tropical forests of South and Central America, Southeast Asia, especially India, Ceylon, Burma, Nepal, Bhutan, Laos, the Philippines, southern China, Japan, Europe, Brazil, New Guinea and Australia.

Orchid diversity in India

Orchids are widely distributed in India and their range extends from the plains to an altitude of 4300 metres. There are about 1300 species of orchids distributed throughout the country (Mishra, 2007; Medhi and Chakraborthi 2009; Singh et al. 2019b). Meitei et al. (2019) have compiled and reported the state-wise distribution of orchids in India. The state of Arunachal Pradesh has the highest number of orchid species (558), followed by Sikkim (543), Meghalaya (532) and West Bengal (467), followed by Nagaland (396), Manipur (251), Uttarakhand (237), Kerala (186), Karnataka (175), Andaman & Nicobar (143), Odisha (128), Maharashtra (122), Madhya Pradesh (89), Andhra Pradesh (83), Himachal Pradesh (76), Tamil Nadu (72), Tripura (66), Jharkhand (63), Jammu & Kashmir (46) and least reported from the newly formed state of Telangana (40). Among them, the eight north-eastern states of India are the paradise of Indian orchids. From these states, 876 orchid species in 151 genera have been reported, accounting for 70% of the orchid richness in the country. Many of these species are rare species have high ornamental value. *Anoectochilus sikkimensis*, *Cymbidium eburneum*, *Dendrobium hookerianum*, *D. densiflorum*, *D. devonianum*, *D. thrysiflorum*, *Paphiopedilum fairrieanum*, *P. insigne*, *P. villosum*, *P. spicerianum*, *P. hirsutissimum*, *P. venustum*, *Papilionanthe teres*, *Pleione humilis*, *P. maculata*, *P. praecox*, *Renanthera imschootiana*, *Rhynchostylis retusa*, *Thunia marshalliana*, *Vanda coerulea*, etc. are some of the promising orchids from this region (Pal and Singh 2016).

Endemism

Endemism in the flora of a country or geographical region provides essential insight into the biogeography of that region. It also contributes to the information on the centres of diversity and adaptive evolution of the floristic components of that region. The complete endemic status of orchids in India is not available. According to a report published in 1983 (Das and Deori 1983), 85 species are endemic to this region.

Of these, 20 species occur in Sikkim, 18 species in Meghalaya, 6 species in Assam and 2 species in Nagaland. 135 species, four subspecies and 3 varieties belonging to 38 genera are endemic to Peninsular India and 195 species are endemic to the Himalayan region (Kumar and Manilal 1994). Jalal and Jayanthi (2012) reported that 130 species belonging to 38 genera are endemic to peninsular India. Of the 1300 orchid species reported from India, nearly 400 are endemic to India (Pal and Singh, 2016).

There are 40 genera endemic to India (Irwin and Narasimhan, 2011), of which four, namely *India* A. N. Rao, *Aenhenrya* Gopalan, *Smithsonia* C. J. Saldanha and *Xenikophyton* Garay, belong to the family Orchidaceae. Genus *India* A. N. Rao is distributed in north-eastern India (Arunachal Pradesh), while the remaining three species occur in the Western Ghats. There are three species in the genus *Smithsonia* C. J. Saldanha, two in *Xenikophyton* Garay and one in the genera *India* A. N. Rao and *Aenhenrya* Gopalan. In 2016, Pal and Singh compiled a list of 127 species and 6 varieties belonging to 52 genera endemic to Northeast India. Thus, 14.29% of the species are endemic to this region. Of these, 79 (62.2%) species are epiphytic, 40 (31.49%) are terrestrial and 7 (5.51%) species are holomycotrophic (saprophytic). The highest number of strictly endemic species, 41, is found in Arunachal Pradesh, followed by 25 in Sikkim, 18 in Meghalaya, 7 in Manipur and 5 in Assam. In India, the Himalayan region is the richest endemic centre with a high degree of endemism. There are about ~300 species of orchids belonging to the endemic category. Endemic species are very site-loyal and sensitive to the microenvironment.

Threatened orchid species

Orchids are severely impacted in their natural habitat due to their complex lifestyle, namely interaction with micorrhizal fungi, pollinators and host trees, habitat destruction and unsustainable removal from natural habitats for horticulture, medicine and food, as well as climate change. The Red Data Book of Indian Plants published by the BSI lists the plant species that are facing various threats and require immediate attention. According to recent estimates, nearly 250 species of native orchids are threatened in several categories. Certain species like *Aphyllorchis gollanii*, *Coelogyne truetleri*, *Anoectochilus rotandifolius*, *Paphiopedilum charlsworthii*, *Paphiopedilum wardii*, *Vanda wightiana* and *Pleione lagenaria* are no longer found in the natural habitats of India. Of the 352 orchids endemic to the country, 40 are “endangered”, and 72 are “vulnerable” (Ram et al. 2011).

Collection and conservation of orchid genetic resources

Since its inception in 1996, ICAR-NRC for Orchids, Sikkim has undertaken several plant explorations in different parts of the country to collect genetic resources of orchids. The institute conducted structured and well-planned explorations in the orchid biodiversity hotspots of the country, especially in the north-eastern states of India. The genetic resources were collected in the form of live plants, tubers, seed pods or seeds. The repository of ICAR NRC for Orchids, Sikkim, consists of ~400 species. Of these, 83 belong to the rare, endangered and threatened species (RET) and 52 have medicinal uses. Some of the *Dendrobium. ruckeri*, *D. praecinctum*, *Diplomeris hirsuta*, *Ornithochilus difformis*, *Paphiopedilum fairrieanum, P. venustum, P. villosum, P. hirsutissimum, P. spicerianum, Renanthera imschootiana* (Red Vanda), and *Vanda coerulea* (Blue Vanda). The genetic resources collected during these explorations are used in the breeding programme to develop new varieties and hybrids. Other research institutions like Jawaharlal Nehru Tropical Botanical Garden and Research Institute, (JNTBGRI), Thiruvananthapuram, Kerala, State Forest Research Institute (SFRI), Arunachal Pradesh and Departments of Forest in orchid rich areas and universities also collect and preserve orchid germpalsm. The collection of orchid germplasm should focus on rare, endangered and threatened species (RET) and germplasm with specific traits important for the development of new cultivars.

Orchids are one of the most threatened plants on this globe due to their specialised life cycle and way of life. Orchid populations are dwindling due to overexploitation, habitat loss, habitat fragmentation, disruption of ecological linkages (pollinators, mycorrhiza and, for holomycotrophic plants, loss of the chlorophyllous hosts), changing abiotic conditions (e.g. soil and hydrology), weeds and the introduction of pests and diseases (Ibama, 2008). This necessitates scientific conservation measures to ensure their preservation and future use without losing their genetic variation. Conservation of plant genetic resources can be broadly divided into (A) *in situ* conservation and (B) *ex situ* conservation.

In situ conservation of orchids is about protecting the species' natural habitat, promoting orchid biodiversity and ensuring the survival of rare orchid species. *In situ* conservation of species is most desirable for orchids as it ensures their natural growth, reproduction and perpetuation, allowing the process of evolution to continue as part of the natural ecosystem. Protection of natural habitats is achieved through the establishment of protected areas, biosphere reserves and forest reserves. However, anthropogenic and non-anthropogenic factors have led to the degradation of natural habitats all over the world.

Ex situ conservation refers to off-site preservation of live plants, the storage of genetically representative seeds, somatic tissues for the regeneration of plants from stored material and also the storage of ecologically competent orchid mycorrhizae. Orchid germplasm can be conserved in botanical gardens, orchidaria, field genebanks, through *in vitro* preservation, cryopreservation, DNA banking, etc. *Ex situ* conservation strategies such as propagation and seed banking are fundamental components of any integrated conservation approach (Cribb et al., 2003) and provide long-term security. Several institutions in the country like National Research Centre for Orchids, Sikkim, Botanical Survey of India, Jawaharlal Nehru Tropical Botanical Garden and Research Institute, Kerala, State Forest Research Institute, Arunachal Pradesh, Regional Plant Resource Centre (RPRC), Odisha have conserved orchid genetic resources as live plants. The National Research Centre for Orchids, Sikkim, has been designated as an Active Germplasm Site for Orchids under the National Active Germplasm System (NAGS) for sustainable conservation and use of orchid germplasm.

In vitro conservation refers to the conservation of genetic resources in germplasm banks in the form of whole plants, isolated cells from plant tissues and organs through the use of tissue culture techniques. It is a very efficient way of conserving orchid genetic resources, which are highly valued in the conservation of species threatened with extinction. *In vitro* conservation is important because it allows the maintenance of cultures in active growth through the regular subculture of buds and nodal segments. This technique allows the preservation of plant germplasm over a short period of time: nine to twelve months, depending on the procedure and the plant species. *In vitro* conservation of orchid germplasm in slow-growing growth cultures requires urgent attention. This preservation technique can also be used to revive orchid germplasm affected by viruses and virus-like diseases by establishing apical meristem cultures. *In vitro* preservation of Indian orchids has not been attempted so far. There is a need for genetic stability studies to avoid somaclonal variants and slow growth cultures for longer storage period to avoid frequent transfers (Chang, 2007).

Conservation of genetic resources at ultra-low temperatures (-196°C) is a comprehensive alternative for long-term storage of orchid genetic resources and is achieved by freezing of tissue at the temperature of liquid nitrogen (-196°C) or in the gas phase (-140°C), thereby suspending all metabolic activity. The critical point in all available methods is to avoid the formation of intracellular ice crystals. Four types of cryopreservation protocols are distinguished in the literature: (i) conventional slow freezing, (ii) simple freezing, (iii) vitrification and (iv) desiccation. Cryopreservation is based on the principle of avoiding the formation of intracellular ice crystals during rapid cooling in liquid nitrogen, as these irreversibly damage the cell membranes and thus destroy their semi-permeability. The concept is based on dehydration of the cells and subsequent vitrification of the intercellular water into an amorphous state. This requires a concentrated cellular solution followed by rapid freezing achieved by air drying, freeze drying, application of penetrating or non-penetrating substances or acclimation (Malhotra *et al*. 2019).

Scientists have studied cryopreservation of orchids using seeds, pollen, shoot tips, flower parts, protocorms, zygotic embryos, etc. Vendrame et al (2014) have studied the cryopreservation strategies of many orchid species. Many researchers have done excellent research on conservation of orchids using cryopreservation strategies of various plant parts such as seeds of species *Anoectochilus*, *Bletilla*, *Brassolaelio cattleya*, *Bratonia*, *Calanthe*, *Cattleya*, *Dactylorhiza*, *Dendobium*, *Doritis*, *Encyclia*, *Grobya*, Laeliocattleya, *Oncidium*, *Phalaenopsis*, *Rhynchostylis* and *Vanda* (Thammasiri 2008) Immature seeds of *Bletilla striata* (Hongthongkham and Bunnag, 2014); Seeds and protocorms of *Bletilla striata*, *Dendrobium candidium*, Rare orchids (Nikishina et al. 2007), and the protocorms of *Doritis*, *Dendrobium*, *Rhynchostylis*, *Seidenfadenia* (Thammasiri 2008; Yin and Hong 2009; Antony et al. 2010; Mohanty et al. 2012); protocorm-like bodies of *Cymbidium*, *Cleistostoma areitinum* (Maneerattanarungroj et al. 2007), Dendrobium Sonia 28 (Hooi et al. 2010); *Phalaenopsis bellina* (Khoddamzadeh et al., 2011); shoot and shoot tips, shoot primordial, zygotic embryos, pollen of *Dendrobium* species (Vendrame et al., 2014); cell suspension cultures of *Doritaenopsis*, leaf segments of *Aerides odorata* are carried out by different researchers.

Characterization and evaluation of orchid genetic resources

The germplasm accessions of the conserved species are evaluated for various horticultural traits and accessions with unique traits are registered with the National Bureau of Plant Genetic Resources (NBPGR). The NRC for Orchids has conserved ~400 orchid species collected across the country at its headquarters and regional station. To protect the rare, endangered and threatened species (RET), the centre is developing production and propagation protocols to cultivate them to reduce collecting pressure on natural habitats. Recently, Pamarthi et al (2019) validated and reported 351 species in 94 genera conserved at ICAR-NRC for Orchids, Sikkim. Among the species collected, 205 species are threatened in their natural habitats, 90 species have breeding value, 87 species are used in traditional medicine, 77 species have fragrance and 11 species are used in traditional dietary. The genus *Dendrobium* represented the most species (68), followed by *Bulbophyllum* (30), *Cymbidium* (21), *Coelogyne* (19), *Calanthe* (12), *Liparis* (11), *Vanda* (10) and the following genera *Eria*, *Pinalia*, *Paphiopedilum*, *Aerides*, *Gastrochilus*, *Oberonia*, *Pholidota*, *Cleistostoma*, *Goodyera*, *Luisia*, *Papilonanthe*, *Phalaenopsis*, *Pleione*, *Sunipia*, *Agrostophyllum*, *Crepidium*, *Epidendrum*, *Micropera*, *Otochilus*, *Phaius*, *Thunia*, *Zeuxine*, *Acampe*, *Ascocentrum*, *Callostylis*, *Ceratostylis*, *Cryptochilus*, *Esmeralda*, *Habenaria*, *Herminium*, *Panisea*, *Phreatia*, *Thelasis* showed less than 10 species. While 45 genera showed only one species. However, wild species are also widely used for pre-breeding in crop improvement programmes.

Uses of orchid genetic resources

The varieties are one of the most critical inputs in the cultivation of orchids. The breeding of orchids requires patience and a deep understanding of the subject and predicts possible future trends in the market. The South Asian countries have a lead over 70 years and have augmented with latest technologies in breeding and have interesting lines with which they infuse their industry every 3-5 years. The orchid growers in India are stuck with old varieties which have low quality and productivity. Therefore, the planting materials of commercial varieties are imported to meet the requirement. An intensive orchid breeding programme needs to be launched to meet future requirements of the region. Breeders, plant propagators, orchid producers, wholesalers and retailers form a significant value chain in the orchid business. In other countries breeding of orchids is owned by the private companies who own the right for multiplication. On transfer of ownership, multipliers or propagators multiply and sell the variety bred by the breeders. Growers grow the plants for cut flowers or pot plants and sell their produce to wholesalers or exporters and then reach retailers. India with its vast orchid genetic resources of orchids has not been properly used for development of new varieties.

a. Major constraints in the development of new varieties

Developing a variety of orchids requires about 8-14 years. Such a long duration is required due time taken from pollination to maturing of seed capsule (3-14 months), raising of seedling in vitro (6-12 months) and long juvenile phase usually 3-5 years depending on species. Once the clone of desired trait is selected it has to micro propagated and has pass through the same juvenile phase and then testing and evaluation for release of a variety. There is dearth of information on the inheritance pattern of economically important in public domain as the majority of orchid hybrids have been evolved by the breeders working for private companies. The different countries have different liking pattern for cut flowers or potted plants. For example, alba forms, intraspecific variations, plants with variegated leaves and fragrance are preferred most in China. However, cymbidium orchids in with large and attractive flowers are preferred in Netherlands, Australia, New Zealand, and America. In China, Japan, Taiwan, and Korea cultivate cymbidium hybrids only for pot plants and appreciate it for flower, foliage, and fragrance (Pal et al. 2020). Though orchids have weak reproductive barriers but many orchid species and hybrids are incompatible. Extensive researches *viz.* species compatibility, apomixis, genetic engineering, mutation breeding, ploidy breeding, etc., have been done by utilizing the native species and hybrids in the orchid improvement programmes.

In addition to native orchids, orchid breeders in India should also make use of advanced materials developed in other countries in their breeding programme to obtain commercially viable hybrids. Intellectual property laws prevent any unauthorized use of planting materials/parental stocks/ hybrids for developing new varieties/hybrids and their commercial utilization. With the enforcement of National and International treaties like ITPGRFA, CBD and BDA, the procurement and introduction of breeding materials with appropriate denomination and parentage is desperately needed under relevant international laws with Standard Material Transfer Agreement (SMTA) and Mutually Agreed Term (MAT). Prior Informed Consent (PIC) of concerned breeders and benefit-sharing agreement.

b. Breeding strategies for orchids

History of orchid breeding is nearly 150 years old. More than 200,000 hybrids have been registered with International Registration Authority, Royal Horticultural Society, Kew London. Most of these hybrids have been registered by private nurseries and private orchid breeders of different countries. The utmost vital traits for orchid breeding include flower self-life or longevity, attractive colours, variants and including pure colour without sustaining, multiple flower spikes, the orientation of flowers on the flower spike, upright round flower shape, free-flowering, compact in growth habit, fast-growing, and self-supporting flower spikes. The flowers should have vibrant colour, and the traits like fragrance, off-season flowering, the extension of the flowering season, and earliness would be of added advantage. A significant advantage of orchid breeding is that it may combine conventional breeding methods (through hybridization), coupled with clonal selection. Orchids cross easily due to the weak crossability barrier. Orchid breeding in India is still in the nascent stage. The current commercial cultivation of orchids in India is based on cultivars developed elsewhere in other countries like Netherland, USA, Australia, New Zealand, Thailand, Japan, etc. Many of these hybrids involve several species in their background. Hence it is challenging to obtain commercially viable orchid hybrids with primary crosses involving different species.

In India over 200 hybrids of orchids have been developed and registered. Majority of them have been developed private orchids laboratories located in Sikkim and Darjeeling district of West Bengal. The public funded organization like Jawaharlal Nehru Tropical Botnical Garden and Research Institute (JNTBRI), Trivandrum, Kerala, State Forest Research Institute (SFRI), Arunachal Pradesh and National Research Centre for Orchids have also engage in developing the orchid varieties. ICAR-NRC for Orchids registered the two crosses namely, Darjeeling Nymph (*Cym* Sleeping Nymph x *Cymbidium lowianum*) and Darjeeling's Delight (*Cymbidium lowianum x Cym Showgirl)* with International Orchid Registration Authority, RHS London in 2014. Several other hybrids of orchids developed at NRCO at various stages of development. Protocols for in vitro seed culture and multiplication through tissue culture in various *Cymbidium* species and hybrids have also been developed successfully (Pal, *et al.* 2020). The wild species have little value in the international floriculture trade due to inferior flower shape, size and colour in comparison to modern-day orchid hybrids. A total of 90 species with potential breeding value have been identified. Extensive researches *viz.* species compatibility, apomixis, genetic engineering, mutation breeding, ploidy breeding, etc., have been done by utilizing the native species and hybrids in the orchid improvement programmes. Orchids are slow-growing plants with a long juvenile period, requiring three to five years on average to evaluate flower quality of the offspring and the attainment of new seeds. Some species exhibit complex reproductive processes (cross-pollination and specific physiology for seed germination), and these factors hinder their propagation and preservation (Nikishina *et al.* 2007).

i. Hybridization and selection

Majority of orchids are highly heterozygous, and crossing between the same species or same genera usually leads to the production of fertile seeds that provides a range of genotypes. The segregating F1 population in these crosses gives useful gene recombinants for selection and cloning of new, desired individuals. Seed germination and raising of seedlings in tissue culture, acclimation of seedling and growing them to flowering size in greenhouses, evaluation of seedlings for desired characters, selection, multiplication of selected clones, testing the elite clones in genotype x environment under trials for testing their stability, and uniformity are the significant steps required for the development of the superior variety through hybridization and selection. It takes nearly about 12-14 years to release a commercial variety of Cymbidium orchid (Pal et al. 2020). The superior diploid and tetraploid clones are used further to improve desirable traits of the cultivar. Pal *et al.* (2020) listed intergeneric hybrids involving two, three, and four genera in crossing with cymbidium.

ii. Polyploidy Breeding

Colchicine played a significant role in developing many beautiful orchid hybrids by doubling the chromosome numbers. The change in ploidy level is also associated with a change in morphological and physiological characteristics of the plant viz. increase in number and size of stomata, increase in cell size and flower size, etc. (Pal *et al.,* 2020). The importance of polyploidy in cymbidium orchids was recognized soon after the flowering of Cymbidium Alexanderi "Westonbirt," a clone of *Cymbidium insigne* x *Cymbidium eburno-lowianum*, registered in 1911. It was a chance tetraploid with a large flower, heavy substance, superior colour, and full-shaped. This clone was repeatedly used to develop excellent varieties of cymbidium: Cymbidium Rosanna, a cross of Cymbidium Alexanderi x Cymbidium Kittiwake, registered in 1927. Cymbidium Alexander was a tetraploid, while Cymbidium Kittiwake was a diploid, but a clone "Pinkie" was a tetraploid. Likely, Cymbidium Alexanderi "Westonbirt" and Cymbidium Rosanna "Pinkie" have had developed through the fertilization of unreduced gametes of their parents. Attempts made in cymbidium on shoots, protocorms, and in PBLs (Pal *et al.,* 2020) tetraploid flowers have a stronger scent than diploid flowers in Cymbidium Golden Elf "Sundust." The micropropagation characteristics, such as rate of proliferation shoot bud and root differentiation changes after chromosome conversion. The importance of polyploidy in the breeding of cymbidium was realized, and a number of superior hybrids were converted into tetraploids for using in the breeding program.

c. Socio-cultural value of orchids

Dendrobium hookerianum, *Dendrobium nobile* symbolises purity and holiness among the tribesmen of Nagaland. A leader of a hunting community carries the plant *Dendrobium acinaforme* in the belief of courage and luck in hunting. The beautiful foxtail orchid (*Rhynchostylis retusa*), called 'Kopou Phul' in Assam, is worn by ladies as a headdress at various festivals, especially the 'Bihu' festival in Assam. It symbolises youthfulness in spring and is a symbol of love for the youth of the Ahom community (Medhi and Chakrabarti, 2009). The flowers of orchids such as *Vanda tessellata* and *Coelogyne nitida* are used in local festivals in Assam and Arunachal Pradesh, and the flowers of *Papilionanthe teres* are used by Tai ethnic groups in Assam and Arunachal Pradesh for offerings to Lord Budha and spirits (Medhi and Chakrabarti, 2009; Meitei *et al.,* 2019a). Dried cymbidium leaves are used to make various attractive eco-friendly products such as lepcha hats, fruit and vegetable baskets, tea trays, containers, sitting mats, hanging pots, litter bins, plant growing pots, etc. In the state of Sikkim, locals collect the raw material of dried cymbidium leaves from their orchards and backyards and make some traditional artefacts from them, which are used for traditional and religious rituals as well as modern lifestyle accessories. These artefacts have a unique intricate style, design and durability for which people have valued them since ancient times. It became a tradition to use certain cymbidium artefacts in certain socio-religious rituals in the region, which has indirectly contributed to the survival of this craft as the traditional knowledge of making these items has been preserved (Singh *et al.*, 2019). Several species of orchids enjoy the status of state flower of the north-eastern states, for example, *Rhynchostylis retusa* (state flower of Assam and Arunachal Pradesh), *Dendrobium nobile* (state flower of Sikkim), *Papiopedilum insigne* (state flower of Meghalaya), *Renanthera imschootiana* (state flower of Mizoram).

d. Orchids in traditional and modern medicine

The epiphytic wild orchid *Acampe praemorsa* is a good source of secondary metabolites such as phenols, terpenoids, saponins, tannins, flavonoids and cyanogenic glycosides, which have potential pharmacological activities such as antimicrobial activity and cytotoxic activity. Ethnobotanical studies in India have found that roots, leaves, seed pods and the whole plant of *Acampe praemrosa* are used to treat a variety of diseases such as arthritis. The roots of *Acampe praemorsa* are used to cure asthma and the paste has been used externally to treat scorpion and snake bites. Tribes in Kerala (India) use the whole plant to cure rheumatic ailments. As a source of antibiotics, the seeds of *Acampe praemrosa* are placed directly on the old wound. The pseudobulbs of *Coelogyne nitida* have several therapeutic uses. The paste and juice are used to treat headaches, fever and burns. The orchid species *Arundina graminifolia* has beneficial therapeutic effects due to its numerous bioactive compounds, namely flavonoids, stilbenoids and arundin . In China, *Arundina graminifolia* is known as the most commonly used antidote. The roots of this plant are used to cure hepatitis, diabetes, tumours and to treat body pain. In Bangladesh, paste and juice from the flower stalk and rhizome of *Arundina graminifolia* are used to treat earache and rheumatism, while the roots are used to treat snakebite and intestinal biliary colic. This genus is considered beneficial for detoxification, anti-arthritic and an antioxidant .

e. Orchids in dietary system

Orchids are part of traditional cuisine in many parts of the world as a side dish or supplement. There are many wild orchid species used as food by the tribal people of north-eastern India. Orchid species like *Habenaria acuminata*, *H. susannae*, *Orchis latifolia*, *Pholidata articulata*, *Satyrium* species play an important role in the diet of the people of Nagaland (Deb 2013). The tribals of Nagaland use the leaves of Cymbidium species as food, vegetative shoots are used along with cereals to make a sauce and pseudobulbs are used in combination with common vegetables like potatoes, tapioca etc (Medhi and Chakrabarti, 2009). The popular drink called 'Faham' or 'Madagascar tea' in the islands of Mauritius and Madagascar is prepared from the orchid *Jumellea fragrans*. In the trade, vanilla flavour or vanillin is extracted from *Vanilla planifolia*. The leaves of Anoectochilus are used as a vegetable in Indonesia and Malaysia. The pseudobulbs of *Cymbidium madidum* and *Dendrobium speciosum* and the tubers of *Microtis uniflora* and *Caladenia carnea* are eaten. The tubers of orchid genera such as *Acianthus*, *Dipodium*, *Glossodia*, *Lyperanthus*, *Prasophyllum* and *Thelymitra* are used as food by the inhabitants of Australia. In Africa, a juice is extracted from the tubers of *Cynorchis*, *Eulophia*, *Disa*, *Habenaria* and *Satyrium*, which is used as a tonic. The roots, tubers or rhizomes of *Eulophia*, *Gastrodia*, *Habenaria*, *Orchis*, *Pholidota*, *Platanthera* and *Spiranthes* are used as food in Asia. The tubers of *Disa engleriana*, *D. robusta* and *D. zambica*, *Habenaria clavata*, *Satyrium ambylosacco*, *S. buchananii* and *S. carsonii* are used as food in Malaysia. In Bhutan, the inflorescences or flowers and pseudobulbs of Cymbidium spp. are cooked and eaten (Bhattacharjee and Das, 2008).

Conclusion

Orchids have become an important segment of the floriculture industry owing to technological advances in propagation, cultivation and variety development. Countries like Thailand, Malaysia, Indonesia and Taiwan dominate in the production of tropical orchids, while the Netherlands, Australia and New Zealand lead in the production and export of temperate orchids. India, with its diverse climatic conditions and extensive genetic resources, has the potential to become a major player in the global orchid industry.

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30. Challenges in genetic resource management and conservation of medicinal and aromatic plants (MAPs)

P. E. Rajasekharan
Principal Scientist (Retd.), ICAR-Indian Institute of Horticultural Research, Bengaluru
Email: rajasekharan.pe@gmail.com

ABSTRACT

Medicinal and aromatic plants (MAPs) are vital for human health and well-being, but their genetic resources face various challenges, including overharvesting, habitat loss and degradation, climate change, intellectual property rights, and lack of awareness and capacity. These challenges are compounded by the complexity and poorly understood biology of MAPs, making the development of effective conservation strategies difficult. A range of approaches, including in situ and ex situ conservation, sustainable harvesting, traditional knowledge, community participation, and research and development, can be used to address these challenges. Addressing these challenges is essential to ensure the long-term availability of MAPs for human health and well being.

Introduction

Medicinal and aromatic plants (MAPs) have played a pivotal role in human history, providing a rich tapestry of remedies, flavors, fragrances, and cultural significance. These plants, often endowed with unique chemical compounds and therapeutic properties, have been integral to traditional medicine systems and have found their way into modern pharmaceuticals, cosmetics, and culinary delights. However, the sustainable management and conservation of MAPs' genetic resources have emerged as paramount challenges, given the confluence of environmental, social, and economic factors in today's world.

MAPs encompass a wide range of botanical species, including herbs, shrubs, and trees, each possessing distinct attributes and applications. The genetic diversity within these species is a source of invaluable biological and chemical variability, essential for adapting to changing environmental conditions and meeting the demands of a growing global population. The intricate relationship between humans and MAPs has deep historical roots, with evidence of their use dating back millennia in ancient civilizations such as the Sumerians, Egyptians, and Ayurvedic practitioners in India.

However, in the face of rapid urbanization, habitat destruction, climate change, and unsustainable harvesting practices, the genetic resources of MAPs are under threat. This has profound implications not only for biodiversity conservation but also for global health, food security, and the livelihoods of countless communities dependent on MAPs

To address these challenges, we must delve into the multifaceted issues that underlie the genetic resource management and conservation of MAPs. This exploration will encompass a holistic understanding of the challenges faced, including the delicate ecosystems that harbor these plants, the impacts of climate change, overexploitation, biopiracy concerns, legal frameworks, and the need for increased public awareness and funding.

In the subsequent sections, we will dissect each of these challenges in greater detail and propose strategies and solutions that can guide efforts to ensure the sustainable management and conservation of the genetic resources of Medicinal and Aromatic Plants. Ultimately, as we navigate these intricate challenges, we aim to emphasize the critical importance of preserving the genetic heritage of MAPs for the well-being of current and future generations.

Table 1 : Number of medicinal and aromatic plants (MAPs) that are threatened or endangered in different parts of the world

Region	Number of threatened or endangered MAPs
Africa	1,500
Asia	2,000
Europe	500
Latin America	1,000
North America	200
Oceania	300
Global	5,500

Challenges: Over exploitation of medicinal and aromatic plants: A looming threat to biodiversity and sustainability

Medicinal and Aromatic Plants (MAPs) have long been coveted for their therapeutic and aromatic properties, serving as a cornerstone of traditional medicine systems and global industries. However, the unrelenting demand for these valuable resources, coupled with unsustainable harvesting practices, has led to concerning consequences - the overexploitation of MAPs. This rampant overharvesting poses severe threats to both the survival of these plants and the delicate ecosystems they inhabit

The perils of overexploitation:

1. **Declining Populations**: One of the most immediate consequences of overexploitation is the depletion of MAP populations. As these plants are often slow-growing and have specific habitat requirements, excessive harvesting can lead to population declines, pushing some species toward endangerment or even extinction.
2. **Loss of Biodiversity**: Overharvesting doesn't just affect the target species; it also disrupts the biodiversity of entire ecosystems. The removal of MAPs can disrupt pollinator interactions, affect the growth of other plant species, and jeopardize the survival of dependent animal species
3. **Economic and Social Consequences**: Many communities rely on the sustainable harvest and trade of MAPs for their livelihoods. When overexploitation occurs, it not only threatens these communities' economic stability but can also exacerbate poverty and lead to unsustainable land-use practices
4. **Diminished Medicinal Resources**: Overharvesting can compromise the quality and quantity of MAPs' bioactive compounds, diminishing their efficacy for medicinal purposes. This not only affects traditional medicine systems but also impacts the pharmaceutical and herbal industries

Causes of overexploitation:

1. **High Market Demand**: The global demand for herbal medicines, aromatics, and natural products has surged in recent years, driven by consumer preferences for natural and alternative remedies

2. **Lack of Regulation**: In many regions, there is a dearth of effective regulation and enforcement of sustainable harvesting practices. This regulatory gap allows for indiscriminate collection and trade of MAPs

3. **Short-Term Economic Gains**: For many communities in developing countries, the immediate economic benefits of overharvesting may outweigh the long-term consequences. This short-term focus can perpetuate unsustainable practices

Table 2: Main causes of threats to MAPs

Threat	Description
Overexploitation	The collection of MAPs at a rate that exceeds their natural regeneration rate.
Habitat loss and degradation	The destruction or fragmentation of MAP habitats due to deforestation, agriculture, urbanization, and other human activities.
Climate change	The changing temperature and precipitation patterns associated with climate change can alter the distribution and abundance of MAPs.
Invasive species	Invasive plants and animals can compete with MAPs for resources and habitat, and can also transmit diseases and pests.
Poor management practices	Unsustainable harvesting practices and inadequate cultivation methods can also contribute to the decline of MAPs.

Mitigating Overexploitation

1. **Sustainable Harvesting Practices**: Implementing sustainable harvesting techniques, such as selective harvesting, cultivation, and rotation, can help preserve MAP populations while meeting market demands
2. **Legislation and Regulation**: Strengthening legal frameworks and enforcing regulations related to MAPs' harvest and trade can curb overexploitation. This may involve setting harvest quotas, protecting critical habitats, and promoting fair trade practices
3. **Community Involvement**: Engaging local communities in the management of MAP resources is crucial. When communities have a stake in the preservation of these plants, they are more likely to adopt sustainable practices
4. **Research and Education**: Continued research on MAP biology, ecology, and sustainable cultivation methods is essential. Additionally, educating consumers, harvesters, and traders about the importance of sustainable practices can drive positive change

In conclusion, the overexploitation of Medicinal and Aromatic Plants is a complex issue with far-reaching ecological, economic, and cultural implications. As the demand for natural remedies and aromatic products continues to rise, it is imperative that stakeholders work collaboratively to implement sustainable practices and policies that ensure the continued availability of MAPs while safeguarding biodiversity and the livelihoods of communities dependent on these invaluable resources.

Challenges – habitat loss and degradation: Threats to medicinal and aromatic plants

Medicinal and Aromatic Plants (MAPs) are intimately connected to the environments they inhabit, relying on specific ecosystems to thrive. These plants have provided essential remedies, flavors, and fragrances to humans for centuries. However, their habitats are increasingly under threat from habitat loss and degradation, which, in turn, imperils the existence of many MAP species and threatens the availability of these valuable resources

Habitat Loss: One of the primary challenges faced by MAPs is habitat loss, driven by various factors including urbanization, agriculture, infrastructure development, and deforestation. As human populations expand, natural landscapes are converted into agricultural fields and urban areas, encroaching upon the habitats of MAPs. This process not only diminishes the available land for MAP populations but also disrupts intricate ecological relationships that are crucial for their survival

Habitat loss is particularly detrimental to those MAPs that are endemic or have specialized habitat requirements. These species often face a heightened risk of extinction when their native habitats are destroyed or fragmented. As a result, the genetic diversity of MAPs is compromised, impacting their adaptability to changing environmental conditions

Habitat degradation

In addition to outright habitat loss, habitat degradation poses a significant threat to MAPs. This degradation can manifest as soil erosion, pollution, invasive species encroachment, and altered water regimes (Lambin *et al.*, 2001). Such environmental changes can lead to reduced growth rates, diminished potency of bioactive compounds, and decreased reproductive success for MAPs.

Furthermore, habitat degradation can disrupt the mutualistic relationships between MAPs and pollinators or other interacting species. This can result in reduced seed dispersal, leading to decreased MAP populations and genetic diversity (Vamosi *et al.*, 2006).

Mitigating habitat loss and degradation

Addressing habitat loss and degradation requires a multi-pronged approach:

1. **Conservation of Natural Habitats:** Protecting and conserving natural habitats, especially those with high MAP diversity, is paramount. Establishing protected areas and promoting sustainable land-use practices can help safeguard these critical ecosystems.
2. **Habitat Restoration:** Efforts to restore degraded habitats can aid in the recovery of MAP populations. Such initiatives can involve reforestation, erosion control, and the removal of invasive species.
3. **Community Involvement:** Engaging local communities in habitat conservation and sustainable resource management can yield positive outcomes. It fosters a sense of ownership and ensures that conservation efforts align with local needs and practices (Khan *et al.*, 2018).
4. **Legislation and Policy:** Governments and organizations must enact and enforce regulations that protect natural habitats and promote sustainable land use. This includes zoning regulations, protected area management, and sustainable forestry practices.
5. **Research and Monitoring:** Ongoing research into MAP ecology and population dynamics can inform conservation strategies. Monitoring the health of MAP populations and their habitats is crucial for early intervention.

In conclusion, habitat loss and degradation are formidable challenges to the survival of Medicinal and Aromatic Plants. As stewards of these invaluable resources, it is imperative that we take immediate action to protect their habitats, conserve biodiversity, and ensure the sustainable management of MAPs. Only through collective efforts can we secure the future of these plants and their essential contributions to human health and well-being.

Climate change and its effects on the medicinal plants sector

Climate change is a major threat to the medicinal plants sector. Changes in temperature, precipitation, and other environmental factors can stress MAP plants and make them more susceptible to pests and diseases. Climate change can also lead to changes in the distribution of MAP species, which can disrupt traditional harvesting practices.

Some of the specific effects of climate change on the medicinal plants sector include

- **Reduced productivity:** MAP plants may produce less biomass or essential oils due to changes in temperature and precipitation.
- **Changes in phytochemical composition:** The chemical composition of MAP plants may change due to climate change, making them less effective as medicinal treatments.
- **Increased pest and disease pressure:** MAP plants may be more susceptible to pests and diseases due to warmer temperatures and milder winters.
- **Changes in distribution:** MAP species may migrate to new areas in response to climate change, making them more difficult to access and harvest.
- The effects of climate change on the medicinal plants sector are likely to be felt most acutely in developing countries, where many MAPs are collected from the wild and traditional knowledge about their use is still prevalent.

Conservation Strategies for Medicinal and Aromatic Plants: Safeguarding Nature's Pharmacy

Medicinal and Aromatic Plants (MAPs) are treasures of the natural world, offering a vast array of therapeutic and aromatic properties. However, due to habitat loss, overharvesting, and other anthropogenic pressures, many MAP species face the risk of depletion or extinction. To address these challenges and ensure the sustainable management of MAPs, a range of conservation strategies have been adopted worldwide.

Table 3: Different types of conservation measures that can be used to protect MAPs

Conservation measure	Description
In situ conservation	The protection of MAPs in their natural habitats. This can be done through the establishment of protected areas, sustainable harvesting practices, and community-based conservation initiatives.
Ex situ conservation	The conservation of MAPs outside of their natural habitats. This can be done through the collection and storage of seeds and other plant material in gene banks, the cultivation of MAPs in botanical gardens and other facilities, and the development of in vitro conservation techniques.

1. In-situ conservation:

Protected areas: Establishing protected areas, such as national parks, wildlife sanctuaries, and botanical reserves, helps preserve the natural habitats of MAPs. These protected zones not only shield

MAP populations from direct exploitation but also serve as vital refuges for other species sharing their ecosystems.

Habitat restoration: Rehabilitating degraded habitats is essential. Restoration efforts involve activities like reforestation, soil conservation, and the removal of invasive species, which help rejuvenate the ecosystems where MAPs thrive.

Community-based conservation: Engaging local communities in the conservation of MAPs and their habitats is crucial. Indigenous and traditional knowledge often plays a pivotal role in sustainable resource management. Involving communities ensures that conservation practices align with local needs and values.

2. Ex-situ Conservation

Botanical gardens and arboreta: These institutions play a pivotal role in ex-situ conservation. They maintain living collections of MAPs, ensuring their genetic diversity is preserved. Botanical gardens also serve as centers for research and public education.

Seed banks: Seed banks store seeds of MAPs and other plant species under controlled conditions, safeguarding genetic diversity. These repositories are critical for plant breeding, research, and potential future reintroduction efforts.

Table 4 : Challenges and opportunities of genetic resource management of MAPs

Challenge	Opportunity
Limited knowledge of the genetic diversity of MAPs	Advances in DNA sequencing and other technologies are making it easier to study the genetic diversity of MAPs. This information can be used to develop conservation strategies and to improve the breeding of MAPs.
Lack of coordination between different stakeholders	Increased collaboration between researchers, policymakers, and industry can help to improve the genetic resource management of MAPs.
Limited access to genetic resources	The sharing of genetic resources can be restricted by intellectual property rights and other regulations. The development of international agreements and other mechanisms to promote the fair and equitable sharing of genetic resources is essential.

3. Sustainable harvesting practices

Implementing sustainable harvesting techniques is essential for the long-term viability of MAPs. Selective harvesting, which involves taking only mature plants or specific plant parts, helps maintain populations and their genetic diversity.

4. Legal Frameworks and Regulations

Governments and international organizations have enacted legislation and regulations to control the harvest, trade, and conservation of MAPs. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and national-level laws are examples of such measures.

5. Research and Monitoring

Continuous research into MAP ecology, biology, and population dynamics is essential for informed conservation strategies. Monitoring the health and distribution of MAP populations helps detect early signs of decline and informs timely intervention.

6. Public Awareness and Education

Raising awareness about the importance of MAPs and their conservation is vital. Public education campaigns, workshops, and outreach efforts inform stakeholders, from local communities to policymakers, about the value of these plants and the need for their protection.

7. Collaboration and Partnerships:

Conservation efforts benefit from collaboration among governments, non-governmental organizations, academia, and local communities. Partnerships foster knowledge exchange, resource mobilization, and coordinated action.

8. Sustainable Trade and Fair Practices

Promoting ethical and sustainable trade practices ensures that the economic value of MAPs benefits local communities and supports conservation efforts. Fair trade certification schemes can help achieve this goal.

In conclusion, the conservation of Medicinal and Aromatic Plants requires a multifaceted approach that spans in-situ and ex-situ methods, sustainable harvesting, legal frameworks, research, education, and collaboration. These strategies aim to protect the rich biodiversity and cultural heritage associated with MAPs while ensuring their availability for future generations and sustaining the invaluable contributions they make to medicine, industry, and human well-being.

ICAR-IIHR's contributions to medicinal plants conservation

1. Nothapodytes nimmoniana

To conserve *Nothapodytes nimmoniana*, a series of eight exploration and collection missions were conducted in various regions, including Shimoga, Yercaud, Agumbe, Joida, Amboli ghat, Khanapur, Jambotti, Sirsi, Wayanad, Dakshina Kannada, Idukki District of Kerala, and Coorg. During these missions, efforts were made to gather seeds, seedlings, and materials suitable for chemical and molecular analysis. Additionally, on-site assessments were carried out to evaluate the morphological diversity within the populations.

Efficient in vitro systems were developed for the conservation of N. nimmoniana, utilizing embryos as explants. These in vitro cultures could be maintained at a temperature of 10°C without requiring subculture for up to one year. To ensure the genetic integrity of tissue-cultured seedlings, ISSR markers were employed for testing.

The distribution of *N. nimmoniana* in the Western Ghats region was mapped using DIVA GIS software. This mapping was achieved by employing a domain model within DIVA GIS to predict the potential distribution of *N. nimmoniana* based on BIOCLIM climate parameters. Primary data collected from the exploration and collection missions, including latitude, longitude, and altitude information obtained through GPS, was digitally recorded. The Bioclim/Domain tool was then utilized to extract climate data from point locations and predict the potential occurrence of *N. nimmoniana*.

Furthermore, a field gene bank was established for *N. nimmoniana*, using the accessions collected during the exploration and collection missions. This effort aimed to safeguard the genetic diversity of the species for future conservation and research purposes (Kareem 2011).

2. RET medicinal plants

The Indian Institute of Horticultural Research (IIHR) has undertaken significant efforts in the conservation and documentation of 32 rare and endangered medicinal plants (RET medicinal plants) originating from Kerala, Karnataka, and Tamil Nadu

In terms of conservation, the institute has collected 374 accessions of RET medicinal plants from their natural habitats and established them in a field gene bank at IIHR. Furthermore, they have generated distribution maps and predicted areas of distribution for these 32 species using DIVA GIS software. For five specific RET medicinal plant species (*Oroxylum indicum, Decalepis hamiltonii, Holostemma adakodien, Embelia tsjeriamcottam, and Embelia ribes*), seed banks have been established. Additionally, they have optimized in vitro multiplication and conservation protocols for three RET medicinal plant species (*Alpinia calcarata, Kaempferia galanga, and Acorus calamus)* and initiated seed cryopreservation for five others (*Oroxylum indicum, Operculina turpethum, Holostemma adakodien, Celastrus paniculatus, and Decalepis hamiltonii).*

In terms of documentation, IIHR has developed a comprehensive database for these 32 RET medicinal plants, which encompasses passport data, evaluation data, abstracts of published research papers, distribution and prediction maps, photographs, and data from various studies such as exploration, field gene bank, in vitro studies, anatomical studies, and pollen studies

Additionally, molecular characterization of RET medicinal plant species from different locations has been carried out using ISSR analysis, and chemical profiling has been conducted for several species including *Decalepis hamiltonii, Oroxylum indicum, Celastrus paniculatus, Alpinia galanga, and Kaempferia galanga*

These concerted efforts by IIHR hold significant importance in the realm of conserving and sustainably utilizing rare and endangered medicinal plants, contributing to their preservation and potential future applications.

3. *Madhuca insignis*

A study focusing on *Madhuca insignis*, a critically endangered riparian tree species, has achieved significant milestones in enhancing our understanding of its distribution, propagation methods, and potential medicinal applications. Notably, this study has successfully identified three previously unknown areas where *Madhuca insignis* populations exist, thereby expanding our knowledge of its range. Additionally, a propagation technique has been developed, and a plant growth-promoting fungal consortium has been isolated. The gene sequences of *Madhuca insignis* have been made available in the public domain, and an initial investigation suggests its promising potential in cancer treatment. Furthermore, the study has played a crucial role in the reintroduction of *Madhuca insignis* into its native niche habitats, protected areas, and non-niche regions. The project's outcomes have received commendation from the review team at DBT, highlighting its valuable contributions to the conservation and exploration of this endangered species(Chrungoo etal,2018)

Conclusion

In conclusion, the conservation and sustainable management of genetic resources of Medicinal and Aromatic Plants (MAPs) represent a multifaceted endeavor, necessitating a holistic approach that incorporates ecological, climatic, socioeconomic, and legal dimensions. The challenges of overexploitation, habitat loss, climate change, and biopiracy threaten not only the biodiversity of MAPs but also the global health, food security, and livelihoods of communities dependent on them. To address these challenges, it is imperative to implement sustainable harvesting practices, strengthen legal frameworks, engage local communities, and foster research and education. Collaborative efforts are paramount to ensure the continued availability of MAPs, preserving their invaluable contributions to medicine, industry, and human well-being for current and future generations

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31. Challenges and future prospects of under exploited and exotic flower crops

Imtiyaz T. Nazki
Professor, Division of Floriculture & Landscape Architecture, Faculty of Horticulture,
Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST-Kashmir),
Shalimar, Srinagar
Email: mitnazki@gmail.com

ABSTRACT

Underutilized cut flower production and marketing offers both small and large-scale growers a way to increase the level of sustainability on their farms. The wide variety of novel ornamental plants can be grown as cut flowers, foliage, pot plants, landscape plants, and this allows growers to choose those which are well-adapted to the farm site and grown without large off-site inputs. This variety also makes diversity in both production and marketing possible. The high value of specialty cut flowers can increase farm income. Use of highly mechanized greenhouses for cut flower production is very beneficial to the farmers but high production and energy costs are associated with their use. The high costs of such production systems can overcome by growing unconventional and novel ornamental species in the field, or in non-mechanized, and less input intensive regime. The cost of growing underutilized ornamentals in the field may be appealing, but the risk of extreme weather, seasonal production, and limited control options can increase the risks for farmers. Studies have been to be conducted to assess underutilized ornamentals performance in field production systems in specific agri-ecologies of India supported by efforts in the direction of crop improvements, nursery production, propagation and easy availability of planting material. Coupled with a sustained efforts in developing post-harvest value chain and value addition and marketing low energy and technology intensive floriculture shall continue to supply bulk of India's floriculture products and services for medium and long-term. and when compared with field production, high tunnel production yielded a greater number of stems/m^2 in most of the specialty cut flowers.

India is a major world economy with a youthful demography that should favour high growth of domestic flower business in the coming years. Around 60% of Indians fall between the age group of 18 to 35 years, a statistic that points to tremendous demographic dividend both in terms of human resource and flower and flower product consumers. Area under floriculture has crossed or is close to 400,000 ha and rough estimate puts value of domestic floriculture sector between 3 to 4 billion US dollars (Rupees 24 to or 32 thousand crores). Roses, Orchids, Carnations, Marigold, Jasmine are the important commercial flowers with a combined total cropped area exceeding 70,000 ha. Indian economy has been growing at a near double digit rate for the last decade. It is pegged at around 5 trillion US dollars in 2027 and is on course to overtake Japan as the third largest economy in just over a decade. India is a huge country with 25 cities having a population of more than 2 million and eight cities having a population of more than 5 million. Around 220 million Indians constitute affluent, middle and upper middle-class section of the population. India's metros are home to upwardly mobile young population which is comparable to population of some the European countries. Changing attitudes, lifestyles, impact of digital age and social media along with disposable incomes have given a fillip to domestic consumption that has also propelled the domestic demand for floral products. In spite of a huge internal demand, India contributes less than one percent to total world flower exports which touched 80 million USD at the end of 2022. However, the potential for growth in Indian flower exports is huge owing to its location between South East Asia and Middle East which gives it a unique access to two big markets as a regional floricultural hub. More and more consumers in India are becoming quality conscious and demand flowers comparable to those available in Europe, US and Japan. The increase in domestic demand for high quality flowers in coming years is expected to make Indian flower exports competitive.

The next big jump in Indian flower exports would be on the back of internal demand for flowers Domestic consumption is going to be the main driver of growth in floriculture in the medium and near term (in the next decade). However, India is destined to remain a net importer of flowers and floriculture products in view of the huge demand. Inspite of this exports are likely to see quantum jump on the back of the growing demand for quality flowers particularly in roses, gerbera, carnation, lilium, value added products in the domestic market, South East Asia and Middle East.

Going forward growth in floriculture is expected to occur in two sectors

1. **High Tech. / High energy requiring floriculture** under controlled environments utilizing costly inputs in terms of technology, imported germplasm , fertilizers etc. This is to cater to the export market and demand for such products and services in the major metropolitan areas of the country.
2. **Low tech/low energy requiring/ minimal environmental footprint floriculture** and flower products sector. These are expected to mushroom around peri-urban areas to cater to the growing demand for diversified farm fresh flowers and value-added flower products.

The second sector accounts for the bulk of production and business currently (40 times the volume of export oriented floriculture) which is likely to continue for foreseeable future. Further, this model is inherently sustainable and is suitable for small farmers who don't have ready access to capital and technology Anil et al., (2018) ; Dansi et al. (2012).However, most of the budget for R &D , govt. support for area expansion and promotion is cornered by the export oriented floriculture sector

There is a need to keep focus on the impending boom in demand for local flowers and floriculture products to cater to the taste sensibilities and requirements in various agro—ecological and economic zones in the country

What are underutilized flower crops?

The phrase "underutilized flower crops" originally referred to all species other than carnations, chrysanthemums, and roses. As recently as 1986, these three cut flower species, plus gladiolus, accounted for more than 80 percent of total cut flower production. (Dole and Greer, 2004) Since then, other species like Lilies etc. have been "mainstreamed" whereas there are innumerable flower species also known as specialty cut flowers or underutilized flowers that have found commercial value in various countries. A classic case is the U.S. cut flower industry. The combined production of carnations, chrysanthemums, and roses and lilies constitutes only 15 percent of total cut flower and foliage production in contrast to other specialty cut flowers.

Scope of underutilized and exotic flowers

Underutilized and exotic flower production has the potential to increase income for both small and large farmers. In Indian context underutilized flowers are more important to as they constitute bulk of production in the floriculture sector. Underutilized or underexploited crops are the species with potential for contributing to food security, health (nutritional or medicinal), income generation and environmental services Cohen *et al.,* (1995), Under-exploited or neglected crops are indigenous or exotic ancient crop species grown and consumed at some level within the local, national as well as international communities without complete cultural information which have the potential to contribute to increasing the national economy Allan *et al.,* (2003) Brien *et al* (2000) Farmers are finding growing these flowers make it easier to compete with imported products. These crops represent an important component of rural communities in different parts of the world but their poor marketing and production conditions make them largely under-utilized in economic terms Malhotra and Ram (2017). They are mostly found in wild habitats and have the potential to generate income through minor crop improvements. Ranil *et al.,* (2015). These crops are highly adaptable to extreme environmental conditions and threatened habitats with high genetic tolerance to biotic and abiotic stresses as they are mostly introduced from forest ecosystems which demands for the requirement of little or no external inputs for their cultivation. Flowers that don't ship well or can't handle boxed transport can be picked by a local peri-urban farmer in the evening and sold in Mandis early next morning. Underutilized flowers can be grown as annuals or perennials, from seeds, cuttings, seedlings, or bulbs, crowns etc. They also may include woody plants from which flowers, stems, fruits, or foliage are harvested. They can be grown in the open field, and in simple growing structures. By producing unusual, high-quality flowers, using proper postharvest handling techniques, and by providing excellent service, growers can continue to expand markets for underutilized flower crops.

Some recently introduced species to commercial floriculture at world level:

Australian native flora: Like Anigozanthos, Banksia, Blandfordia, Boronia, Blandfordia, Chamelaucium, Grevillea, Leptospermum, Telopea and Thryptomene Forrest (2002).; Seaton *et al.* (2009) and Bester *et al.* (2009).

Israel and Turkey: Source of many commercial ornamental plants e.g., anemones, ranunculus, cyclamen, hyacinth, Narcissus tazetta, *Lilium candidum*, several tulips, Oncocyclus irises, Uriginea maritima, Scilla hyacinthoides, *Asphodelus ramosus*, several Allium species, *Lupinus pilosus, Eremostachys laciniata* and *Helichrysum sanguineum*.

South Africa: Contributed novel cut flowers like Clivia, Freesia, Gerbera, Gladiolus, Ornithogalum, Lachenalia, *Amaryllis belladonna*, Nerine, Cyrtanthus, Crinum and Protea after hybridization and propagation techniques Bester, *et al*. (2009).; Kenneth and Richard, (1999).

Colombian native flora: Contributed ornamentals viz., *Begonia sp, Bomarea sp, Cuphea sp, Fuschia sp, Hypericum sp, Senecio spp*., and the list is endless

New species such as Protea, Banksia, Gravillea, Leucadendron, Leucospermum, Sandersonia, Leptospermum, *Chamelaucium uncinatum*, Anigozanthus (kangaroo paw), *Ornithogalum dubium* and others have been successfully introduced to the cut-flower industry.

A classic case is the growth of floriculture industry in South Africa and Australia powered by indigenous proteas, pincushions, and greens which originate from the Cape Floristic Region and Australian Ecological Zones – one of the planet's most biodiverse areas. These unique and beautiful plants quickly claimed a distinctive niche within global markets. In recent decades, the so-called 'Cape Flora' sector has undergone a transformation from its rustic beginnings, based on the harvesting of flowers from wild landscapes, to a model that combines wild harvesting with a modern sector that cultivates higher value species such as Proteas.

Potential repositories of underutilized flowers in India

India is home to four biodiversity hot-spots

1. **North western Himalayas:** Home to 10 % of world plant species and 50 % of India's Indigenous flora (Thakur and Jhoshi, 2020)
2. **North East:** Of 17,000 species of orchids in the world, about 1,250 occur in India and about 700 occur in the north eastern region. The native species of orchids having ornamental value and market potential usually belong to *Aerides, Anachnantha, Arundina, Cymbidium, Dendrobium, Paphiopedillium, Phaius, Renanthera, Phycostyllus* and *Vanda* (Deka *et al.* 2015)
3. **Western Ghats:** Apart from the 7,402 species of flowering plants occurring in the Western Ghats, 5,588 species are native or indigenous and 376 are exotics naturalized; 1,438 species are cultivated or planted as ornamentals. Sindhu., *et al.*, 2020
4. **Andaman and Nicobar Islands:** About 2,200 species of plants have been recorded, out of which 200 are endemic and 1,300 do not occur in mainland India.

Underutilized crops can belong to any of the following Horticultural classes

1. **Woody Ornamentals:** *Albizzia julibrissin, Benthamedia capitata, Bombax ceiba, Cassia fistula, Lyonia ovalifolia, Prunus cerasoides, Picea smithiana, Rhododendron arboreum. Barleria cristata, Cocculus laurifolius, Hypericum oblongifolium, Indigofera pulchella, Inula cappa, I.cuspidata, Woodfordia fruticosa, Pteracanthuss alatus, Rhododendron campanulatum, Sophora mollis*
2. **Herbaceous perennial :** *Blazing star – Liatris spicata , Perennial Salvia – Salvia dorrii, Yarrow-Achillea millefolium Garden Phlox – Phlox paniculata , Japenese Anemone - Anemone hupehensis, Clustered bell flower – Campanula glomerata , Purple cone flower- Echinacea pupurea , Peony - Paeonia lactiflora , New England Asters- Smyphotrichum novae-angilae, Bee Balm- Monarda didyma Coral bells - Heuchera sanguinea Veronica – Veronica officinalis Anabelle Hydrangeas Niko Blue Hydrangea s, Balloon flowers – Platycodon grandiflorus Beard tongue – Penstemon , Pin cushion flowers- Scabiosa Shasta Daisy – Leucanthemum x superbum*
3. **Bulbous ornamentals:** *Alstroemeria – Alstroemeria x hybrida, Lilium – Lilium spp., Freesia-Freesia refracta, Tulips- Tulipa hybrida, Iris- Iris tuberosa Narcissus- Narcissus poeticus, Tuberose – Polianthes tuberosa Calla Lily - Zantedeschia aethiopica*
4. **Annuals:** *Zinnia elegans, Antirhinum majus, Centaurea cyanus, Mimiosa pudica, Lobularia maritime, Angelonia angustifolia, Calendula officinalis, Phlox drummondii, Cosmos bipinnatus, Lupinus albus, Papaver rhoeas, Impatiens hawker, Verbena bonariensis, Fuchsia magellanica, Delphinium elatum, Celosia cristata, Nigella damascene, Rudbeckia hirta L., Calibrachoa hybrida*

5. **Ferns and Foliage**: *Sarcococca saligna, Cocculus laurifolius, ferns, etc*

Challenges:

Identification and inventorization:

There is lack of awareness both among Scientific and farmer communities

Crop Improvement:

There are no robust and focused breeding programmes available

Propagation and availability of plant material in bulk:

Lack of knowledge regarding the propagation and no specialized nurseries and nursery standards available

Standardization of package of practices:

Very little knowledge regarding effective agri practices for a commercial enterprise

Flower regulation:

No knowledge regarding flower regulation for sustained returns to farmer over a longer period of time

Harvesting index, post-harvest, Value addition, value chain and Marketing:

No established protocols available

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Some potential underutilized and exotic ornamental plants suitable for largescale commercial utilization

S. No.	Botanical Name	Common Name	Family	Blooming Time	Propagation Type
1	*Achillea millefolium*	Common Yarrow	Asteraceae	June to September	Seed
2	*Aconitum napellus*	Monkshood or Wolf's-bane	Ranunculaceae	Summer	Seed and Division of Tubers
3	*Ageratum houstonianum*	Floss flower or Bluemink	Asteraceae	June through first frost	Seed
4	*Allium sphaerocephalon*	Drumstick chives	Liliaceae	Spring, but through all fall bloomers	Seed and Division of Bulbs
5	*Alstroemeria*	Peruvian Lily	Alstroemeriaceae	Summer	Seed, Rhizome division and Tissue culture
6	*Amaranthus caudatus*	Love-lies-bleeding	Amaranthaceae	July to frost	Seed
7	*Antirrhinum majus*	Snapdragon	Scrophulariaceae	Spring to fall	Seed
8	*Callistephus chinensis*	China aster	Asteraceae	Fall, Summer	Seed
9	*Campanula*	Bell flower	Campanulaceae	July to September	Seed and Division of crown
10	*Caryopteris incana*	Blue spirea	Verbanaceae	Mid-summer to early fall	Seed and cuttings
11	*Celosia argentea*	Silver cockscom	Amarantheceae	Summer-fall	Seed
12	*Cosmos bipinnatus*	Lace cosmos	Asteraceae	Summer through fall	Seed
13	*Delphenium*	Larkspur	Ranunculaceae	Early to Mid summer	Seed and cuttings
14	*Eustoma grandiflorum*	Lisianthus, Prairie gentian	Gentianaceae	Summer,Fall	Seed and cuttings
15	*Gomphrena globosa*	Globe amaranth	Amaranthaceae	June to frost	Seed
16	*Helianthus annus*	Annual sunflower	Asteraceae	Summer, fall	Seed
17	*Hydrangea macrophylla*	Bigleaf hydrangea	Hydrangeaceae	Mid-Summer through fall	Softwood cutting
18	*Lavatera trimestris*	Rose mallow	Malvaceae	Summer to fall	Seed
19	*Nigella damascena*	Lone-in-a-mist	Renunculaceae	Spring, summer fall	Seed
20	*Paeonia*	Peony	Renunculaceae	Late spring to late summer	Division of crown
21	*Phlox paniculata*	Summer phlox	Polemoniaceae	Summer	Root cuttings, stem cuttings and division
22	*Physostegia virginiana*	Obediant plant	Lamiaceae	Summer, fall	Seed, cutting and division
23	*Salvia leucantha*	Mexican bush sage, Velvet sage	Lamiaceae	Late summer	Terminal cuttings
24	*Zinnia elegans*	Common Zinna	Asteraceae	Late spring through first fall	Seed

32. Functional genomics for understanding and improvement of medicinal and aromatic traits

Dinesh A. Nagegowda
CSIR-Central Institute of Medicinal and Aromatic Plants, Research Centre, Bengaluru
Email: da.nagegowda@cimap.res.in

Introduction

Plants produce an amazing diversity of compounds termed "specialized or secondary metabolites" as means of defense against herbivores and pathogens, and interaction with the surrounding environment. These specialized metabolites have undergone natural selection through the course of evolution, as the presence of certain specialized metabolites granted ecological advantages to the species. Besides their importance to the plant, specialized metabolites are useful to mankind because of their immense medicinal, flavor and aromatic properties. Specialized metabolites in plants are produced at low levels in tissue-, response-, and species- specific manner due to which the production cost is generally expensive. Hence, a thorough understanding of the biosynthesis and factor affecting the biosynthesis is necessary to overcome the limitation and to improve the production of target specialized metabolites. Proper understanding of the pathways and regulatory factors involved in the formation of specialized metabolites of interest will not only facilitate metabolic engineering, but also will help crop improvement through molecular breeding for enhanced production of target specialized compound. Also, the knowledge derived from characterized genes/regulators involved in pathways leading to the formation of specialized metabolites could be utilized for improving medicinal and aromatic plants by latest gene-editing approaches to achieve higher production of specialized compound(s) of interest. Moreover, if the entire biosynthetic pathway for the specialized metabolite of importance is deciphered, it can be introduced into heterologous plant or microbial hosts through synthetic biology for production in a faster and higher amount. Genomics and transcriptomics combined with metabolomics provide a straightforward means and can be the starting point for isolation and characterization of genes/regulators and even entire pathways involved in biosynthesis and regulation of specialized metabolites. This talk will cover some recent work carried out by our research group on understanding the biosynthesis and regulation of specialized metabolites including application of genome-editing strategy for trait improvement in different important medicinal and aromatic plants.

Decoding the regulation of anticancer alkaloid metabolism in *Catharanthus roseus*

Madagascar Periwinkle (*C. roseus*) is an important medicinal plant producing more than 130 monoterpene indole alkaloids (MIAs) and is the best characterized MIAs-producing plant species. To date, *C. roseus* remains the only natural source of two medicinally valuable dimeric MIAs vinblastine and vincristine, and their monomeric precursors vindoline and catharanthine. While leaf specific dimeric alkaloids vinblastine and vincristine are used either directly or as derivatives in chemotherapy of various cancers, roots accumulate monomeric alkaloids ajmalicine and serpentine which are used as anti-hypertensive agents. Extremely low *in planta* accumulation of MIAs makes them highly expensive. Moreover, total chemical synthesis these alkaloids is economically not viable due to their complex structures. Previous efforts of overexpression or silencing of transcriptional regulators and some pathway genes in *C. roseus* cell cultures have had limited success in improving MIAs production, indicating a complex regulatory mechanism that balances metabolic flux and thus MIAs accumulation in *C. roseus*. Research from our group has led to a better understanding of the biosynthesis and regulation of MIA pathway and could be adopted to overcome the low production and high price of MIAs. It was demonstrated that the initial steps of the pathway of terpene moiety formation (GPPSS: geranyl diphosphate synthase; GES: geraniol synthase) plays critical role in the biosynthesis of MIAs (Rai *et al.*, 2013; Kumar *et al.*, 2015). Though *C. roseus* possessed both heteromeric and homomeric GPPS, only hetermeric GPPS contributed for precursor supply to GES and in turn to MIAs biosynthesis. Next, GES was functionally characterized and it was demonstrated that transcriptional regulation of GES and in planta availability of geraniol plays critical role in the formation of MIAs. Having established the regulatory role of GPPS and GES, metabolic engineering of *C. roseus* by overexpressing GPPS, GES and GPPS+GES was carried out, which significantly enhanced MIAs at the *in planta* level (Kumar *et al.*, 2018). In addition, a novel role of a *bona fide* GGPPS in geranylgeranylation-dependent regulation of MIA biosynthesis demonstrating that the plastidial GGPPS2 plays an indirect but necessary role in MIA biosynthesis. GGPPS2 catalyzes the formation of GGPP which is utilized by protein geranylgeranyl transferase and thereby regulates the biosynthesis of MIAs by transcriptionally regulating the gene and transcription factors of MIA biosynthesis in *C. roseus* (Kumar *et al.*, 2020).

Understanding biosynthesis and regulation of withanolides in Ashwagandha

Ashwagandha (*Withania somnifera*), a member of Solanaceae family, is a plant of high repute in Ayurveda as well as in modern medicine due to the presence of withanolides in leaves and roots. Its various medicinal properties are attributed to the presence of naturally occurring triterpenoid steroidal lactones collectively termed as withanolides. Antitumour, anti-inflammation, cardioprotective and neuroprotective properties are some of the major pharmacological activities reported for *W. somnifera* extracts. So far more than 40 withanolides have been isolated from this plant in which withaferin A and withanolide D have been reported to inhibit angiogenesis, Notch-1 and NFκB in cancer cells and induce apoptosis in breast cancer cells. Despite the importance of withanolides, their application is still limited owing to their low accumulation (0.001%–0.5% dry weights) in the plant and challenging nature of pure compound isolation from complex mixture. Current knowledge of withanolides biosynthetic pathways is limited due to the lack of available genome sequence data and more importantly due to nonavailability of reliable and technically undemanding methods for functional gene assays in *W. somnifera*. To understand withanolides biosynthesis in Ashwagandha, our group, for the first time, established virus-induced gene silencing (VIGS). It was shown that squalene synthase, the first committed enzyme of triterpene metabolism, regulated sterol and defense-related genes, in turn regulating phytosterols and withanolides accumulation and biotic stress tolerance (Singh *et al.*, 2015; Bomzan *et al.*, 2020). In a collaborative study, we showed that application of simple nitrogenous fertilizers improved the sterol contents thereby enhancing the withanolides (Pal *et al.*, 2017). Further, our group has characterized a phytohormone-inducible WRKY transcription factor from *W. somnifera* (WsWRKY1) that positively regulates phytosterol and withanolide biosynthesis, and defense against biotic stress. It was also demonstrated that WsWRKY1 can be a great metabolic engineering tool for enhancing triterpenoids and defense in other crop plants like tomato and eggplant (Singh *et al.*, 2017). With regards to downstream genes of withanolides pathway, three genes encoding cytochrome P450 enzymes were functionally characterized and their *in planta* characterization indicated their role in withanolides biosynthesis (Shilpashree *et al.*, 2022).

Exploring essential oil biosynthesis in Ocimum, curry leaf and lemongrass

Ocimum L. is a well-known genus for its ethnobotanical, medicinal and aromatic properties. Through functional genomics, a specific 4-coumarate: CoA ligases (4CL) was identified and for the first time demonstrated its involvement in creation of virtual compartments through substrate utilization and committing metabolites for eugenol biosynthesis at an early stage of the pathway (Rastogi *et al.*, 2013). Further to enrich genomic resources for understanding various pathways in *Ocimum* species, *de novo* comparative transcriptome analysis of two important *Ocimum* species was carried out using NGS. This analysis identified genes and regulators of terpenoid and phenylpropanoid metabolism along with SSR and SNP markers linked to phenylpropanoid and terpenoid pathway genes, paving the way for functional characterization of genes, their regulation, and breeding special chemotypes with unique essential oil composition (Rastogi *et al.,* 2014). In the case of Curry tree (*Murraya koenigii* L.), which is a rich source of aromatic terpenes and pharmacologically important carbazole alkaloids, using transcriptomics combined with metabolomics, we have identified the genes responsible for terpenoid and carbazole alkaloids biosynthesis along with molecular markers. Through this, we have demonstrated that a plastidial (−)-sabinene synthase and a cytosolic (*E,E*)-α-farnesene synthase are responsible for the formation of major leaf volatiles (Meena *et al.,* 2017). Similarly, to understand and develop high-yielding aromatic grasses of the genus *Cymbopogon*, we have performed *de novo* transcriptome assembly and analysis of *C. flexuosus* (lemongrass) by NGS. Further, based on gene expression and metabolic analysis combined with molecular docking, genes of pathway responsible for various aromatic terpenes were identified, thereby providing the first insight into the essential oil biosynthesis of aromatic grasses (Meena *et al.*, 2016).

Deciphering the role of terpene synthases in potato biotic stress tolerance

Terpene synthases (TPSs) produce a variety of terpenoids that play numerous functional roles in ecological interactions. His group has identified two pathogen-inducible TPSs (StTPS6 and StTPS18) from potato. While StTPS6 encoded a bulnesol/elemol synthase catalyzing the formation of sesquiterpenes bulnesol/elemol utilizing farnesyl diphosphate (FPP) as substrate (Dwivedi *et al.,* 2021), StTPS18 encoded farnesol synthase forming (*E-E*)-farnesol from FPP and localized to the cytosol (Dwivedi *et al.,* 2022). Further, biochemical, *in planta* overexpression and silencing studies, combined with transcript, metabolite and bacterial growth analyses revealed that bulnesol/elemol, the product of StTPS6 could have a direct role in providing tolerance against biotic stress, whereas (*E-E*)-farnesol formed by StTPS18 confers defense against bacteria indirectly via regulation of phytosterol biosynthesis (Dwivedi *et al.,* 2021; 2022). These genes can be utilized for enhancing tolerance against pathogens in crop plants and also for heterologous production of bulnesol and farnesol that have high value in aroma industries.

Besides these above studies, the talk will cover about development of different varieties of medicinal and aromatic plants (MAPs) for improved traits, and possibilities of genome editing mediated medicinal and aromatic trait improvement in select MAPs.

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33. Collection and characterization of germplasm of an underutilized fruit *Balanites roxburghii* (Desert date) from South India

Gugglada Govardhan Yadav[1] and Hosakatte Niranjana Murthy[1,2*]

[1]Department of Botany, Karnatak University, Dharwad 580003

[2]Department of Horticultural Science, Chungbuk National University, Cheongju 28644, Republic of Korea

*Email: hnmurthy60@gmail.com; hnmurthy@chungbuk.ac.kr

Introduction

Balanites roxburghii is an underutilized fruit-yielding species, native to India (Fig. 1) (POWO 2023). It is popularly known as 'Desert date' or 'Hingot'. It grows throughout the dry regions of India and is well known for the medicinal properties it possesses, especially to cure jaundice. It is also used in curing snake bites, deworming in children, skin infections, and as an anthelmintic. In some regions of Southern India, the leaves are eaten as a vegetable during food scarcity periods. Using seed oil for cooking and eating ripened fruits is also observed in some regions of Southern India. The cattle, sheep, and goats graze the leaves and ripe fruits of this species, especially during the summer. These facts manifest the importance of *B. roxburghii* in rural areas, especially where the rainfall is very low. It accommodates more than 50% of nutraceutical-rich oil in seed kernels and an impressive amount of diosgenin, a commercially important compound, in all the parts. Systematic cultivation of this species would facilitate the commercial production of its seed oil and diosgenin. Besides, the majority of the areas where the *B. roxburghii*is distributed receives very little rainfall, has low irrigation facility, and possess suitable soil conditions. It could be grown commercially in those areas, to get valuable products and generate income for local people. Thus, the present work is an attempt to explore the wild germplasm of *B. roxburghii* to select promising genotypes for its cultivation programs.

In the present study, 45 accessions from 35 natural populations of *B. roxburghii* grown in the forest or protected areas were identified, followed by the collection of fruits from each selected accession (Table 1) (Yadav and Murthy 2022). We analyzed the fruits from all the accessions for twelve key morphological traits having importance in cultivation. Based on morphological characterization data, 19 superior accessions were selected for the subsequent fruit pulp and seed oil biochemical characterization and fruit diosgenin quantification. Based on the pulp and seed oil biochemical data, certain superior genotypes concerning each biochemical trait are identified. Similarly, from the diosgenin quantification data, superior genotypes are identified on which importance shall be given in future cultivation programs. In addition, we also did the nutritional analysis of pulp, seed kernel, and leaves and diosgenin quantification in the root, stem, and leaves for the samples collected from one accession (Yadav et al. 2022). Thus, we obtained impressive results from the present study and we summarized our key findings and conclusions in the following paragraphs.

Distribution and morphological diversity of *Balanites roxburghii* accessions

Balanites roxburghii is distributed throughout the dry regions of Southern India, majorly concentrated in the Central, Southern, and Northern interiors of Karnataka and Rayalaseema and Eastern Ghats regions of Andhra Pradesh. Northern Telangana and North-Western Tamil Nadu regions are also major centers of distribution. It has a high drought-tolerant capacity, occurs mainly in scrubby and deciduous forests, and prefers black cotton, sandy and red soils. A total of 45 accessions from 35 populations were collected, and morphological variations in 9 quantitative and 3 qualitative traits related to fruits were analyzed. Fruit weight showed the highest variation, ranging from 10.23 to 37.69 g, pulp weight from 1.71 to 10.24 g, and seed kernel weight from 0.77 to 3.87 g. PCA analysis showed that fruit weight, length, width, pulp weight, rind weight, and endocarp weight were the major traits contributing to the diversity.

Cluster analysis resulted in the formation of four groups. Cluster 1 comprises nineteen accessions and is characterized by the highest percentage composition of pulp. Accessions of Cluster 2 had smaller-sized fruits. Cluster 3 has two accessions, KA-04A and TE-04, with the largest seed kernels. Cluster 4 is formed by six accessions, KA-03, KA-04B, KA-13A, KA-13B, TN-03, and TE-05A, that accommodate the highest pulp content and large-sized seed kernels. Thus, the accessions of cluster 3 could be utilized for seed kernel-related traits and cluster 4 for pulp-related traits. Further, the accessions of cluster 2 possess the highest percentage composition of pulp. The superior accessions mentioned above could be used effectively in future cultivation and crop improvement programs (Yadav and Murthy 2022).

Nutritional profile of pulp, seed, and leaves of *Balanites roxburghii*

The pulp, seed kernel, and leaves of *B. roxburghii* are used as minor nutrient sources in the South Indian region, as mentioned earlier. Hence, nutritional and phytochemical analysis of the parts mentioned above was done in our study to know the exact nutrient composition. Proximate analysis, mineral composition, anti-nutritional factors, total phenolic content, and antioxidant activities of pulp, seed kernels, and leaves were determined, and we got impressive results. Pulp possesses the highest carbohydrate and ash content, 38.65% and 11.27%, respectively. It also contains a significant amount of proteins and fiber. Pulp accommodates 16.02 mg/g DW of potassium and 10.56 mg/g DW of calcium, whereas total phenolic content was 11.54 mg GAE/g DW, which is higher than seed kernels and leaves. The seed kernels showed outstanding proximate composition with 43.20% oil and 10.96% proteins. Seed kernels were rich in minerals, such as nitrogen (28.40 mg/g), iron (1419 μg/g DW), zinc (431 μg/g DW), manganese (44.50 μg/g DW), copper (36.80 μg/g DW) and boron (28.96 μg/g DW). The total phenolic content was 2.72 mg GAE/g DW. The leaves showed 61.67% moisture and 21.12% fiber content, higher than pulp and seed kernels. It is rich in both macro and microelements, especially potassium (20.30 mg/g DW), calcium (18 mg/g DW), magnesium (6.6 mg/100 g DW), iron (1346.01 μg/g DW), copper (22.9 μg/g), zinc (344.02 μg/g), manganese (67.9) and boron (34.78 μg/g). The total phenolic content was 8.76 mg GAE/g DW. All these parts showed superior antioxidant activities, which indicates the presence of biologically active phytocompounds. Considering the data mentioned above, such as the availability of materials, oil, proteins, carbohydrates, fiber, mineral composition, and bioactive compounds, pulp, seed, and leaves of *B. roxburghii* could be considered as a good food source to increase the food base of people and to get a variety of nutrients (Yadav et al. 2022). Hence, these parts could be encouraged to be a good source of nutrition for the rural population, where it grows naturally. Even though the presence of anti-nutritional chemicals hinders the importance of nutritive value, appropriate food processing methods can be followed to minimize their effect.

Table 1: Geographical locations of *Balanites roxhburgii* accessions collected from South India

State	Population	Accessions	Location	District	Latitude	Longitude	Altitude (m)
Andhra Pradesh	AP-01	AP-01A AP-01B	Giddangivaripalli	Kadapa	14°18'14.07"N	78°19'28.46"E	362
	AP-02	AP-02A AP-02B	Jaladurgam	Kurnool	15°15'06.25"N	77°53'42.56"E	412
	AP-03	AP-03	Kallampalli	Anantapuram	13°55'15.82"N	77°38'48.29"E	697
	AP-04	AP-04	OmkarTemple	Kurnool	15°36'08.45" N	78°36'37.95"E	236
	AP-05	AP-05	Pacherla	Kurnool	15°25'36.85" N	78°43'42.76" E	320
	AP-06	AP-06	Rachepalli	Kadapa	14°12'48.74" N	78°49'30.19" E	324
	AP-07	AP-07	Siddapuram	Kurnool	15°49'46.15" N	78°40'07.99" E	285
	AP-08	AP-08	Thummalabailu	Prakasam	15°58'36.93" N	78°54'09.13" E	656
	AP-09	AP-09	Venkatagaripalli	Anantapuram	14°06'13.65" N	77°44'15.52" E	508
Karnataka	KA-01	KA-01	Amareshwara	Raichur	16°15'50.96" N	76°32'35.95" E	444
	KA-02	KA-02	Bannerghatta	Bengaluru rural	12°42'22.54" N	77°34'55.56" E	806
	KA-03	KA-03	Chennagiri	Davanagere	13°58'04.89" N	76°01'46.17" E	732
	KA-04	KA-04AKA-04BKA-04C KA-04D	Chowdlapura	Tumakuru	13° 19' 21.80"N	76° 43' 50.49"E	870
	KA-05	KA-05	Gudibande	Chikkaballapura	13°41'58.25" N	77°41'50.87" E	844
	KA-06	KA-06	Jenukallupalya	Ramanagara	12°52'22.15" N	77°14'03.19" E	837
	KA-07	KA-07	Kalinganahalli	Tumakuru	13°34'14.44" N	76°48'28.43" E	756
	KA-08	KA-08	Kappathagudda	Gadaga	15°13'14.34" N	75°42'31.29" E	674
	KA-09	KA-09	Malebennuru	Davanagere	14°19'02.64" N	75°42'34.64" E	637
	KA-10	KA-10A KA-10B	Moka	Ballari	15°15'18.55"N	77°04'16.36"E	406
	KA-11	KA-11	Ranebennuru	Haveri	14°38'50.06" N	75°41'01.61" E	585
	KA-12	KA-12	Ratnapura	Raichur	15°51'18.95" N	76°29'27.22" E	495
	KA-13	KA-13A KA-13B	Shiruguppi	Bagalakote	16°14'58.74"N	75°47'16.88"E	545
	KA-14	KA-14	Thondala	Kolara	13°10'57.82"N	78°14'49.33"E	814
Tamil Nadu	TN-01	TN-01	Chinna Sakkanavaram	Krishnagiri	12° 41' 23.83"N	78° 14' 29.53"E	620
	TN-02	TN-02	Coimbatore	Coimbatore	11°01'06.61"N	76°56'37.91"E	436

Characterization of fruit pulp of *Balanites roxburghii* accessions

Pulp forms the major part of the fruit in *B. roxburghii*and constitutes up to 35% of some accessions. Its content ranged from 1.71 to 10.24 g among the accessions collected from South India. Following the nutritional composition, we further analyzed the total phenolic content and antioxidant activities of pulp and tocopherol content of pulp oil in selected nineteen morphologically superior accessions. The total phenolic content of the pulp ranged from 10.10 to 17.83 mg GAE/g DW. α-Tocopherol was prominent compared to β, γ, and δ-tocopherols. However, δ exceeds α in a few accessions. The highest amount of α-tocopherol was recorded in CHOW-A accession, i.e., 24.60 mg/100 g oil, followed by 15.63 and 13.48 mg/100 g oil in CHOW-B and TALA accessions, respectively. δ-Tocopherol was highest in MOKA-B, followed by CHOW-A and CHOW-B accessions with 21.93, 7.72, and 7.05 mg/100 g oil, respectively. All the accessions showed impressive antioxidant activities analyzed with four in vitro methods, viz., DPPH radical scavenging activity, total antioxidant activity, ferric reducing antioxidant power, and ABTS radical scavenging activity.

Osmotic Dehydration of Mango Slices

Fig.1. Habit and morphology of *Balanites roxburghii.*
A. Habit; B. Twig with leaves; C. Spines bearing spinules and leaves; D. Flower; E. Fruits

Seeds possess a high amount of oil, which could be a new source of edible oil. Here we report the compositional analysis of *B. roxburghii* seed oil (BRSO) and its variability among the South Indian populations. Oil content ranged from 43.2 % to 61.0 %. Oleic, linoleic, palmitic, and stearic were the major fatty acids, and their content varied greatly among the accessions. Carotenoid content was up to 22.6 mg/kg oil. α-Tocopherol ranged between 1.21 and 10.6 mg/100 g, whereas β and γ-tocopherols ranged between 0.89 and 4.98 mg/100 g. β-Sitosterol was the major phytosterol (52.5–147 mg/100 g), and squalene quantity was significant (up to 65.4 mg/100 g). BRSO has no cytotoxic effects on 3T3-L1 cell lines. Results suggest that the BRSO is a significant source of oil and nutraceuticals (Yadav et al. 2023). The clustering of accessions using the biochemical variability data resulted in three groups. Cluster 1 consists of only MOKA-A accession, and it is superior for δ-tocopherol and contains a good amount of α-tocopherol. Cluster 2 was formed by fifteen accessions that accommodate a moderate amount of all the phytochemicals analyzed. However, JENU accession from this cluster possesses the highest total phenolic content among all the accessions. Cluster 3 was formed by three accessions, CHOW-A, CHOW-B, and TALA, and they are superior for α, β, and γ tocopherols. Thus, these superior accessions could be helpful in future cultivation programs. However, there is a need to study additional biochemical components among the accessions for the more efficient selection of superior genotypes. *B. roxburghii* is an underutilized species and nutritionally rich as that of *B. aegyptica* (Murthy et al. 2020) and it needs thorough attention for its conservation and utilization.

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34. Coconut based multi-storey cropping system in horticultural crops

B Hanumanthe Gowda
Coconut Development Board, Kochi

ABSTRACT

Coconut based multi storey cropping systems with other horticultural crops offer immense potential in improving the farm income. The crops of different heights and compatible nature are selected for growing along with the coconut palms. Coconut based multi storey cropping system improve the production of coconut as well as companion crops through circular loops of nutrient recycling. Multi-storey cropping in coconut need to be popularized in large scale plantations with a perspective of food security, land productivity, crop diversification, resource utilization, economic viability etc.

Introduction

Coconut is eulogized as the '*Kalpavriksha*', the 'Tree of life', due to its multifarious utilization as food, fuel, medicine, timber and other utility purposes of different parts from root to leaves, from tender nut water to outer husk, etc. thus offering scope for sustaining the livelihood of growers, farm communities and industries in major coconut growing countries of the world. The crop is intricately woven into the socio-economic and cultural backdrop of the Indian subcontinent. As per 2020 statistics of ICC, India is the largest coconut producing country in the world, with more than 30% share of global production. In India coconut is cultivated in 2.17 M ha area spread mainly across the south peninsular region of the country. The crop sustains livelihoods millions of farmers. The coconut farmers are generally small and marginal in the country. Coconut as a monocrop is not efficient in sustaining the farm income; however the coconut based cropping systems with suitable other horticultural crops offer immense potential in improving the farm income. More than 100 different crops and systems have been identified across the globe that can be grown as intercrops in coconut plantations. The multi-storey cropping in coconut lands depends on the age of the coconut palms, water availability, shade of understory, soil characteristics, the slope of the land, labor availability, market demand, economic status of the grower, and social characteristics.

Coconut based multi-storey cropping system mainly focus on growing of different horticultural crops targeting maximum utilization of resources in the unit area. The selection of crops is done such a way to avoid competition among the crops and ensuring optimal use of resources. The crops of different heights and compatible nature are selected for growing along with the coconut palms. There are different vegetable crops, cut and loose flowers, indigenous and exotic fruit crops, medicinal plants, fodder crops, spices etc which can be part of the multi-storey cropping system.

Coconut plantations are ideal for multi-storey cropping production systems across stages of growth and development. The crop is widely spaced one and has peculiar morphological characters giving ample space for taking up other crops. The spacing followed in coconut plantations are generally 7.5 m between rows and 7.5 m between plants offering wider interspaces in the gardens. The soil area effectively utilized by coconut palms in plantations having 7.5 m spacing is only 23 percent and the effective root zone spread around the base of the palm within a radius of 2m. Thus the root spread coconut plantations allow the uninterrupted growth of other horticultural crops.

The penetration of sunlight in coconut gardens also favours multi-storey cropping system. The venation structure of the coconut crown and the orientation of leaves allow part of the incident solar radiation to pass through the canopy and fall on the ground. The leaves in a coconut palm crown are not randomly distributed but clumped around growing point. This non-random distribution will greatly influence photo synthetically active radiation (PAR). Based on the growth habit of palm and amount of light transmitted through its canopy, the life span of coconut palm can be divided into three distinct phases viz. planting till full development of canopy (about 8 years), young palms (8 - 25 years) and later stage palms (more than 25 years) The plantations which are in the age group below 8 years have good light transmission and is recommended for cultivating mainly annuals and biennials. The light transmission reduces as the palms grow and this period is ideal for growing shade loving crops. Once the plantation crosses the age of 25 years; maximum light penetration happens and is ideal for taking up perennial crops in this period. (CPCRI,2005)

In Indian conditions the most recommended multi-storey cropping system is a combination of coconut with black pepper, cocoa and pineapple. In other coconut growing countries like Philippines, Sri Lanka etc crops like betel, pepper, cinnamon, papaya, taro, coffee are also recommended.

Scope of multi-storey cropping system

Coconut based multi-storey cropping system is gaining popularity among farming community mainly attributed from the benefits like increase in income from unit holdings, assured markets for one crop or another at a time, maximum and efficient utilization of resources, crop diversification etc. In Indian

a) **Increase in nut and copra production:** The coconut production and copra yields improve especially in the initial years of multi-storey cropping. Margate and Magate (1983) reported that planting of black pepper, pineapple, papaya/cocoa together under coconut increased yield and total profitability of all the crops planted on the same area. Coconuts have a synergistic effect, resulting in higher coconut yield in multiple cropping systems(Nampoothiri *et.al*,2018). The impact of intercropping on coconut yields has been studied as companion crops grow vigorously and deplete nutrients and soil moisture. Experiments revealed that the yields are not decreasing over time when management practices were appropriate for each crop (Gunasekaran *et.al*,2017). Increased nut yields are achieved under the introduction of companion crops over five years (Maheswarappa *et.al*,2005). The coconuts benefitted very likely from the additional fertilizers applied on the intercrops, in addition to spinoffs from weed management and cultivation, thereby increasing yield.

b) **Improving the income:** Multi-storey cropping system offers great potential for increasing the income of small and marginal farmers. Coconut when cultivated as monocrop offers the income only from coconut and its bye-products. The multi-storey cropping system help farmer to double the income from plantations. The additional income realized from the intercrops protects the farmers from price fluctuations of coconut and coconut products in the market.

c) **Sustainable and circular agriculture:** The move to multi-storey cropping is a move towards sustainable agriculture through recycling and reuse of plant wastes. The crop residues from different intercrops can be incorporated to improve the soil organic matter content. Multi-storey cropping system promote reuse and recycling of waste water among all crops, reduce dependence on external inputs, circulate the nutrients among the companion crops, regenerate the soil and minimize impact on the microenvironment.

d) **Improving the micro environment:** Coconut plantations with multi-storey cropping system tends to have improved soil organic matter

Priorities and emerging trends

The emerging trends in coconut cultivation specifically in the field of multi-storey cropping are the following.

New and exotic crops

Coconut based multi-storey cropping systems with crop combinations are being experimented. High value agricultural cops, cut flowers, exotic fruit crops are few crop combinations that are suited as companion crops in coconut based multi-strey cropping system.

Agri-based business

The integration of coconut based multi-cropping paves the way for starting of different Agri-start ups. Coconut plantations integrated with multiple farming systems including dairy, pisci-culture, bee keeping etc earn additional income to the farmers. The multispecies of crops aid in

Carbon sequestration

Coconut based multi-storey cropping system is also useful in carbon sequestration. Global warming attributed from the increasing levels of green house gases is causing adverse impact on agriculture. Sequestration of atmospheric carbon in the plant biomass and soil is one of the vital strategies to alleviate the climate change impact. Coconut plantations with prolonged lifespan offer substantial carbon sequestration potential. The high standing bio mass storage capacity of coconut plantations also add to the carbon sequestration potential. The coconut plantations with multi cropping systems have higher biomass storage capacity than the monocropped ones. The circular nuclear loops in coconut multi cropping systems also the biomass by way of recycling organic matter.

Conclusion

Coconut based multi-storey cropping has been practiced in small holdings, but the same need to popularized in large scale plantations with a perspective of food security, land productivity, crop diversification, resource utilization, economic viability etc. The conversion from monocropping to heterogenous multi cropping is advantageous as it avoids the environmental and social issues associated with monocropping. Multi-storey cropping systems based on coconut can cater to the sustainable goals. Research and development programmes orienting towards development of more cropping models including exotic and high value horticultural crops are the need of the hour. Coconut plantations with multi-storey cropping having immense potential in offsetting the carbon emissions are the future strategies for research programmes.

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35. Potential underutilized palms

B. Augustine Jerard* and S. Sumitha

* Project Coordinator, ICAR-AICRP on Palms, ICAR – Central Plantation Crops Research Institute, Kasaragod
*Email: jerardba@gmail.com

Introduction

Palms are monocotyledonous angiosperms that belong to Arecaceae family with 2500–2700 known species including six sub-families and 200 genera as reported by several workers. Their geographic distribution between 44° North and 44° South indicates that they mostly prefer tropical ecosystems with few exceptions. The highest palm diversity is reported from Asia and the Pacific region with 1385 species, followed by north and South America with about 1,147 species. Globally, palms are utilized for various products, including its seed oil, leaves for thatching houses, and cigarette wrappers; the fruits of some palms are edible, and some of them are known for their sap exudates. The medicinal uses of a few palms have been known to the tribal communities in different parts of the world.

Palms such as *Cocos nucifera* (Coconut palm), *Areca catechu* (Betel nut palm), *Elaeis guineensis* (African oil palm), *Phoenix dactylifera* (Date palm), *Borassus flabellifer* (Palmyra palm), *Nypa fruticans* (Nypa palm), *Caryta urens* (kitul palm), *Arenga pinnata* (Sugar palm), *Hyphaene* spp. (Real fan palm, Ivory palm), *Phoenix sylvestris* (Sugar date palm), *Corypha umbraculifera* (Talipot palm), *Raphia* spp.(Raffia palm, Wine palm, Bamboo palm)and *Bactris gasipaes*(Pejibaye-peach palm) are of great economic importance owing to their diversified uses both local consumption and industrial applications.

Palms of India are represented by 20 genera and about 96 species among which 24 species belonging to nine genera are endemic to India. The largest genus, *Calamus* with 44 species is followed by *Phoenix* seven, *Pinanga* five and the rest with less than five species each. The genera *Borassus, Salaca, Livistona, Nypa*, *Hyphaene* and *Ptychoraphis* are represented by a single species each. In addition, C. *nucifera* and A. *catechu* are extensively cultivated as plantation crops. They have almost naturalized in parts of Kerala and Andaman Nicobar Islands. Except *P. sylvestris*, *C. urens* and *B. Flabellifer* which are widespread in peninsular India, the rest are of restricted distribution in specialized eco geographical regions of the country. The forests of Andaman- Nicobar Islands (13 genera, 24 species), northeastern and eastern Himalayan region (12 genera, 36 species) and the Western Ghats (7 genera, 30 species) are major centres of palm concentration. *Nypa fruticans* and *Phoenix Paludosa* are fringe mangrove species occurring in salt marshes of Sundarbans and Andaman- Nicobar Islands. *P. Paludosa* is also found in Orissa. *Hyphaene dichotoma* is restricted to the sandy coastal belt from Goa to Saurashtra shores. Besides the utilized palms, most of our forest palms are experiencing severe threat to their existence, due to anthropogenic factors. (Kulkarni and Mulani, 2004). Most of the palm occurred in India are underexploited expect coconut and Date palm. This article covers certain underutilized palms, their potentiality for the exploitation, current status and strategies for conservation and utilization.

Palmyrah

Borassus flabellifer L. or palmyrah palm, belonging to the family Arecaceae is a widely adapted, tropical dioecious palm distributed along the coastal belts of India, northern Sri Lanka, Southeast Asia and eastern Indonesia (Davis and Johnson, 1987). The term *Borassus* is derived from a Greek word '*Borassos*' meaning ‘the membrane surrounding the date palm’ and ‘*flabellifer’* from the Latin word ‘*flabellatus*’ meaning ‘fan-bearer’. It can live more than 100 years reaching a height of 30 m. It is a robust tree of significant economic importance with almost all parts of the tree having multifaceted uses. Due to its multifarious uses, it is often quoted as wish-fulfilling tree (‘Karpaha’ in Tamil), or ‘celestial tree’. It is declared as the national tree of Cambodia, state tree of Tamil Nadu, India (Sankaralingam *et al*., 1999) and is an iconic symbol of the Palakkad district of Kerala, India. It is considered as an underutilized palm in Asia and Africa with characteristic pest and disease resistance, requiring very low or limited agronomic input.

Distribution and habitat

The natural occurrence of palmyrah palm is reported from Asian (India, Pakistan, Bangladesh, Sri Lanka, Malaysia, Thailand, Myanmar and Indonesia) and African countries

(Nigeria, Congo, Sudan and Tanzania) (Sankaralingam *et al.*, 1999). In India, this palm is disseminated across all agroecological regions (coastal belt, agricultural margins, waste lands and secondary forests) but mainly concentrated in Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, Maharashtra, Madhya Pradesh and Chhattisgarh (Bhaskar, 2017). It is drought tolerant in nature due to high chlorophyll stability index and relative water content (Arulraj and Jerard, 2008). India harbour nearly 102 million palmyrah palms and half of the trees are found in Tamil Nadu. In Tamil Nadu, the trees are concentrated in the southern districts of Thoothukudi (*10 million trees), Tirunelveli, Virudhunagar and Ramanathapuram (Ponnuswami *et al.*, 2008). It is a well-adapted palm species that can grow in arid zones (marginal rainfall of 500–900 mm), high altitudes (about 800 m above sea level) and could withstand extreme temperatures (0–45°C) (Arulraj and Jerard, 2008).

Dioecy in palmyrah

Palmyrah is a slow-growing perennial dioecious palm. The plant has a long juvenile stage and it takes 12–15 years to attain sexual maturity and start flowering (George *et al.*, 2008). Hence, farmers are hesitated in planting this multipurpose tree. Moreover, both male and female trees exhibit considerable variations in terms of yield and quality. Female palms yield more toddy on tapping (Davis and Johnson, 1987) and give better and hard timber than the male trees (Kalarani and Annathurai, 1991). Even though, both male and female trees produce spikes of flowers, females only bear fruits. The female flowers appear in densely clustered spikes which further transforms into large, brown coloured, round fruits (Vengaiah et al., 2017). The male flowers are smaller than the female flowers. Though palmyrah palms are mostly dioecious, a high- yielding monoecious palmyrah palm has been identified in Undeswarapuram, Andhra Pradesh (George *et al.*, 2008)

Multipurpose tree

Palmyrah is a multipurpose tree and is often stated as ‘tree with 800 uses’ with wide applications in food, beverage and fibre industries (Arulraj and Jerard, 2008). Every part of the tree has one or more uses. Palmyrah palm is a source of many raw materials for household articles, therebygenerating source for income and employment. They also serve to meet daily consumption needs of the local people (Chandrasiri, 1997). The main product is the sweet sap (neera), obtained from tapping the inflorescences. Neera is usually consumed as such or processed further into value-added natural products such as palm sugar and jaggery (unfermented) and toddy (the fermented product). Fermentation of fresh sap initially turns into palm wine and further into vinegar (Saidi *et al.,* 2018). Other wide array of nutritive and value-added products made from palmyrah include treacle (highly concentrated palm sap), flour (crushed and powdered young shoot), vinegar (fermented product), palm toffee, palm cola (aerated soft drink), palm pickle, etc. (Mani *et al.,* 2018). The mesocarp of the ripened fruits and the fleshy cotyledon of germinating nuts are other edible products obtained from palmyrah. The major uses of each part of the tree (Table 1) are described below.

Table 1. Commercial products prepared from different parts of *B. flabellifer*

Edible Products	
Sap-based Products (inflorescence)	(a) Non-fermented products: neera, jaggery, palm sugar, treacle, sugar candy (b) Fermented products: toddy, palm wine, arrack, vinegar, beer
Fruit-based products	Ice apple, mesocarp of ripened and roasted fruit for preparing delicacies
Pulp-based products	Cordials, jams, soft drinks, preserved pulp and confectionaries
Tuber-based products	Boiled tubers, boiled and ground flour for making confectionaries
Non edible products	
Timber-based products	For preparing beams and pillars for houses, used as rafters and building canoes, making walking sticks and windows grills
Leaf-based products	Storage and utility items such as container boxes, mats, toys, fancy items, cake trays, fancy cards, etc.
Fibre-based products	Making brushes, brooms

Advantages of cultivating Palmyrah palm

Palmyrah palms are drought tolerant since the chlorophyll stability Index and relative water content are higher when compared to coconut. They require less rainfall and care and hence they can be planted in *teri* lands, sandy plains, field bunds and on sides of rail tracks. Then palm can be used as wind break to prevent soil erosion and used as fire breaker in forest areas. Hence, Palmyrah is referred as tree of life with nearly 800 uses including food, beverage, fibre, fodder, medicinal and timber. The tree serves as a source of raw material for several cottage Industries.

Phoenix sylvestris Roxb

Phoenix sylvestris is commonly known as Indian date and is native to India and southern portions of Pakistan. It is traditionally important and known for its nutritional values throughout the world. It is a rich source of carbohydrate, phenols, amino acids, flavonoids, tannins, alkaloids, terpenoids, dietary fibers, essential vitamins and minerals. Different parts of the plant exhibit diverse medicinal properties such as being antipyretic, cardiotonic, laxative, diuretic and antioxidant. The synonyms of *P. sylvestris* are Date-sugar palm, Indian wild date, Indian wine palm, Silver date palm, Sugar date palm, and Sugar palm. The word Phoenix means purple, while '*sylvestris*' means wild. This palm produces edible fruits but it is generally called Wild date palm to distinguish it from the closely related *Phoenix dactylifera*, which is known as Date palm and is cultivated agriculturally as the commercial source of edible dates. The Silver date palm is very popular among landscapers because of its low maintenance and beautiful appearance.

Distribution

P. sylvestris, together with 13 other species, forms the genus Phoenix. All these species share similar morphological, anatomical and genetic characteristic with Date palm (*P. dactylifera L*.). *P. sylvestris* grows naturally and is cultivated around homesteads, farmland periphery and in marginal lands along the roadside and canals, even on fallow land. It can survive in disturbed areas, such as wastelands or seasonally inundated areas. *P. sylvestris* is widely distributed in India, Pakistan, Myanmar, Nepal, Bhutan, Bangladesh, Mauritius, China and Sri Lanka. In India, it is most commonly found in Rajasthan, Gujarat, Himachal Pradesh and Haryana states (Newton *et al.*, 2013).

Cultivation

P. sylvestris is mainly found in drier-to-moist tropical and subtropical climatic zones. This tree occurs at an altitude of 1500 m. It cultivates better in the temperature range 20- 40^{o} C. It requires a mean annual rainfall in the range 40- 70 cm for growth, but it can survive with a minimal rainfall. *P. sylvestris* grows in a wide range of soil types, preferably sandy, well drained and moist. It can grow in a pH range of 5.5- 7.5, and it can tolerate pH from 5 to 8. Fully matured *P. sylvestris* are known as a drought adaptor (Barrow, 1998).

Botanical description

P. sylvestris shares several characteristics with *P. dactylifera* (Date palm). It is a medium height tree of 9-50 m. It has a solitary, robust trunk. Leaves are 3- 4.5 m in length, greenish brown in color with thorns on the base, slightly curved, with 100- 120 sharply pointed at the end leaflets. Leaflets usually of 30- 45 cm long by 2.5- 5 cm wide and arranged in groups of 2 or 3, often criss-crossed. The leaf sheath is a reddish-brown, fibrous, pseudo petiole 40- 50 cm long and 3-5 cm wide at the base. Acanthophylls are yellow-green, very sharp, conduplicate and arranged in several planes on each side of the rachis. Staminate flowers are white-yellow, musty-scented, wherein the calyx is a deep cupule with three poorly defined lobes 2- 2.5 mm long. Usually the three or rarely four petals include obtuse apices, slightly hooded. Anthers are 3- 4 mm long; pistillate inflorescences are erect and changed arch-shaped on fruit maturation. The peduncle is green, upright and becoming golden-orange with arching on fruit maturation. Fruits are obovoid in shape 15- 25 mm long and 12 mm broad and change color from green to orange-yellow on ripening. Fruits contain a moderately fleshy and astringent mesocarp. Seed are 15- 20 mm long and 7- 10 mm wide with obovoid and rounded apices (Barrow, 1998; Robert and Paul, 2003).

Caryota urens L

Caryota urens L. is an underutilized palm belong to the family Arecaceae which is native to low land forests of tropical Asia including India, Malaysia and Indonesia. It is popular as Kithul, Jaggery, Treacle and Toddy (Fermented beverage) are produced from sap of the young inflorescence of *Caryota urens* in

Sri Lanka. In India, stem starch of *Caryota urens* represents a food source among some tribal peoples (Wimalasiria *et al.*, 2016). Inflorescence sap of *Caryota urens* and sap-based products possess health promoting properties, according to folkloric knowledge and are used in treatments in the ayurvedic medical system practiced in India. *Caryota urens*, commonly known as Fishtail palm or Indian Sago and locally as Sulphi in Bastar Plateau agro climatic zone of Chhattisgarh. Stem is strong and durable, used for building huts, agricultural implements, etc. the most important produce from this tree is sap extracted from the stem which is very famous as Bastar Bear in Bastar as well as whole Chhattisgarh. Fresh toddy from this tree is very nutritious and is recommended to tuberculosis patients by traditional healers in Bastar.

Toddy is extracted from the inflorescence, and is considered somewhat powerful compared to toddy extracted from few other palm trees. The heart of the trunk contains a starch similar to sago (sabudaana). Pulp of the fully grown-up plant is cut, sun dried, powdered and is edible with sweet in taste. The sap extracted from the inflorescence of the plant is used to make sugar and alcoholic beverages. Sap collected from the inflorescence is fermented with a crude, mixed inoculum of yeast to obtain toddy. This beverage can be distilled, as is coconut toddy, to prepare a more concentrated spirit in south India. The mature wood in the outer portion of the stem is strong, heavy and durable. Sap harvesting was revealed that tapping of the *Caryota urens* for sap production started from October and continued to mid-June for approximately 273 days in the winter season. In the 273 days, palm is tapped in every day morning and evening sap production. Palms aged 20-30 years growing in the field and in the axils produced the most sap. Sap harvesting timing sap is harvested 2 times in a day i e. morning and evening (Patel and Nema, 2021). The *Caryota urens* is among the most popular plants in tribal dominated area *i.e.* Bastar, it is one of the most important flora of the tribal society from the utility point of view in the form of fermented beverage, jaggery and as medicine too, it is also one of the preferred plant in the farmers field for livelihood and socio-economic point of view . Sulphi tree generates high income from less effort and less man power. Sulphi tree is worshipped in Bastar as religious tree and very popular among the tribal communities, in Gondi language, it is called as "Gorga" and "Akashpani". There is a need to initiate research programmes especially on the collection, conservation and utilization of genetic resources and also by product utilization. A peculiar disease of unknown etiology occurring in this region needs additional research efforts as the disease causes high economic loss to the tribal community in the region.

***Nypa fruticans* Wurmb**

Nypa palm *(Nypa fruticans* Wurmb., Arecaceae) is an important component of the East Asian mangrove vegetation. It is one of the oldest living palms. It grows along coastlines and estuarine habitats in the Indian and Pacific Ocean. It is a stem-less palm with tall erect fronds and underground rhizomatous stem possessing an extensive root system, well suited to resist swift running water. Its sap may be a prospective source for production of sugar, vinegar and alcohol. Nypa palm serves as the first line of defense against the impacts of tsunami, hurricanes, and cyclones that reduce the damages in the coastal zones.

Botanical description

Nypa is a monocious and pleonanthic palm; it also exhibits viviparous germination as in many other mangrove species. The leaves of Nypa palm can grow up to 10 m, and arise from a dichotomously branched underground rhizome that grows to about 50 cm in length. The species lacks a visible upright trunk, and the leaves appear from the ground. The younger leaves appear from the middle of the crown and push the older leaves aside before they dry and fade away, leaving bulbous leaf bases or scars behind. The diameter of the cluster could be up to 75 cm and a single leaf may attain a height of 8 m. The mature crown may contain 6 to 8 living leaves and 12 to 15 bulbous leaf bases at a time.

The total flowering period of *N. fruticans*is between 8.2–9.6 months, and divided into seven stages. In the third stage of its cycle, the female flower starts to form in a single spherical shape, yellow in color, and is found at the tip of the inflorescence trunk. At the same time, the male inflorescence is positioned below the female inflorescence. In the fifth stage (about two months old), young or unripe fruits start to grow and the fruits are oval in shape and lighter brown in color compared with ripe fruits, which area darker brown color. In total, fruits take 180 days to turn from young into ripe fruits (from the fifth to the sixth stage)

Uses of Nypa palm

Nypa palm is utilized by humans for several purposes, such as roof thatching, wall partitioning, making of sun hats and mats, foods like edible young seed, aromatic tea from leaf blade, sugar from xylem sap, medicinal purposes, bio-ethanol production, and remediation of heavy metal from polluted sites. Newly developed shoots are to be used as a vermicide. Ash from Nypa palm is used as an analgesic against tooth pain and headache. Dry leaves, petiole, stem wood, fruit residues etc. are used as fuel. In fishing rhizomes of Nypa palm are extensively used, facilitating the fishing net to float over the water surface. Farmers also report that Nypa palm in the river or sea attracts deep-water fish. The juice is used for making molasses and alcohol. The tapping of the palm for beverages such as wine or toddy and identify this as an ancient and traditional practice in Pan-Pacific and South and Southeast Asian countries. Nypa palm has a great potential for commercial use in housing and medicine in Bangladesh. It is using for housing and other important purposes. The long, pinnate leaves (fronds) provide material for thatching houses. In the Philippines, Malaysia, Indonesia and Thailand the fabrication of thatching panels, called locally 'shingles', 'pawid' or 'atap', is a significant local source of income. Leaflets and midribs are used for manufacturing of brooms, baskets, mats and sunhats. The white endosperm of immature seeds is sweet and jelly-like and is consumed as a snack. The cuticle of young, unfurled leaves has locally been used as cigarette wrapping.

Various parts of Nypa palm are a source of traditional medicines such as juice from young shoots is used against herpes, ash of burned Nypa palm material against toothache and headaches. Nypa palm material also use for salt extraction. The use of the hard shell (mesocarp) in the making of buttons, necklaces and other fashion apparels is successful in Nigeria. Nypa fronds are commonly used as sails by local fishermen. The sugary sap from the inflorescence stalk is used to make vinegar, and like those of other palms such as the coconut, its sap is also used to make a popular alcoholic beverage better known as “toddy” in Malaysia, India, and Bangladesh. The gelatinous endosperm from the young seeds is edible and can be eaten raw or preserved in ‘heavy syrup’ while the hardened ones from the ripened fruits are used as vegetable ivory and buttons. Parts of the palm like young shoots, decayed wood, and the burned roots and leaves are also used as traditional medicinal remedies for the treatment of headaches, toothaches, and herpes. Before the inflorescence blooms, it is tapped to collect a sweet sap. Young Nypa Palm shoots can be eaten. The petals of the flower can be brewed to make an aromatic tea. The immature fruits are white translucent and hard jelly-like. Called attap chee, they are a common ingredient in local desserts. In South-East Asia, there is a long tradition of using palm sap obtained by tapping the inflorescence stalks (peduncle) as a source of treacle (molasses), amorphous sugar ('gula malacca'), alcohol or vinegar. The slightly fermented sap called 'toddy' ('nera' in Indonesia and Malaysia; 'tuba' in the Philippines) is sold and consumed as local beer.

'Toko' *Livistona jenkinsiana* griff.

Livistona jenkinsiana Griff., variously known as Major Jenkins' fan palm or Assam fan palm or Himalayan fan palm, an endangered and multipurpose palm species, belongs to family Arecaceae and is native tothe Indo-Burma region. The palm is distributed across the tropical and subtropical regions of Bangladesh, China, India, Malaysia, Myanmar, and Thailand (Dowe, 2001; Payum, 2018). In India, the species, locally known as 'toko', is endemic to north-eastern India and grows abundantly in East Siang district of the state of Arunachal Pradesh. The district is spread over 3655 km^2 (27°30′–29°42′ N, 94°42′–95°35′ E). The tribal people of Arunachal Pradesh have been using this palm species over centuries and play a vital role in its conservation (Singh *et al.,* 2010).

The palm is a slow-growing, 15 m tall, with an unbranched trunk and a globose crown with fan-shaped leaves. The Inflorescence is axillary with reddish brown spathe and creamy white to yellow flowers. The fruitis a drupe, globose, 2.0–3.5 cm in diameter, copper blue when ripe. Seeds are globose, horny, apricot in colour, with a whitish endosperm (Kumar *et al.,* 2008; Patel *et al.,* 2010). *Livinstona jenkinsiana* has been categorized as an endangered and even threatened species (Dowe, 2001; Payum, 2018). It is a multipurpose species: its mature leaves are used for thatching; young leaves serve as a broom; the fibre is used in making hand-crafted art objects (Singh and Srivastava, 2010); and the fruit is edible, sold in the local markets in north-eastern India the rind is used for making chutney, and the seeds are used for propagation; Patel *et al.* (2010). The plant produces secondary metabolites such as phenols, flavonoids, and anthocyanins as part of its defence against pests and fungi, and these metabolites also confer many health benefits owing to their anti-allergic, anticarcinogenic, anti-inflammatory, anti proliferative, antiviral, cardio-protective and vaso-protective properties (Ganeshpurkar and Saluja, 2017; Bhargav *et al.,* 2018).

Mature leaves are used for thatching

***Hyphaene* spp.**

Worldwide 11 species of *Hyphaene* genus are distributed in the dry regions of continental Africa, Madagascar, the Red Sea region, and the coasts of the Gulf of Eilat, Arabia and western India. Species of *Hyphaene* commonly grow in sandy lowlands, open secondary forests and inland or coastal savannahs, although some species are also present in the riverine forest. Highly adapted to dry and xeric conditions, they grow from sea level up to 1400 m. *Hyphaene* provides essential resources for rural people ranging from construction materials to food, including wine, and to raw materials for thatching, handcrafts, medicines and livestock feed. The leaves of *H. compressa* are used in many economic needs of the nomadic pastoralist and agro-pastoralist communities in the northern and eastern regions of Kenya (Amwatta, 2004). The fruits of *Hyphaene* are regarded as a central author of nutrition during the remainder of the dry season when food is scarce throughout Africa, mainly in Djibouti, Sudan, Kenya, Nigeria and Namibia (Aboshora, 2014). *H. thebaica* is considered as an invasive palm in Curaçao, in the West Indies

(Delnatte, 2003). *Hyphaene dichotoma* (White) Furtado (Indian Doum Palm) is a near threatened palm categorized by IUCN in 2014. The species is distributed along the watercourses, coastal sand dunes and flat areas of Gujarat, Union territories of Dadra, Diu and Daman, Goa and Maharashtra and some parts of Sri-Lanka. Indian Doum Palm is also maintained in the Indian Botanical Garden, Calcutta. Blatter in 1926, published a plate of an Indian Doum palm growing at Bassein, north of Mumbai. Kiran and Das (2010) reported *Hyphaene dichotoma* in Andhra Pradesh. Along the Coromandel coast of India, the fruits are edible and eaten locally. The leaves are also used for making hats, mats, bags and baskets and the seeds are made into buttons and beads.

Corypha umbraculifera L

Corypha umbraculifera L., is a tropical monocarpic palm, commonly known as Talipot palm belonging to the family Arecaceae which inhabits in moist climate and is native to semi-wild coastal plains of south western India, Sri Lanka, Malaysia, and Myanmar. The palm is tali in Bengali, Kannada and Marathi. In Bengali it is also called 'bajarbatur'. It is 'kodapana' in Malayalam and 'kudaipanai' in Tamil; both mean 'umbrella palm'. The Telugu name is 'shritalam'. The tali palm is not to be mistaken for the palmyra, *Borassus flabellifer* which too shares the local name'tali'. It is one of the three sago palms, which is considered as the promising palm for future. It is a multipurpose palm with a great utility which produces commercial and subsistence products from its stem, leaf, and seed. The sap and stem from the Talipot palm are the two major portions which are widely utilized. A Talipot palm yields two liters of sap per day for 3–4 months, which is used to produce products like alcohol, wine, vinegar, and sugar. The pith of the mature Talipot palm is a storage house of abundant amount of light brownish colored starch. About 100–250 kg of edible starch can be procured from the stem of a fully matured palm before its fruiting and flowering. The yield of starch thus found to be 76% which is similar to starch from other non-conventional sources such as babassu, breadfruit and turmeric. The Talipot palm four and starch have a low amount of protein and lipid content. In India, the Talipot palm starch once served as a genuine source of carbohydrate to the tribes in the tropical region in famine-prone areas and was locally eaten as their staple food in the form of gruel and bread and performed as their source of supplement nutrition.

Conclusion

Underutilized palms such as Nypa palm (*Nypa fruticans*), kitul palm (*Caryota urens*), palmyra palm (*Borassus flabellifer*), wild date palm (*Phoenix sylvestris*) and toko (*Livistona jenkinsiana*) are mostly highly ornamental as well as are dependable candidates for its products. The local communities which are already involved in harvesting various products from these palms must be encouraged in conserving the palms through their traditional communal strategies. The local government must take active measures in large scale planting of these palm species thereby promoting the traditional tapping workers. Phytochemical studies will lead to the scientific evaluation of the palm products and a hike in its pharmacological value. The development of value-added products from the palm wine can enhance its economic value and can raise the income of the workers involved in the palm establishment and harvesting. Seed physiological studies in these palm species will lead to the discovery of the ideal conditions for large scale seedling establishment which in turn lead to conservation of these valuable palms.

36. Exploitation of genetic diversity of indigenous underutilized horticultural crops of North-east India

T. K. Hazarika
Professor, Dept. of Horticulture, Aromatic and Medicinal Plants, School of earth Sciences and natural Resources management, Mizoram University, Aizawl, Mizoram
Email: tridip28@gmail.com

Introduction

The North-east region represents eight states namely Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Tripura, Nagaland and Sikkim consisting 7.79% of the Indian national geographical area. The altitude difference (50m-7000m) coupled with varied physio- geographic and agro-climatic conditions; varying intensity of rainfall (800-12000 mm) and topography harbour various vegetation types of tropical, temperate and alpines zones. In India, there are about 800 plant species used as food plants chiefly by the tribal population (Singh and Arora, 1978). Out of these about 300 species are prevalent in the northeastern region (Singh *et al.* 1983).

Being one of the hot spots of the biological diversity and because of diversities in topography, altitude, soil and climate, large extent of variability of indigenous underutilized horticultural crops exists in this region with variation in plant type, morphological and physiological characteristics, reactions to diseases and pests, adaptability and distribution. These indigenous underutilized horticultural resources are known to play an important role in food and nutritional supplement of human beings from time immemorial. These crops are hardy in nature, easy to grow and generate additional income to the farmers. Most of them are used in day to day diets of tribal people of the region and are often sold in the local markets. They are also used as life sustaining diversified food bases and for nutrient security of rural people throughout the year. These indigenous underutilized horticultural resources have the ability to grow under stressed and adverse conditions. They have outstanding adaptation capabilities like drought tolerance, salt tolerance and are also resistant to major pests and diseases. A few of them have excellent flavour, juiciness and have very attractive appearance. Many of these species are used as traditional medicinal plants and a few have found important place in the Indian system of medicine since time immemorial. These indigenous underutilized horticultural resources play a major role in the socio-economy of the inhabitants of the areas where they occur to support income and nutrition.

Diversity of indigenous underutilized fruits in Northeast India

The region is also considered as original home of citrus species. As many as 17 Citrus species, their 52 cultivars and 7 probable natural hybrids are reported to have originated in the North-eastern region of India. Besides two commercial species viz. Khasi mandarin (*C. reticulata*) and Assam lemon (*C. limon*), the indigenous citrus species found in the region includes Citron (*Citrus medica*), Ada Jamir (*Citrus assamensis*), Pummelo (*Citrus grandis*), rongpur lime (*Citrus aurantifloia*), hatkara (*Citrus macroptera*), gol nemu (*Citrus jambhiri*), and bor tenga (*Citrus megaloxycarpa*). Presence of three wild types of sweet orange (*C. sinensis*) viz. Soh bitara, Soh nairiang and Tasi in Meghalaya and Arunachal Pradesh provided a strong evidence that most of the *Citrus* species originated in this region. The Indian wild orange, *C. indica*, is found in garo hills of Meghalaya and Arunachal Pradesh.

The north-eastern region of India is major hotspots of banana diversity. In addition to numerous cultivated triploids, *Musa acuminata* and *M. bulbisiana* diploids are found in semi wild state in this region. *M. flaviflora* is localized to Manipur and Meghalaya. Seeded Ladiarit and Ladison, Rigitchi and other elite types, Hatigola, Eboke, Ginde, Egitchi and Essing are some of the local landraces from Meghalaya. Bhimkal, Athiakal, Bhog manuhar, Honda, Malbhog, Cheni Champa, Champa, Saker Champa, Amrit Sagar, Agnisagar, Jahaji, Bor Jahaji, Kabuli Jahaji, Digjoa, Kachkal, Jatikal *etc.* are some other species found Assam. Each of these having own appearance, taste, flavour and unique organolaptic qualities.

Jackfruit is common in Tripura, Meghalaya and Assam with large number of cultivars. Both the cultivated (*Artocarpus heterophyllus*) and wild (*Artocarpus chaplasha*) type of jackfruit are available in the region. Soh-Shang (*Elaeagnus latifolia*) is one of the important underutilized fruit crops widely distributed in Northeast India. Two species of *Elaegnus*, viz., *E. latifolia* and *E. pyriformis* are known to be grown in NE region. It is quite common in Sibsagar (Dikho valley), Naga Hills, Khasi and Jaintia hills. Wide variability is observed in this fruit. The fruits are rich in bioactive compounds and fairly rich in essential fatty acids. *Docynia indica* and *D. hookeriana* are commonly found in the region. *Pyrus pashia*, a medium sized deciduous fruit tree is also found in NE region. Khasi hills particularly harbour genetic variability for several temperate fruits such as *Malus spp*, *Pyrus spp*, *Prunus persica*, *Rubua spp*., *Castanea sativa* etc. (Sharma et al., 2005). *Prunus napaulensis* (Ser.) Steud., *P. undulata* Buch.-Ham ex. D. Don and *P. cerasoides* C. Don., while *Pyrus pyrifolia* Nakai var. cubha makai (*P. serotina* Rehdar) is grown semi commercially. Wild kiwi (*Actindia callosa* and *A. stragosa*) is found in the natural forests of Arunachal Pradesh and Sikkim.

A number of indigenous fruits *viz.* custard apple (*Anona squamosa*), wood apple (*Aegel marmelos*), carambola (*Averrhoea carambola*), sapida (*Baccaurea sapida*), indian star apple (*Chrysophyllum roxburghii*), elephant apple (*Dillinia indica*), amla (*Emblica officinalis*), bon mirika (*Embelia nutans*), black plum (*Eugenia jambolona*), rose apple (*Eugenia jambos*), olive (*Elacocarpus floribundus*), flacourtia (*Flacourtia gangomus*), mulbery (*Morus accidosa*), thereju (*Prunus jenkinsii*) are grown in the region.

Table 1. Underutilized fruit crops of Northeast region

Scientific name	Common/ local name	Family	Distribution
Actinidia strigosa	Wild kiwi	Actinidaceae	Sikkim
A. callosa	Wild kiwi	Actinidaceae	Arunachal Pradesh
Baccaurea sapida (Roxb.)	Leteku	Euphorbiaceae	Sikkim, Meghalaya, Assam, A.P., Tripura
Averrhoea carambola L	Carambola (Star fruit)	Oxalidaceae	Meghalaya, Assam
Docynia indica, D. hookeriana (Eriolobus indica Schn.)	Indian crab apple	Rosaceae	Khasi hill (Meghalaya), Sikkim
Emblica officinalis	Aonla	Euphorbiaceae	All NE States
Elaeagnus latifolia Linn. E. pyrifolia	Soh-shang (Khasi)	Elaeagnaceae	North east frontier tracts, lower Assam Meghalaya

Garcinia lanceaefolia	Thekera tenga (Assamese)	Clusiaceae	Meghalaya, Mizoram, Nagaland, (Assamese) Assam
Myrica esculenta M. nagi	Soh-phie (Khasi)	Myricaceae	All north eastern hill region
Myrica fraquhariana	Soh-phie (Khasi)	Myricaceae	Sibsagar (Dikho valley Assam), Naga hills, Khasi & Jaintia hill (Meghalaya)
Passiflora edulis P. edulis var. flavicarpa	Passion fruit (Soh-rub)	Passifloraceae	Meghalaya, Mizoram, Manipur, Nagaland, Sikkim
Pyrus pashia	Soh-shur (Khasi)	Rosaceae	Khasi & Jaintia hills (Meghalaya)
Prunus nepalensis	Soh-iong (Khasi)	Rosaceae	Khasi and Jaintia hills (Meghalaya)
Dillenia indica	Outenga (Assamese)	Dilleniaceae	Meghalaya, Assam
Machilus edulis King. Syn. Percea *fructifera Kost*	Pumsi (Sikkim)	Lauraceae	Sikkim, A.P. and other NE Region

(Deka *et al*., 2012

Diversity of indigenous vegetables in North East India

North-eastern region is the centre of origin of a number of vegetables viz., brinjal, cucumber, radish, taro, yam, and cowpea. This region is rich in diversity for many other vegetables especially cucurbits namely bottle gourd, pumpkin, ash gourd, sweet gourd, spine gourd, chayote, pointed gourd, tuber crops namely taro, swamp taro, greater and lesser yams, elephant foot yams etc; solanaceous vegetables viz., chilli and brinjal; leguminous namely hyacinth bean, velvet bean; leafy vegetable like amaranthus and bulbous crops onion and garlic.

Solanaceous vegetables

There is wide range of *Solanum spp*. found in north east India. This region is one of the important centre for brinjal and other solanaceous germplasm with variability in plant characters, fruit shape, size and colour. Many of the indigenous genotypes are totally resistant to wilt disease. Some of the common genotypes cultivated are brinjal (*Solanum melongena*), Turkey berry (*Solanum torvum*), poison berry (*Solanum indicum*), bitter brinjal (*Solanum gilo*), African eggplant (*Solanum macrocarpon*), thorny nightshade (*Solanum xanthcarpum*), kotahi begena (*Solanum khasianum*), spiral nightshade (*Solanum spirale*), sticky nightshade (*Solanum sisymbrifolium*), bhekuri (*Solanum kurzii*) and scarlet eggplant (*Solanum aethiopicum*) etc. *Solanum khasianum* and *S. torvum* are important species of medicinal value (solasodine content) and extensively used in the Ayurvedic medicine. These species have also been found to possess resistance to shoot and fruit borer, and root diseases respectively (Kalloo et al., 2005). Some of the local varieties and landraces namely Singhnath, Bholanath, Laffa and RCMBL2 are commercially important. Chillies are known to grow well in the warm to hot and humid climate of Manipur, Mizoram, Nagaland, and Tripura. Due to the long history of cultivation, out-crossing, and popularity of the crop, large genetic diversity has evolved in the form of a number of local landraces, with great variability for fruit shape, size, colour, bearing habit and pungency. Various species diversities of chilli found in NEH region are, common hot pepper (*C. annum*), bird pepper (*C. annum* L. var. avicular), sweet pepper (*C. annum* var. grossum), Indonesian red chilli (*C. annum* var. *longum*), Habanero type pepper/ Bhut Jolokia/king chilli/ Naga chilli (*C. chinense*), purple-flowered capsicums (*C. eximium*), tobacco pepper/bird chilli (*C. frutescens*) and bird eye chilli (*C. minimum*). Apart from species diversity, there is a wide range of intra specific diversity in *C. annum*, *C chinensis*, *C. minimum* and *C. frutescens* found in different states in NEH region. In Manipur, six different indigenous chilli cultivar belonging to three species of Capsicum: *Capsicum annuum* L. (cvs'Meiteimorok' and 'Haomorok'), *Capsicum lutescens* L. (cvs 'Uchithi' and'Mashingkha') and *Capsicum chinense* Jacq. (cvs 'Umorok' and 'Chiengpi') form important food crops of the region (Sanatombi et al., 2008). *C. minimum* Syn. *C. fastigiatum* (Bird-eye-chilli), it is cultivated all across the NE region on a very limited (Sanwal et al., 2007). Germplasm of wild species of tomato *L. pimpinellifolium*, has been found in NE region. *Lycopersicon pimpinellifolium*, naturalized to this region, has also expressed resistance to late blight and tomato leaf curl virus (Seshadri and Srivastava, 2002).

Table 2 : *Solanum* species in North East India

Cultivates species	Remarks
Solanum macrocarpon L.	Introduced in NE region
Solanum xanthcarpum Schard & Wendl	Used as vegetable and medicinal purpose
Solanum indicum L.	Domesticated, used as vegetable and medicine
Solanum mammosum L.	Possibly introduced, ornamental with high solasodine percentage
Solanum khasianum Clarke	Wild and cultivated for solasodine alkaloid
Solanum torvum Swartz. Wild,	sold in the market in Mizoram
Solanum berbisetum Nees	Ripe fruits are eaten
Solanum ferox L.	leaves are used medicinally
Solanum spirale Roxb.	Wild but domesticated for medicinal use in Arunahcal Pradesh
Solanum sisymbrifolium Lam.	Native of Africa, wildly grown in Meghalaya
Solanum kurzii Br.	Endemic in Garo hills, Meghalaya
Solanum gilo Raddi.	Introduced in NE region as vegetable

(Asati and Yadav, 2004)

Cucurbitaceous vegetables

There are many local genotypes of various cucurbitaceous vegetable crops in the region. North East region is part of the primary centre of diversity for cucumber (*Cucumis sativus*). In addition, wild relatives of several cucurbits have also been reported from the region with significant genetic variability, such as *Cucumis hardwickii*, *C. sativus* var. *sativus* is cultivated in north-eastern region in tropical and subtropical conditions. Among gourds, in north-eastern region maximum variability has been recorded for bottle gourd in fruit shape and size. Bottle gourd and pumpkin tender shoots of 90-150 cm length are very popular as vegetables. Soft young leaves are consumed as leafy vegetables, or mashed after boiling into paste with chilly and onion-garlic, or even used in preparation of dry fish or fish pieces after wrapping with these leaves. Male flowers are deep fried with corn flour/rice floor/besan coating. Local types of bottle gourd, ash gourd and pumpkin especially grown in 'Jhum' areas are very much popular as vegetables. The NE region has rich diversity in genetic resources of ridge gourd (*L. acutangula*) and sponge gourd (*L. cylindrica*). Small as well as large sized forms of bitter gourd are also available. Cho-Cho (*Sechium edule*), a native of tropical America, is a very popular vegetable in the region commonly called squash and grows abundantly without much care and attention (Asati and Yadav, 2004). Various species are, cucumber, ridge/sponge gourds, spine gourd (*Momordica dioica*), sweet gourd (*Momordica chochinsinensis*), pointed gourd (*Trichosanthers dioca*) and tinda (*Praecitrullus fistulous*) etc. are very much indigenous to NEH region. However, many other cucurbitaceous crops namely ash gourd (*Benincasa hispida*), snake gourd (*Trichosanthes anguina*), spong gourd/dhundhul (*Luffa cylindrica*), Rakhalsasha/ Kundari (*Melothria heterophylla*), Jangli karela/wild bitter gourd (*Momordica charantia* var. municata), ribbed melon (*Hodgsonia macrocarpa*), ivy gourd (*Coccinia grandis*), Kachri (*Cucumis callosus*). There are several minor/ underutilized cucurbitaceous vegetables, which includes *Cucumis hystrix*, *Cucumis trigonus*, *Luffa graveolens*, *Momordica macrophylla*, *Momordica subangulata*, *Trichosanthes cucumerina, Trichosanthes khasiana, Trichosanthes ovata* and *Trichosanthes truncasa*. Several lesser known cucurbitaceous crops like *Cylanthera pedata, Luffa acutangula, L. cylindrical, Cucumis hystrix, Luffa graveolens, Momordica macrophylla, Momordica subangulata, Trichosanthes cucumerina*, *M. cochinchinesis*, *M. Dioica, Sechiumedule* etc. are grown as indigenous vegetables

Table 3: Diversities of cucurbits in North East India

Cultivates species	Area of concentration for diversities	Range of diversities
Cucurbita maxima	Throughout the NE region	Extensive
Cucurbita moschata	Hilly areas	Moderate
Cucurbita ficifolia	Meghalaya	Introduced, neutralized
Cucurbita pepo	Meghalaya, Mizoram	Limited
Coccinia grandis	Assam, West Bengal	Limited
Cucumis sativus	Throughout the country	Wide
Cucumis callosus	Foothill areas of Assam	Confined to limited pockets
Luffa acutangula	Tropical areas of Assam	Wide
Luffa cylindrica	Tropical and subtropical areas of Assam, Meghalaya, Manipur, West Bengal	Moderate
Momordica charantia	Throughout the NE region	Moderate
Momordica Cochinchinensis	Assam, Meghalaya, Manipur, West Bengal	Limited
Momordica dioca	Garo Hills	Rare
Trichosanthus anguina	Meghalaya, Tripura, Assam, West Bengal	Limited
Trichosanthus dioca	Tropical areas of Assam, Tripura	Limited

Cylanthera pedata	Hills of Meghalaya, Manipur, Nagaland and Arunachal Pradesh	Moderate
Benincasa hispida	Assam, Nagaland, Meghalaya	Wide
Lagenaria siceraria	Throughout the NE region	Wide
Sechium edule	High hills of Meghalaya, Manipur, Mizoram, Nagaland, Sikkim and Darjeeling of West Bengal	Moderate

(Asati and Yadav, 2004)

Leguminous crops

This region may be called centre for secondary diversity for various leguminous crops which are consumed as ethnic foods by the tribal as well as non-tribal communities of NEH region. Out of these pea (*Pisum sativum*), cowpea (*Vigna unguiculata*), winged bean (*Psophocarpus tetragonolobus*), Indian bean (*Dolichos lablabs*), jack bean (*Cannavalia ensiformis*), mucuna bean (*Mucuna pruriens*), cluster bean (*Cyamosiste tragonoloba*), etc. are important. The other beans include tree bean (*Parkiarox burghaii*), sword bean (*Cannavalia gladiata*) and broad bean (*Vicia faba*). Higher polymorphism has also been recorded in local landraces. Additionally, *Vigna radiata* var. sublobata is known for yellow mosaic virus resistance, whereas *V. umbellata* var. *radiata* is known for resistance to diseases and insect pests. Broad bean (*Vicia faba*), it is a cool season crop in high altitude areas, grown on a limited extent in the north eastern region. Tree bean [*Parkia roxburghii* (G.) Don.], locally known as Yonkchak, is a medium-large tree which may attain upto 30 m height with spreading branches. Flowers, tender pods and seeds are consumed as vegetable. It is one of the most common of multipurpose tree species in Manipur and Mizoram (Kumar et al., 2002). Hyacinth bean(*Lablab purpureus*), there is a vast diversity in hyacinth bean in the region in terms of stem colour, flower colour, leaf shape, pod colour, shape, seed shape and colour etc. Sword bean (*Canavalia gladiate*) and Jack bean (*Canavalia ensiformis*) has white seeded varieties (bushy in nature) and red seeded varieties (trailing type). Jack bean is cultivated on a limited scale (CSIR, 1950), tender pods and soft seeds are consumed as vegetable, though it has anti-nutritional properties. Winged bean (*Psophocarpus tetragonolobus*) is also consumed by ethnic communities. It is confined to the humid subtropical parts (Sarma, 2001). There is a wide diversity in cow peas (*Vigna unguiculata*), yard long bean (*Vigna unguiculata* sub sp sesquipedalis), vegetable French bean, kidney bean (*Phaseolus vulgaris*), Yam bean (*Pachyrrhizus erosus*) and Velvet bean (*Mucuna pruriens*).

The region is known for several wild forms and high variability in rice bean (*Vigna umbellata*), with profuse branching types reported from Mizoram and Manipur; higher seeds per pod from Mizoram; higher number of pods per peduncle, bold seeds and high grain yield from Manipur; higher polymorphism has also been recorded in local landraces for seed color. Landraces with a rare uniform light green colour occur in the Mao hills. In French bean, climbing or pole type is popular among the tribals, since it is used for mixed cropping with maize, which acts as the support. *Atylosia geonsis*, *Atylosia scaraboides, Canavalia gladiata, Mucuma monosperma, Mucuma nivea, Mucuma utilis, Dolichus bifflorus, Bauhinia purpurea, Vigna vexillata* etc. are the other legumes species of north-east region.

Tuber and rhizomatous crops

There is rich diversity in various type of tuber crops which are very much popular as ethnic food as well as ethno-medicinal purposes. Based on the colour and the skin two broad types of sweet potato are grown in the region. These are the white skinned and the red skinned types. Yams have their center of origin in this region, however, there are varieties of indigenous tuber crops in NEH region. A number of *Dioscorea* species like *alata, bulbifera, brevipetiolata, esculenta, hamiltonii, hispida, kamaonensis, nummularia, pentaphylla, puber and quinata* are grown in NE region. *D. hamiltonii* occurs in humid forests of NE hills (Sarma, 2001). In colocasia also there is a wide variability even within one species such as *Colocasia esculenta Eleocharis dulcis* (kakthum), *Sagittoria sagithefolia* (kaukha), *Flemingia vestita* (sohphlang), *Trapa bispinosa* (heikak) are the potential species of Manipur.

Table 4. Tubers and rhizomatous crops of north-east India

Crop name	Scientific name	Edible parts used
Elephant foot yam	*Amorphophallus paeoniifolius* (Dennst.)	Tuber and petiole
Wild elephant foot yam	*Amorphophallus bulbifer* (Roxb.) Blume., *A. sylvaticus* (Roxb.) Kunrth. and *A. muelleri* Blume	Immature bud sprouts, petiole and tuber
Greater yam	*Dioscorea alata* L.	Tuber
Lesser yam	*D. esculenta* (Lour.) Burkill	Tuber
Aerial yam	*D. bulbifera* L.	Tuber and aerial bulbils
Mountain yam	*D. hamiltonii* Hook. F.	Tuber
Five leaf yam	*D. pentaphylla* L.	Tuber
Chinese yams	*D. oppositifolia* L.	Tuber
Cassava	*Manihot esculenta* L.	Tuber
Taro: Eddoe type (Taro)	*Colocasia esculenta* var. *antiquorum* Schott	Rhizomes, petiole and leaves
Taro: Dasheen type (Bunda)	*C. esculenta* var. *esculenta* (L.) Schott	Rhizomes, petiole and leaves
Taro (Semi wild green petiole)	*C. esculenta* (L.) Schott	Petiole, leaves, stolon and Rhizome
Taro (Semi wild red petiole)	*C. esculenta* (L.) Schott	Petiole, leaves and stolon
Sweet potato	*Ipomoea batatas* (L.) Lam.	Tubers
Swamp Taro: Green petiole	*Colocasia esculenta* var. *stolonifera* L. Schott	Rhizome, petiole and stolon
Swamp Taro: Red petiole	*C. esculenta var. stolonifera L. Schott*	Rhizome, petiole and stolon
Swamp Taro: Purple petiole	*C. esculenta var. stolonifera* (L.) Schott	Rhizome, petiole and stolon
Swamp Taro: Semi wild type	*C esculenta var. stolonifera* (L.) Schott	Small rhizomes, petiole, leaves and stolon

Elephant Ear taro/Giant rooted taro	*Alocasia macrorrhiza* (L.) G. Don	Giant rhizome
Giant arum.	*Steudnera colocasioides* Hook. f	Giant rhizome
Bengal arum	*Typhonium trilobatum* (L.) Schott	Tender leaves and stems
Tannia: Blue/purple petiole	*Xanthosoma violaceum* (L.) Schott	Petioles
Tannia: Green petiole	*X. violaceum* (L.) Schott	Petioles
Tannia: Errow leaf elephant's ear	*X. sagittifolium* (L.) Schott	Rhizome and petiole

(Das *et al*. 2020)

Zingiberaceous crops

Out of 19 genera and 88 species of zingiberaceae available in NE India, 42 species have been reported from Manipur alone. There are few zinger varieties such as *Zingiber cassumar* and *Zingiber zerumbet* which are used in indigenous folk medicines (Talukdar, 2009). *Curcuma caesia* (Black zedoary), *Curcuma angustifolia* (East Indian arrowroot), *Heychium coronarium*; (Common ginger lily), *Hedychium spicatum*; (Spiked ginger lily) are the crops wild species of Manipur which have great potential. *Hedychiums* of the family Zingiberaceae which have edible underground rhizomes and the following are rare and threatened ornamental species of this group: *Hedychium luteum*, *H. aureum*, *H. radiatum*, *H. robustum*, *H. dekianum*.

Leafy vegetables

The important leafy vegetables of north east India include lai (*Brassica juncea*), lafa (*Malva verticillata*), palak (*Spinacea oleracea*), amaranth (*Amaranthus spp*), puroi sag (*Basella rubra* and *B. alba*), sorrel (*Rumex rasicarius*), etc. Other indigenous leafy vegetables used occasionally are jilmil sag (*Chenopodium album*) and Kalmou sag (*Ipomea reptans*). *Amaranthus viridis, A. lividus, A. retroflexus* and *A. spinosus* are important leafy types grown in north east India (Sarma, 2001).

Spices and condiments

The region is known for variability in different spices. Turmeric (*Curcuma longa*) is indigenous to this region with wide range of diversity among which Lakadong and Megha Turmeric 1 (earlier known as RCT-1) are commercially popular. Singhat the local cultivar, used for clonal selection of improved variety Suvarna, a highly oil content turmeric variety, which is widely grown in Manipur (Kumar et al., 2003). Variability is there in ginger also. Nadia is one popular cultivar of ginger in this region. Ginger cultivars such as Manipur No. 1, Basar, Tura local, Thingpui, Meghalaya Local, Thinglaidum, Kachai Ginger and Nagaland local are some of the popular one. Other species viz., Bayleaf/ tejpat (*Cinnamomum tamala* T.Nees & Eberm.), Bengal cardamom (*Amomum aromaticum* Roxb.), camphor tree [*Cinnamomum glanduliferum* (Wall.)Meisn., *C. pauciflorum* Nees], snap ginger [*Alpinia calcarata* (Roscoe) Merrill, *A. malaccensis* (Burm. f.) Roscoe], kaempferia (*Kaempferia galangal* L.), black pepper (*Piper nigrum* L.), long pepper (*Piper longum* L.), *Piper peepuloides* Roxb., etc. are also found in the region.

Flower crops

The commercial crops like rose, anthurium, lilium, and gerbera are introduced and commercially cultivated in open and protected cultivation. Orchids are very popular and north-east is known for its rich diversity.

Orchids, believed to have evolved in this region, form a very noticeable feature of the vegetation here. Out of about 1331 species of orchids, belonging to 186 genera reported from India; North-east India sustains the highest number with about 856 species. Amongst them, 34 species of orchids are identified among the threatened plants of India and as many as endemic to different states of this region. Out of the eight orchid habitat regions in India, the two most important areas namely; the Eastern Himalayas and the north eastern region fall within the political boundaries of north-eastern region. Epiphytic orchids are common in north-eastern India which grows up to an elevation of 2,000 mmsl. Some of valuable Indian orchids from this region includes: *Aerides multiflorum, Aerides odoratum, Arundina graminifolia, Arachnis, Bulbophyllum, Calanthe masuca, Coelogyne elata, C. flavida C. corymbosa; Cymbidium aloifolium, C. lowianum, C. devonianum, C. hookerianum, C. lancifolium, Dendrobium aphyllum, D. nobile, D. chrysanthum, D. farmeri, D. chrysanthum, D. densiflorum, D. moschatum, D. fimbriatum, D. jenkinsii, Paphiopedilum venustum, P. spicerianum, P. hirsutissimum, P. insigne, Phaius wallichii, Pleione praecox*, *Renanthera imschootiana*, *Rhyncostylis retusa*, *Thunia alba*, *Vanda cristata*, *Vanda coerulea* and *Vanda coerulescens*.

Table 5. Genetic resources of Orchids in NEH Region

State	Genera	Species
Arunachal Pradesh	133	614
Assam	75	195
Manipur	66	207
Meghalaya	73	230
Mizoram	104	374
Nagaland	74	249
Sikkim	122	520
Tripura	34	52

(NRC on Orchids, ICAR, Sikkim, 2010)

Medicinal plants

The tribal communities in north-east India are well aware of the wild plants having medicinal values. The tribal people are using these plants for treating various ailments. Meghalaya is endowed with 850 medicinal plants, of which 377 species are used by majority of people for their primary health care needs. Sikkim has vast reserve of medicinal plants and rich culture of folk medicine. The rich flora of Sikkim has a number of raw drugs described in Ayurvedic texts. There are about 420 plants are used by the tribal people for various diseases in Sikkim Himalayas region, out of which few are in utilized on commercial basis. The rural people of Assam also consume many herbs as nutritional diet used in Indian system of medicine viz. *Bacopa monnieri* (L.) Penn., *Centella asiatica* (L), *Dioscorea bulbifera* Linn., *Emblica officinalis* Gaertn, *Eryngium foetidum* Linn., *Terminalia chebula* Retz., *Zanthoxylum alatum* Roxb., *Mentha spicata* Linn., *Ocimum sanctum* Linn., *Terminalia bellirica* (Gaertn.) Roxb., *Paederia foetida* Linn., *Euryale ferox* Salisb., *Solanum nigrum* Linn., *Piper longum* Linn., *Garcinia cowa* Roxb. Ex D.C., *Garcinia Morella* (Gaertn.) Desr., *Garcinia pedunculata* Roxb., *Dillenia indica* Linn., *Calamus* *rotang* Linn., *Parkia roxburghii* G. Don., *Alpinia allughas* Rosc., *Clerodendrum glandulosum* Lindl., etc. About 900 species of medicinal herbs and plants are known to exist in abundance in the forest area of the state with the Brahmaputra valley itself having 50 species of herbs and plants of commercial value.

Conclusion

The north-eastern region is gifted with wide range of diversity of indigenous underutilized horticultural crops. Although the region has great potentiality for commercial exploitation of indigenous underutilized horticultural crops for enhancing the nutritional and livelihood security, but, due to a number of threats like habit destruction, rapid pace of urbanization, over exploitation from ecosystem, declining soil health, climate dynamics, have greatly affected the growth of the indigenous underutilized horticultural crops of north-eastern region.

To safeguard the existing diversity of indigenous crops, systematic exploitation, collection, characterization, multiplication, and conservation are urgently needed to ensure food and nutritional security of rural population and to achieve sustainable development of NE region of India. E*x situ* and *in situ* conservation of rare and endangered species should urgently be undertaken to ensure safe storage of germplasm for dynamic conservation and sustainable use of genetic resources of all available germplasm. On farm conservation constitutes well recognized scientific alternative that ensures dynamic conservation and sustainable use of available genetic resources.

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37. Beekeeping in northeast region of India

Naveen Kumar Patle[1] and Meribeni Shitiri[2]
[1]Additional Commissioner (Hort.) and Executive Director (National Bee Board)
Department of Agriculture & Farmers Welfare, Ministry of Agriculture & Farmers Welfare
Krishi Bhawan, New Delhi.
[2]Horticulture Specialist, CIH, Medziphema, Nagaland

Introduction

Apiculture, also known as beekeeping, plays a pivotal role in the sustainable development of agriculture, serving as the fifth crucial element for the agricultural development. Furthermore, it stands as the fifth essential input for enhancing yields and ensuring the quality of production in cross-pollinated agricultural and horticultural crops. The Northeast of India boasts abundant floral resources, diverse plant life, and an exceptionally favourable climate for honey production. However, the region has yet to unlock its potential as a 'honey capital' in the country, primarily due to a lack of awareness, insufficient skilled labour, limited integration of beekeeping with agriculture, and an inadequate supply of bee colonies for commercial cultivation. In this region, honey is sourced from both wild and cultivated beehives, with an estimated 40,000 beekeepers. A majority of these beekeepers operate at a marginal scale, managing just one or two beehives. Despite the significant role that beekeeping plays in generating employment and sustaining livelihoods, its full potential remains untapped.

Apiculture, or beekeeping, holds significant relevance in the north-eastern part of India due to its numerous benefits for the region's ecology, economy, and livelihoods. The Northeast, comprising the states of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, and Sikkim, is a region known for its rich biodiversity and varied agro-climatic conditions, making it an ideal place for beekeeping. Integration of beekeeping with agriculture will not only benefit the farmers with the direct benefits in the form of honey, bees wax, hive products and employment opportunities, but indirectly benefit greatly through increased crop production. Insect pollination is extremely important as only 5.0 per cent of flowers are self-pollinated and 95.0 per cent are cross-pollinated. Among 95 per cent, 85 per cent of pollination is brought about by insects. Evidently for increased crop production and sustainable agriculture, it is essential to explore the possibility of planned bee pollination.

This shall be a strategic and sustainable approach that offers a wide range of benefits to the region's farmers, environment, and overall agricultural ecosystem. This integration creates a mutually beneficial relationship between beekeeping and agriculture.

Honeybee’s diversity

In the northeastern hill region, five distinct honeybee species thrive. These include the small honeybee (Apis florea), rock bee (Apis dorsata), giant honeybee (Apis laboriosa), Asian honeybee (Apis cerana), and European honeybee (Apis mellifera). The first three species are wild insect pollinators and cannot be domesticated. In contrast, the latter two, Asian honeybee and European honeybee, are hive bees that can be managed in wooden hives. They are known for their industrious nature and adaptability to human interaction. These bees can be relocated as needed, exhibiting similar pollination behavior. The effectiveness of honeybee pollination depends on factors such as colony strength, colony number, shifting schedules, hive placement, weather conditions, competition from other crops, and crop attractiveness.

Within the Northeast region, a distinct subspecies of the Asian honeybee, Apis cerana himalaya, exists, differing from Apis cerana cerana in the North-west Himalayas and Apis cerana indica in South India. Furthermore, this subspecies exhibits three locally adapted populations or ecotypes corresponding to (1) the Naga and Mizo hills, (2) the Brahmaputra valley and Khasi hills, and (3) the foothills of the northeast Himalayas. These ecotypes vary in several biological and economic characteristics. The region's abundant forests, agricultural resources, and horticultural crops make it an ideal candidate for beekeeping development.

Integrating apiculture with agriculture in Northeast India offers numerous benefits, such as increased agricultural productivity, income diversification, environmental preservation, and sustainable farming practices. By endorsing and facilitating this integration, the region can harness beekeeping's potential to enhance farmers' livelihoods and contribute to agricultural sustainability and biodiversity conservation.

Constraints in Beekeeping

The Northeast region boasts immense potential for the advancement of beekeeping, thanks to its abundant natural resources, diverse landscapes, and rich cultural heritage. Despite the numerous opportunities, several challenges must be addressed, including:

- Inadequate infrastructure for the production of genetically superior queen bees for beekeepers.
- Limited technical expertise for effective bee colony management and maximizing honey production.
- Insufficient awareness of the benefits of beekeeping for crop yield improvement through pollination.
- The need for research and strategies for disease management and control in bee colonies.
- A lack of financial support from institutional sources.
- Limited consumer awareness regarding honey and its related products.
- Poor quality control measures in honey production.
- Ongoing deforestation.
- The indiscriminate use of insecticides, pesticides, and weedicides.
- The impact of global warming and unforeseen climatic changes.

Opportunities:

The potential for beekeeping development in Northeast India is vast and offers a range of opportunities, including:

1. Diverse Agro-Climatic Conditions: The region's varied agro-climatic conditions create an ideal environment for the growth of beekeeping.
2. Rural Empowerment: Beekeeping presents significant self-help potential for rural communities, tribals, small and marginal farmers, and landless laborers. It opens doors to various opportunities, such as:
   - Honey, with its high nutritional value, can provide a source of cash income.
   - Beeswax, valued at twice the price of honey, is in high demand.
   - Other products like bee-collected pollen, propolis, bee venom, and royal jelly are several times more valuable than honey and beeswax.

3. Bee Pollination Services: Offering bee pollination services to farmers is a mutually beneficial endeavor, increasing crop production while bolstering honeybee productivity—essentially a dual-benefit service.
4. Processing and Value-Added Products: Beyond honey, there's a wealth of value-added products derived from bee by-products, presenting additional avenues for development and revenue generation.

Strategies for development of beekeeping in Northeast India

To promote beekeeping as a significant and sustainable source of income for the rural poor, landless laborers, marginal farmers, and other disadvantaged groups, especially the poverty-stricken tribals in the northeastern region, the following strategies can be implemented:

- Encourage Organic Beekeeping: Provide support and incentives, including financial assistance, to established beekeepers to adopt organic beekeeping practices.
- Establish Commercial-Scale Beekeeping: Identify and develop commercial-scale beekeeping operations in the most favorable and natural habitats within the region.
- Develop a Systematic Marketing Network: Create a well-structured marketing network for organic honey and other hive products to facilitate their distribution and sale.
- Raise Awareness through Media: Emphasize the significance of honey production through extensive coverage in print and electronic media to promote beekeeping.
- Conduct Workshops: Organize specialized workshops dedicated to educating beekeepers on the methods and benefits of organic honey production.
- Foster Collaboration: Promote collaboration and coordination among beekeepers and research and development organizations operating in the region.
- Implement Buyback Policies: Initiate buyback policies through beekeeping cooperative societies and other honey trading organizations to ensure a fair and sustainable market for beekeepers.

Government support for beekeeping in North East Region (NER):

The Government of India has initiated the "National Beekeeping & Honey Mission (NBHM)" with a budget of Rs. 500 crores to promote scientific beekeeping as part of the Aatma Nirbhar Bharat Programme. The NBHM comprises three Mini Missions:

1. Mini Mission-I: Focused on enhancing crop production and productivity through scientific beekeeping. Initiatives include setting up beekeeping centers, capacity building, infrastructure development, training facilities, honey testing labs, and empowering women in beekeeping.

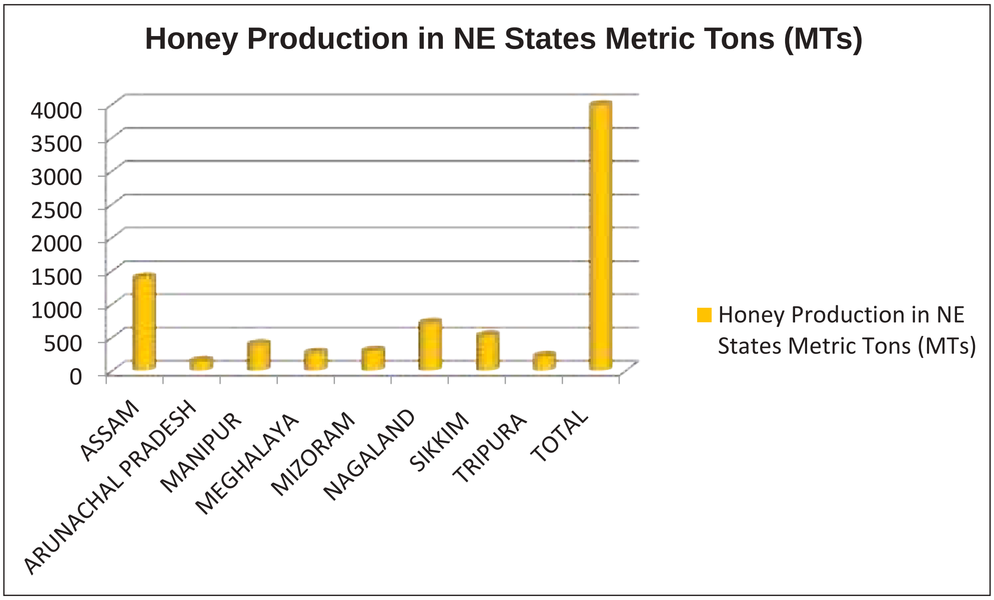
2. Mini Mission-II: Concentrates on post-harvest management, including collection, processing, storage, marketing, and value addition of bee products.

3. Mini Mission-III: Aims to generate research and technology suited to various regions, states, agro-climatic conditions, and socio-economic contexts.

The NBHM operates through project-based interventions. Northeastern states receive 90% support, while government agencies in these states receive 100% assistance, benefiting individuals, institutions, organizations, cooperatives, self-help groups, and various other groups involved in beekeeping activities.

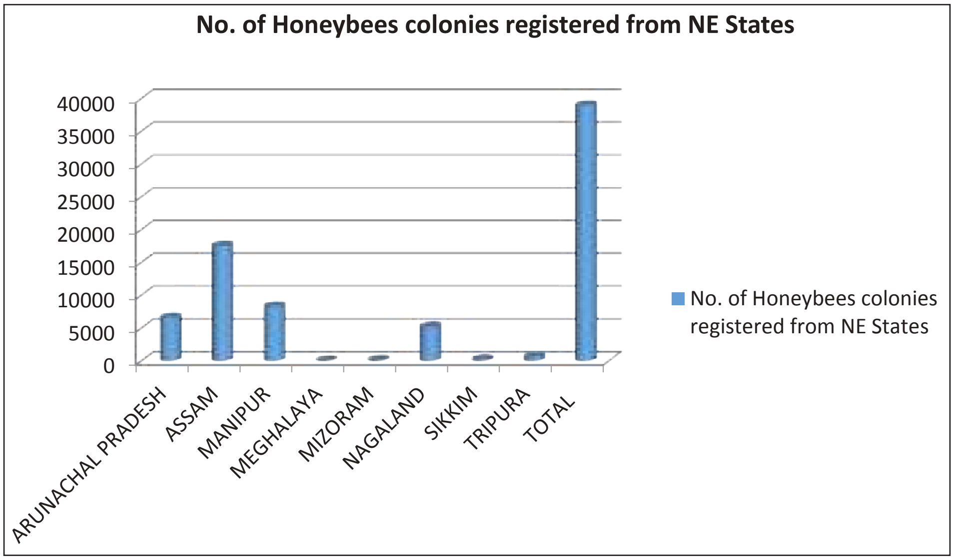
Status of beekeeping in NE Region:

- The North-Eastern Region, blessed with rich flora and fauna, offers an ideal habitat for honeybees due to its moderate climate and lush vegetation. This region, comprising both hills and plains in the North-Eastern Himalayas, supports various economically significant honeybee species.
- Prominent honeybee species adapted to the Northeastern states' agro-climate include Apis cerana (Gharasia Mow), A. dorsata (Bor Mow), A. florea (Punpuni Mow), and the Stingless bee (found in the hills of North East India). Apis cerana, a vital indigenous bee, predominantly reared by beekeepers, holds a special place in the mountain communities' natural heritage. Among the states, Assam leads the way in beekeeping.
- The honey production in the North East region is about **3990** Metric tons during 2021-22.



Honey Production in NE States (2021-22)

- The Total no. of honeybee colonies registered on **Madhukranti portal** from NE States as on date (06.10.2023):



No. of Honeybee colonies registered on Madhukranti portal from NE States

- **Projects sanctioned under NBHM in NE States:**

  NBHM aims for the overall promotion & development of scientific beekeeping in the country which is being implemented through National Bee Board (NBB). The following projects have been sanctioned in NE States under NBHM during 2020-21 to 2022-23.

  - Some projects of Assam State have been sanctioned to the implementing agencies under NBHM during 2020-21 to 2022-23. The amount sanctioned to the agencies is Rs. 1136.33 Lakhs and fund release to the agencies is Rs. 902.75 Lakhs.
  - Projects have been sanctioned of the Arunachal Pradesh State to the implementing agencies under NBHM during 2020-21 to 2022-23. The amount sanctioned to the agencies is Rs. 288.3 Lakhs and fund release to the agencies is Rs. 183.18 Lakhs.
  - Projects have been sanctioned of the Manipur state to the implementing agencies under NBHM during 2020-21 to 2022-23. The amount sanctioned to the agencies is Rs. 132.59 Lakhs and fund release to the agencies is Rs. 84.04 Lakhs.
  - Projects have been sanctioned of the Sikkim state to the implementing agencies under NBHM during 2020-21 to 2022-23. The amount sanctioned to the agency is Rs. 21.74 Lakhs and total sanctioned fund release to the agency.

- 17 Districts of NE States have been allotted to NAFED and NDDB for formation of FPOs of Beekeepers/ Honey Producers under the scheme entitled “Formation and Promotion of 10,000 new Farmer Producer Organizations (FPOs)” of Govt. of India as under:

TRAINING PROGRAMMES CONDUCTED FOR THE NORTH EAST REGION'S FARMERS ON BEEKEEPING.

Fig 1. 7 days Training cum awareness training on Scientific Beekeeping organised by Salt Range Foods Pvt Ltd, Assam

Fig 2. Awareness programme on beekeeping in Nagaland in collaboration NBHM, Nagaland

Fig 3. Demonstration on beekeeping (A. mellifera) at CIH, Nagaland

Fig 3. Training cum awareness on scientific beekeeping conducted in different districts of Assam

Fig 4. Training cum awareness on scientific beekeeping conducted in different states of the region.

Bekeeping Field

38. Scope, innovation and commercial exploitation of underutilized root and tuber crops

M. Nedunchezhiyan*, G. Byju, V.B.S. Chauhan, K. Pati, K.H. Gowda and R. Arutselvan

Regional Centre, ICAR- Central Tuber Crops Research Institute, Bhubaneswar- 751019, Odisha, India

*Email: m.nedunchezhiyan@icar.gov.in; mnedun@gmail.com

Introduction

The world's population is expected to reach 10 billion in 2050, which compels a significant increase in the production of affordable, healthy and nutritious food. During 2050, 349 m. tonnes of food shall be needed for approximately 1667 million people. But, over 820 million people in the world suffer from hunger, while about two billion people experience moderate or severe food insecurity. The world is not on track to achieve Sustainable Development Goal (SDG) 2 of Zero Hunger by 2030 and if these trends continue, the number of people affected by hunger would surpass 840 million by 2030. Nearly one-third of the global population is currently suffering from some form of malnutrition, ranging from undernourishment (i.e. the main hunger indicator), stunting (short for age), micronutrient deficiencies to overweight and obesity with an associated risk of non-communicable diseases (NCDs), e.g., diabetes, cardiovascular diseases and cancer. The double burden of malnutrition refers to the coexistence of obesity and undernutrition because of high energy diets with poor nutritional content and is a condition of increasing concern in areas with rapid nutrition transitions. The root and tuber crops are the alternative for filling the deficit nutritious food production. Root and tuber crops are the third most important food crops after cereals and legumes, and are either a staple or subsidiary food for about one-fifth of the world population. They have the highest rate of dry matter production per day and are major calorie contributors. The productivity of tuber crops is as high as 60 t/ha. The root and tuber crops find an important place in the dietary habits of small and marginal farmers especially in the food security of tribal population. They generally constituted an important source of income in rural and marginal areas, whereas they are cultivated and valued for their stable yields under circumstances such as severe drought and salinity, in which other crops may fail. The root and tuber crops, being a rich source of carbohydrates (starchy roots), have multiple uses, most notably as regular food crops and are increasingly used as livestock feed, raw material for industrial purposes, and also processed for human consumption. Recently, commercial starches, obtained from root and tuber crops dominate in the world markets of food and pharmaceutical industries. The most important root and tuber crops are cassava (*Manihot esculenta* Crantz.), sweet potato (*Ipomoea batatas* (L.) Lam.), taro (*Colocasia esculenta* (L.) Schott.), yam (*Dioscorea* spp.) and elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson). Many people in the developing world are highly dependent on root and tuber crops as contributory if not the principal source of their food and nutrition. Root and tuber crops play a major part in daily diet, accounting for over 50% of the total staple. Besides their nutritional attributes these crops hold strong economic potential and could be financially rewarding to the farm economy.

Underutilized root and tuber crops

The term 'underutilized crop' refers to plant species whose nutritional value has not been properly studied or appreciated. A variety of native plant species that serve as food sources are underutilized and widespread. Many of these food kinds, in addition to belonging to the category of foods that have come to be recognized as functional foods, offer substantial health, nutritional, and economic advantages. The Food and Agriculture Organization (FAO) has discovered several underutilized food plants that might considerably contribute to enhancing nutrition and health, supporting the food basket and livelihoods, ensuring future food security, and promoting sustainable development. In India, the underutilized root and tuber crops grown in region specific areas are arrowroot (*Maranta arundinacea* L.; *Curcuma ungustifolius* L.; *Canna edulis* Ker-Gawler*)*, yam bean (*Pachyrrhizus erosus* (L) Urban*)*, tuber cowpea or Zombi pea (*Vigna vexillate* L.), Chinese potato (*Plectranthus rotundifolius* (Poir.) Spreng), tannia (*Xanthosoma sagittifolium* (L.) Schott.), giant taro (*Alocasia macrorrhizos* (L.) G.Don), winged bean (*Psophocarpus tetragonolobus* (L.) DC.), swamp taro (*Colocasia esculenta* var. *stoloniferum* (L.) Schott.), giant swamp taro (*Cyrtosperma chamissionis* (Schott.) Merr.), typhonium (*Typhonium trilobatum* (L.) Schott.), costus (*Costus speciosus* (Koenig) Sm. (J. Konig) C. Specht.), Jerusalem artichoke (*Helianthus tuberosus* L.), tacca (*Tacca pinnatifida* Frost and Frost. f.) etc.

Among root and tuber crops, underutilized root and tuber crops play significant role in food and nutrition security of poor and downtrodden. The tubers of some of the underutilized root and tuber crops are consumed after boiling and baking. Some of the underutilized root and tuber crops are cultivated for starch purpose. The underutilized root and tuber crops are rich in minerals and vitamins. They have quality starches and easily digestible. The underutilized root and tuber crops are having varied growth habit, drought and flood resistance and crop duration. Though underutilized root and tuber crops are perennial in nature but domesticated as seasonal/ annual. This provides an opportunity for staggered harvesting as per household and market needs. The underutilized root and tuber crops are also having great flexibility in planting and can fit into any cropping/ farming system. This is possible because the propagating material is asexual stem or vine or tuber cuttings. As the economic part is swollen roots or modified stem, photoperiod has no significant effect on yield forming factors. Thus, underutilized root and tuber crops are both thermo and photo insensitive. However, extreme high and low temperature affects the growth and yield. The underutilized root and tuber crops grow well in marginal soil with fewer inputs where other crops usually fail to grow. They are tolerant to drought and some of them grow fast and provide a wide soil cover to prevent erosion. It also produces high amount of dry matter per unit area per unit time compared to cereals. They are most efficient in converting solar energy, arrowroot produces higher dry matter under partial shaded conditions compared to other species. Thus, underutilized root and tuber crops are suitable candidature to include in crop diversification, food and nutrition programmes. These crops have great flexibility in mixed cropping systems to generate additional employment and income. The underutilized root and tuber crops are capable to utilize available resources more efficiently especially in partial sunlight and residual moisture.

Scope, innovation and commercial exploitation

Arrowroot

Starch is a major energy source in human diet. The use of starch products as a food ingredient is usually not based on their nutritional value but on their functional value. In India, three types of arrowroots are cultivated for starch purposes. They are (1) West Indian arrowroot (*Maranta arundinacea* L.), (2) East Indian arrowroot (*Curcuma* spp.) and (3) Queensland arrowroot (*Canna edulis* L.). The starch is extracted by traditional methods from the above three arrowroot crops by the farmers as an off-seasonal activity and marketed locally.

West Indian arrowroot is grown for its edible rhizomes and starch extraction. The high-quality starch content of arrowroot is used as food for infants. West Indian arrowroot starch possesses demulcent properties and is sometimes used in the treatment of disorders of the intestine. It may also be employed in the preparation of barium metals and in the manufacture of tablets where rapid digestion is desirable. The starch is also used as a base for face powders, in the preparation of certain specialized glues and more recently in the manufacture of carbonless paper for computers. West Indian arrowroot starch is one of the purest forms of natural carbohydrate and has maximum viscosity. The arrowroot starch is used as a raw material baby food for decades in our country. The comparatively short crop duration coupled with its innate capacity for tremendous dry matter production elevated this crop as a foremost tuber crop in respect of calorific value. The dry matter content varied between 29.5-31.6%. The chemically estimated starch content ranged from 19.1 to 23.0%, whereas extractable starch varied between 16.1 and 19.9%. The crop is native of tropical America and has long been cultivated in West Indies particularly St. Vincent. In India, it is grown in Odisha, West Bengal, Assam, North Eastern states and in South India, mostly in Kerala. In Odisha, it is cultivated in Khurdha and Nayagarh districts commercially, and homestead garden in Puri, Cuttack, Ganjam, Kendrapada, Bhadrak, Balasore and Jagatsinghpur districts. It is cultivated around 75 ha in Odisha. The crop grows best at temperature of 20-30˚ C with a minimum annual rainfall of 95-150 cm favours its growth. A slightly acidic fertile, deep, sandy loam to loam soil with better drainage facility is most-suited for its cultivation. The plant grows to a height of 1-1.5 m and is shallow rooted- with deeply penetrating long, fleshy, cylindrical, subterranean rhizomes, which are the edible part.

Small rhizomes are used for generating planting material whereas bigger sized rhizomes are mainly used for starch production through further processing. For preparing starch, the rhizomes are washed, cleaned and made into a paste in a grinding stone. The starch gives highly viscous paste with water. The paste is stirred up with water and starch is allowed to settle. The supernatant liquid is decanted residue again stirred up with water strained through muslin and starch allowed to settle. The process is repeated several times to remove dust and a white starch is obtained. The starch flour is finely dried in the sun. The West Indian arrowroot rhizomes are eaten after boiling or roasting. The arrowroot powder is made by grounding dried roots into very fine flour. Unlike cornstarch, it doesn't impart a chalky taste when undercooked. The West Indian arrowroot thickens at a lower temperature than does flour or cornstarch. It is recommended to mix arrowroot with a cool liquid before adding to a hot fluid. The lack of gluten in arrowroot flour makes it ideal as a replacement for wheat flour in baking. So, it is employed widely in the preparation of pastries, biscuits, cakes, puddings, and jellies. The West Indian arrowroot makes clear, shimmering fruit gels and prevents ice crystals from forming in homemade ice cream. In India, it is added to vegetable, fish and meat dishes not only as spice for taste but also as food thickener. The leaves of the plant are used with meat and fish. In Kerala state of India, Arrowroot *Halwa* is a popular food, which is recommended for people with digestive disorders. The *halwa* is prepared using arrowroot flour along with Jaggery, nuts, raisings cooked in ghee. The West Indian arrowroot is respected as food for infants, invalids and convalescents due to its easy digestibility. The arrowroot flour is used as binder in soups and sauces.

East Indian arrowroot (*Curcuma* spp.) is a perennial herb and grown for its starchy rhizomes. In India, it is locally known as ‘Shoti’. In India, *Curcuma angustifolia* Roxb. and *Curcuma zedoaria* Rosc. are cultivated for starch production. The tubers are rich in starch. The ‘Shoti’ starch is highly valued as an article of diet, especially for infants and convalescents. In Odisha state of India, the starch extracted from East Indian Arrowroot is used for preparation of a baby food, 'Palua', which is mixed with milk for feeding babies. The dry matter content varied between 24.5-25.2%. The extractable starch is varied between 14 and 15%. It is widely cultivated in many parts of India, Srilanka and China. In Odisha, it is cultivated in Keonjhar and Mayurbhanj districts commercially, and homestead garden in Kandhamal and Koraput districts. It is cultivated around 50 ha in Odisha. It grows well upto 3000 ft altitudes and requires 100-125 cm rain/year. It can be grown as a crop after summer fallows. The rhizomes are large, fleshy branched and the inner part of which is pale yellowish brown. The yield of tubers varies from 20-22 t/ha. For preparing 'Shoti' starch, the rhizomes are washed, cleaned and made into a paste in a grinding stone. The starch gives highly viscous paste with water. The paste is stirred up with water and starch is allowed to settle. The supernatant liquid is decanted residue again stirred up with water strained through muslin and starch allowed to settle. The process is repeated several times until the bitter taste is removed and a white product is obtained. The flour is finely dried in the sun. Steam distillation of the rhizome yields 1-2 per cent light yellow oil.

Queensland arrowroot (*Canna edulis* L.) is a perennial herb and grown for the branched fleshy rhizomes. The plant is hardy and in view of the low incidence of pests and diseases and wind resistance of the crop in the typhoon prone regions, it is considered easy to grow. The tuber and top of the plant are used as livestock feed. The starch extracted from the Queensland arrowroot is easy to digest and hence used as a food for children and invalids. The young rhizomes are eaten as vegetable. The cooked tubers are delicious whereas the young shoots and petioles are used as fodder. The dry matter ranged from 24.5 to 26.4%, whereas starch ranged between 18.2 to 20.9%. It is native of tropical America. The genus *Canna* contains about 65 species and widely distributed in the tropics and subtropics particularly in the western hemisphere. It is commercially cultivated in Australia for its starch. In India, it is cultivated in Odisha and Kerala. In Odisha, around 125 ha cultivated in Koraput and Rayagada districts. The crop grows best at temperature of 20-30˚ C with a minimum annual rainfall of 100-150 cm favours its growth. It grows in most of the soils except gravelly and heavy wet clay soils. Maize is intercropped in *Canna* to increase farm productivity and income. In Odisha, *Canna* is planted at 60 x 60 cm spacing. *Canna* being a long duration crop gives return after 7-8 months. Wide spacing allows short duration intercrops. Maize being short duration crop is sown in intra-rows at a spacing of 60 cm i.e. 1:1 ratio. Thus, full population of *Canna* (27,777 plants/ha) and 27,777 plants/ha of maize is accommodated. Maize is harvested 3 months after sowing at physiological maturity to facilitate *Canna* to grow without any competition at the later stage. The plant withers and dries upwards in December-January. The rhizomes are large, fleshy branched purple in colour. The yield of tubers varies from 20-25 t/ha. *Canna* starch is obtained from the tubers by a process of rasping, washing, and straining. The final product is a shiny cream coloured powder.

Yam bean

Yam bean (*Pachyrizhus erosus* (L) Urban), is a native to South and Central America. Yam bean commonly called as Jicama or Mexican yam bean or Mexican turnip, native to North America. In India, it is commonly called Misrikand, Kesaru, Shankalu or Sankesh in different parts. A total six species are grown for its edible tubers, but *P. erosus*, *P. tuberous*, *P. aphipa* are important. It is belonging to the family Leguminaceae and sub family Fabaceae (Papilionaceae), is a starchy root crop with comparatively high sugar content and a moderately good source of ascorbic acid. The starchy conical or turnip shaped fleshy tubers are eaten. High sugar content in tubers imparts sweet taste when eaten raw. The fresh tubers are used as salad and can also be made into chips. The young tubers have crisp juicy and refreshing flesh. In many developed countries the tubers are processed, canned and many sweet preparations are made. The over matured tubers become fibrous, hence unsuitable for consumption. The functional properties of yam bean starch, allows it to be used as potential source of starch. In China, mature dried roots are reported to be used as a cooling agent for people suffering from high fever. In many countries young immature pods are used as a vegetable. The stem is tough and fibrous and is used for making fish nets in Fiji. The mature seeds have high content of alkaloids and insecticidal properties. The seeds are characterized by high oil (20-28%) and protein (23-34%) contents. Seed oil contains high concentrations of palmitic (25-30% of the total fatty acids), oleic (21-29%), and linoleic acids (35-40%). However, the mature seeds contain up to 0.5% rotenone (an isoflavonoid), an insecticidal compound that makes them inedible but this metabolite can prevent harmful insects in vegetable fields. Yam bean powdered seed is applied to treat the prickly heat during summer months especially in Java, skin eruptions and as fish poison. The ethanol extract of the seeds decreased locomotor activity, produced muscle relaxation and showed anti-anxiety and anti-aggressive activity. In India, it is mostly grown in North Bihar extending parts of West Bengal, Assam, Odisha and eastern Uttar Pradesh. Yam bean is adapted well in subtropical to humid, hot temperate zones. Its main climatic requirement is frost free conditions during vegetative growth. It can be grown upto 1000 m above mean sea level. Sandy loam soil of good depth is favourable for its cultivation. The soil pH of 6.0-7.0 is ideal. The crop is harvested 110-130 days after sowing depending upon the location. The variety RM-1 produces an average yield of 30-35 t/ha.

Costus

There are different species in *Costus* genus, but *Costus speciosus* is mostly exploited for its medicinal use in Ayurveda. Different parts of Costus used as traditional medicine, especially rhizomes are used for treatment of diabetes, abdominal pains, gall bladder pain, chest pains, liver problems and jaundice, fever, skin diseases, worm infection, leprosy, burning sensation and bronchitis. It is thrived so abundantly in the Himalayan Region and eastern ghat hill regions. Cultivation is primarily focused upon the rhizomes of the plants. Most of the rhizomes are exported to China and Japan and as they serve as a big commodity for commerce in Kashmir. Rhizomes are bitter in taste and exhibit anthelmintic, astringent, expectorant properties and also used in the treatment diabetes, herbal remedy for fever and treating boils. Leaves are used for treatment of scabies, stomach ailments and its paste applied to the fore head to bring down the fever. Saponins are reported in seeds and rhizomes of *Costus* plant. Diosgenin, sitosterol, dioscin, gracillin, cycloartanol, cycloartenol, cycloalaudenol, costunolide, eremanthin were extracted from rhizomes. Various compounds like 5α-stigmasten-3b-ol, sitosterol-β-Dglucoside, dioscin, prosapogenins A and B of dioscin, gracillin and quinines were isolated from rhizomes of *Costus*. Five new compounds such as tetradecyl 11-methyltridecanoate, tetradecyl 13- methylpentadecanoate, 14-oxotricosanoic acid, 14- oxoheptacosanoic acid and 15-oxooctacosanoic acid isolated from rhizomes. Two sesquiterpenoid compounds were isolated (costunolide and eremanthin) from the *Costus speciosus* hexane extract and showed antibacterial and antifungal activities.

Chinese potato

Chinese potato (*Plectranthus rotundifolius* Syn. *Solenostemon rotundifolius, Coleus rotundifolius, Plectranthus tuberosus, Coleus parviflorus*) belongs to the family Lamiaceae (Labiatae). This is commonly known as hausa potato, sudan-potato, country potato. It is popularly known as poor man's potato, because it fetches low price in market as compared to the other tuber crops. The preparation of boiled leaves of the Hausa potato is used to treat such disorders as dysentery, blood in urine and eye disorders including glaucoma. Tubers of the crop provide essential dietary and energy requirements to the populace during lean periods. The tubers taste similar to Irish potato and trifoliate yam and can be eaten as the main starchy staple or part of it in combination with legumes, rice and vegetables. It possesses elite flavour and taste and has medicinal properties due to the presence of flavonoids that help to lower the cholesterol level of the blood. It has an aromatic flavour and delicious taste on cooking. These tubers are rich in minerals like calcium, iron and certain vitamins including thiamine, riboflavin, niacin and ascorbic acid. The aromatic flavor of the tuber makes it a sought vegetable and is reported to have medicinal properties due to the presence of flavanoids that help to lower the cholesterol level of blood. Leaves also have reported medicinal uses such as treatment of nasal congestion, sore throat, coughs and also have antifungal, anti-inflammatory properties and enzyme inhibitors. Chinese potato is a very important crop in several countries of Africa and Asia. It is reported to be originated from East Africa then it spread to tropical West Africa and then to Southeast Asia including India, Sri Lanka, Malaysia and Indonesia. In Asia, Chinese potato is reported to be cultivated in Sri Lanka, South India and Java. They occur wild in grassland in East Africa region and even at high altitude (2200 m) in Kenya. It grows over a wide range of climatic and edaphic conditions, consequently, morphological characters also vary among populations. It grows well in regions receiving an annual rainfall of between 700 mm and 1,000 mm. Yield sunder favorable condition may reach 20-25 t/ha.

Tuber cowpea

Tuber cowpea (*Vigna vexillata* (L.) A. Rich) is a pan-tropical herbaceous legume. It is widely distributed throughout southern and eastern Africa, the Indian subcontinent, south-east Asia, Indonesia, Papua New Guinea and Australia. Two domesticated forms of *Vigna vexillata* have been reported; seed type and tuber (storage root) type. Considered to have domesticated the seed type in Sudan (Africa), the tuber type is thought to have originated in the Indonesian region that extends to India. The cultivation of *Vigna vexillata* as a root crop has been reported in East and North-eastern India, where it is locally known as 'halunda, and in the foothills of the Himalaya region. Cultivated forms of *Vigna vexillata* from several localities in Bali and West Timor in Indonesia, where it is known to be more adapted to drought compared with other traditional, non-legume, root crops. In Bali, the local people know the crop as Jempirangan, while in West Timor, it is recognized as Kamberiti. In the islands of Sumba and Flores, where the plant is called Oehala and Fanuatuful, the tubers are collected from plants in the wild. Wild forms of *V. vexillata* have also been used as a 'bush tucker' plant by aborigines in Australia. It is a potential and under-exploited legume bearing both edible green pods and root tubers in the same plant known by several names viz. tuber cowpea, zombi pea, wild cowpea, etc. The main roots develop tubers after 2-3 months of growth. These resemble those of sweet potato and average 12-13 cm long. The plant can be propagated by seed and vegetatively by stem cuttings. *Vigna vexillata* is considered as a donor for cowpea improvement because of resistance to bruchids, flower thrips, pod borer, powdery mildew and cowpea mottle virus. The storage roots had a light brown skin, a creamy coloured flesh inside had a taste like potatoes with a small groundnut aroma. The protein content of edible tubers of *Vigna vexillata* is about 15%, which is about three times higher than that of potatoes and yams and six times more than that of cassava. It grows well in sub-tropical and temperate conditions in sandy loam soil. The four-month duration crop yields tuber of 11-15 t/ha and green pod yield of 5-6 q/ha.

Tannia

Tannia (*Xanthosoma sagittifolium* L.) is a fast-growing herbaceous plant widely cultivated for underground stems. It may have originated in the northern part of South America and spread through the Antilles and Mesoamerica. When the Europeans arrived, it was known from southern Mexico to Bolivia, but was possibly more intensive in the Antilles. Domestication may have occurred in various places and with different materials, and was based on processes such as roasting and cooking the tubers, thereby eliminating the irritant substances, calcium oxalate crystals and saponins. Tannia is a valued food crop in most of the Caribbean islands, Florida (USA), western Africa, parts of Egypt, India, and Oceania. In most regions, it is grown for sale in local markets. Costa Rica and the Dominican Republic are exporters of the crop. There are only a few varieties of tannia, and most have white flesh. Pink and yellow-fleshed types are less common and occasionally classified as *X. violaceum* Schott and *X. atrovirens* C. Koch, respectively. The edible portions of these two types are club-shaped, underground offshoots of the main corm that develop into cormels weighing as much as 1 kg each. The main corm of the yellow-fleshed types is the part that is consumed. Young leaves are occasionally cooked as pot herbs. In the western hemisphere, tropics plants of *X. brasiliense* (Desf.) are occasionally grown solely for their edible leaves. In India it is grown in South India, Andhra Pradesh, Odisha, Bihar, eastern U. P., West Bengal and the North Eastern states. A secondary use is of consumption of the young leaves, similar to spinach, and this is more common with tannia than in the case of the taro. The usable parts is the subterranean tuberous stems which contain, 15-39 % carbohydrates, 2 - 3 % protein and 70 - 77 % water; it has a nutritional value comparable to the potato and are probably easier to digest.

Swamp taro

Swamp taro (*Cyrtosperma chamissonis* (Schott) Merr) is pre-Polynesian and considered to be among the oldest of the South Pacific food crops. Swamp taro is the important staple food on Pacific atoll islands and volcanic islands of Micronesia. The plants are large and grow to a height of 15-20 feet and are grown in swamp areas and fresh water marshes. Swamp taro flourishes in warm, humid climates. Production is mostly limited to the low islands of Micronesia, where it is primarily grown as a traditional food crop. Varieties are differentiated by their acrid factors, leaf shape, color, spininess of the petiole, and flowering habit. The time to maturity (measured in years) and tolerance to saltwater intrusion vary slightly. The main corm is the edible portion of the plant, increasing in size from one year to the next; 10-yearold corms can weigh as much as 300 kg. Side-shoots are used as propagules. The carbohydrate content of swamp taro is similar to that of taro and tannia. Plants are harvested as needed, except when storms raise the salinity levels of the coastal bogs. At such times, plants are harvested immediately and stored until planting conditions are favorable. Swamp taro tubers are consumed in the cooked form, coarse-textured, compared to taro, giving a gritty feeling in the mouth. It is important staple food in many islands of pacific, nevertheless few studies not been conducted on swamp taro nutritional composition. The presence of carotenoids (b- and a-carotene, βcryptoxanthin, lutein, zeaxanthin, and lycopene) and minerals (including iron, zinc, and calcium) in swamp taro cultivars were reported. *Cyrtosperma* cultivars were found to be rich in β-carotene and other carotenoids in range of 50 to 2040 mg of β-carotene/100g.

Giant Taro

Giant Taro (*Alocasia macrorrhiza* L.) is belonging to the family Araceae. It is native to Malesia (including Peninsular Malaysia, the Philippines and parts of Indonesia), Queensland and the Solomon Islands. It is currently widely distributed and naturalized in many tropical and subtropical regions in North, Central and South America, the West Indies, tropical Africa and the Indo-Pacific Islands. It is cultivated in India, Sri Lanka and Bangladesh, and also in Myanmar, Thailand and Peninsular Malaysia and in tropical America and in some parts of Africa, where it is a minor crop. It is grown extensively in Samoa, Tonga, the Wallis and Futuna Lau group of Fiji and parts of Vanuatu. Giant taro is a coarse, erect, monoecious, rhizomatous and evergreen plant which grows to about 5 m high with large, sagittate, rosette leaves measuring upto 0.9-1.8 m long and 0.6-1.2 m wide. The leaves are glossy in medium green color. The fruit is spathe, oblong top ellipsoid, green and 8 cm long. Each fruit possess several, pale brown seeds with 4 mm as a diameter. It has upright, erect, elongated, woody stems of 1-1.2 m long and 25 cm in diameter. It prefers tropical, subtropical climates and well-drained soil. Giant taro is an important starchy crop with medicinal and nutritive values.100 grams of raw Giant taro serves 70 grams of water, 100 calories, 2.2 grams of protein, 0.1 grams of lipid fat, 23 grams of carbohydrate and 1.9 grams of dietary fiber. The same amount cover minerals such as 38 mg of calcium, 0.8 mg of iron, 52 mg of magnesium, 267 mg of potassium, 30 mg of sodium and 1.6 mg of zinc. It provides the vitamins such as 0.02 mg of Vitamin B1, 0.02 mg of Vitamin B2, 17 mg of Vitamin C and 2 mg of Vitamin E. Traditionally different parts of giant taro are being used in treatment of inflammations and leaves extract is used for treatment of many diseases. The presence of glycosides, tannins, alkaloids, organic acids, steroids, triterpenes, saponins, flavonoids, gallic acid, ascorbic acid, glycosides, cyanogeneticglucosides and alocasin etc. are reported in giant taro tubers.

Tacca

Tacca pinnatifida Forst and Forst. f. is originated in South East Asia and is widely distributed on the moist tropics of Asia, Australia and Pacific islands. The genus *Tacca* includes about 30 species of perennial herbs with tuberous or creeping rhizome. The plant is a perennial herb grows to a height of 60-90 cm. The tubers are globose 15-20 cm in diameter and harvested after the lops have died down. The tubers are used for the treatment of piles. Rubefacient, a bitter extract is prepared by washing the grated tubers in running water and that is given in diarrhea and dysentery. The fresh acrid bitter tuber yields a nutritive starch having excellent culinary properties. It is known as 'Tahiti' or 'Fiji'. The starch is used to prepare porridges, cakes and other sweet meals. It is also mixed with wheat flour for making bread. The starch is recommended as a food for invalids and also used as laundary starch. Tuber yield ranged from 150-250 g/plant and the shape of the tubers resembles potato. The tubers possess 22.4% dry matter and 10.2% starch.

Winged beans

Winged beans (*Psophocarpus tetragonolobus* L.) are versatile edible legumes of tropical origin, belonging to the family, Fabaceae. It is, commonly called winged bean, asparagus pea, or Goa bean. Winged bean has a twining habit, tuberous roots, longitudinally winged pods and both annual and perennial growth forms. It serves as root vegetable as well as it produces the edible leaves, shoot, pods, flowers and seeds. Winged beans are bountiful sources of minerals, fibre, vitamin C, vitamin A. Rural people are consuming the leaves and seed to cure skin sores such as boils and ulcers. The most remarkable feature of winged bean tubers is that they are rich sources of protein, starch and B-complex vitamins (Thiamin, pyridoxine (vitamin B-6), niacin, and riboflavin). It is reported that 100 g tuber provides 11.6 g of protein on comparison to 2.02 g/100 g and 1.36 g/100 g protein content in potato and cassava respectively. Immature pods of winged bean are commonly used as very low-calorie vegetables that contains 49 calorie per 100 g beans but mature beans comprise of high calorie content and high in protein content that equivalent to soy bean protein. The pods are potential sources of novel antimicrobial compounds and high LC50 value signified that this plant is not toxic to human. The plant grows in profusion in hot, humid, equatorial countries such as Indonesia, Malaysia, Thailand, the Philippines, India, Bangladesh, Myanmar and Sri Lanka. Some varieties produce starchy underground tubers that are 2–4 cm in diameter and 8– 12 cm long.

Jerusalem artichoke

Jerusalem artichoke (*Helianthus tuberosus* L.) is one of the tuber yielding crops in the genus Helianthus which comprises about 75 species. The tubers resemble potatoes but with larger eyes. Jerusalem artichoke tubers are eaten as raw or boiled. In food value they are considered equal to potatoes. They are also pickled made into chips or ground into flour. Jerusalem artichoke has aroused much interest since the commercial source of levulose used as sweetening agent for diabetics. Fresh tubers are sliced and juice is acidified and heated to hydrolase inulin and inulides. Neutralization with lime yields calcium levulate which is separated by precipitation and filtration. Carbonation of calcium levulose yields a syrup containing levulose from which sugar is crystallized (yields 6% on fresh weight of tuber). Fructose syrups suitable for use as sweeting agents may be prepared. The tuber may also be utilized for the preparation of industrial alcohol by fermentation and beer like beverages. Tubers are used as feed for stock. A rich palatable feed for good digestability comparable to sugar beet in feeding value is obtained by ensilage. Green tips and stems of young plants are used as feed for cattle, they may be ensilaged. The stalks may be treated by soda chlorine process to give a pulp which is suitable for the manufacture of certain type of papers. This hardy crop is cultivated for its edible tubers in Europe, parts of Asia and throughout the temperate regions of many parts of the world. In India, it is reported to have been introduced in Assam, Bengal, Uttar Pradesh, Maharashtra, Gujarat and Andhra Pradesh. In India, the plant is grown to a limited extent in gardens and in the hill stations at an elevation of 300-800 m but it can be grown under wide range of soil and climatic conditions. It can be cultivated successfully even in lands unsuitable for many other vegetable crops. It is well adapted to rich sandy or light loam and alluvial soil, the digging of tubers is easier. The crop takes 4-6 months from planting to mature. The tubers are ready for harvest when the leaves are withering and the stem commences to die down. It is advisable to leave the tubers in the soil until required as they preserve their delicacy and flavor better when left undisturbed. The yield of tubers varies from 12.0-24.5 t/ha.

Conclusion

Institutions, government organizations, and researchers all over the world are enhancing their understanding of the production and utilization of new or lesser-known alternative plant species in response to the global food crisis, which is having devastating effects on the environment and raising concerns about the loss of crop varieties. The role of underutilized root and tuber crops in the future is bright as these crops are considered as climate resilient crops and having ability to survive in harsh conditions. With the capacity to survive in wide range of environments and ability to produce high quality starch tubers, the underutilized root and tuber crops cater to the food and nutritional security of the downtrodden people. However, the problems like non availability of quality planting materials, lack of knowledge and skills on improved technologies, lack of enthusiasm among the potential entrepreneurs to start processing units, marketing problems, inadequate storage facilities, and stiff competition from other crops affect underutilized root and tuber crops technology transfer. The socio-economic strategies like popularization of tuber crops as alternate crops, integrated product development, production and distribution of quality planting materials, participatory technology development, capacity building and market regulation with government policy support will improve the underutilized root and tuber crops scenario in India. So, it is high time for various actors involving in the development, to understand, accept the promote underutilized root and tuber crops among the farming community.

39. Vegetable grafting: Scope to promote and sustain yield and quality of vegetables in developing countries

M. Senthilkumar[a*], Madhu S. Giri[a], Somashekhargouda Patil[a], Anilkumar Nair[b] and DS.S. Hebbar[b]

[a]Central Coffee Research Institute, Coffee Research Station Post- 577 117, Chikkamagaluru Dist., Karnataka, INDIA

[b]ICAR- Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bengaluru- 560 089, Karnataka, INDIA

*Corresponding E-mail: drccri2022@gmail.com

Introduction

Vegetable farming is one of the most lucrative areas of agriculture since it offers good returns quickly and helps provide nutritional security. In this sector, there is fierce competition to provide high-quality produce that meets particular specifications for both the home and international markets. On the other hand, in order to reduce the additional costs associated with importation from other regions, vegetables, particularly the perishable ones, needed to be produced locally. Due to the wide disparity between demand and supply for local food, which is constrained by difficult surroundings, the current market price of the majority of vegetables varies substantially across the country. This explains why there are significant disparities in the production of vegetables across the nation. The use of appropriate cultivars for certain conditions along with the adoption of cutting-edge tools and techniques for vegetable production present a significant opportunity to increase vegetable productivity. However, given the regular changes in customer preferences for specialty vegetable cultivars, it is undoubtedly a highly volatile business.

Vegetables are crops with great nutritional value, high market value, and enough income to displace subsistence farming. They are, however, extremely susceptible to various biotic and abiotic stresses which at any stage of crop growth can impact normal growth, blooming, fruit development, and ultimately output. Under such circumstances, vegetable grafting has become a potentially effective surgical substitute to rather slow conventional breeding techniques for boosting resistance to biotic and abiotic stresses. It offers a chance to transfer some genetic variations of particular rootstock features to affect the overall function of the scion. In order to combat numerous soil-borne diseases, the genetic potential of different rootstocks in vegetable crops has thus proven to be a more effective alternative to chemical sterilants which not only pollutes the soil but also very badly affect the microflora of the soil.

Grafting is the process of combining two separate plant components to create a new plant. It is a time-honored method used in plant research to increase financial gains. With regard to growth and development, both components are influencing one another in certain ways. The above-ground portion of the plant, known as the "scion," is selected based on its fruiting potential or horticultural qualities, while the below-ground component of the plant, known as the "rootstock," is chosen for its capacity to withstand or tolerate soilborne illnesses or abiotic stresses. Both pieces in the grafting process may be from the same species or from different species. In Japan and Korea, research on vegetable grafting using watermelon as the scion and pumpkin as the rootstock was conducted in the late 1920s. Due to their succulent nature, vegetables are particularly vulnerable to many illnesses, pests, and abiotic stresses. Commonly, soil-borne infections are the most harmful and result in significant crop losses in vegetables including tomato, cucumber, brinjal, pepper, and watermelon. By using grafting, soil-borne illnesses can be reduced and vegetable yield can be raised. The grafting process is recognized as more advantageous and environmentally favorable for sustainable vegetable cultivation, and the use of plant protection measures can be decreased by using resistant or tolerant rootstocks.

A grafted plant combines two different genotypes and demonstrates effective interaction of rootstock (R) scion (S) environment (E), thereby determining the positive and negative influence of rootstocks on plant performance and fruit quality of scion. Plants developed using conventional methods only reflect the genotype (G) environment (E) interaction. In addition to giving the plant vigor, grafting increases its resistance to harmful environmental factors and infections that are carried by the soil. Additionally, it increases the plant's ability to absorb resources and its effectiveness in using those resources. By increasing the number of bacteria and actinomycetes in the soil, grafting improves the soil's biological qualities, which has the ability to better defend plants from various infections.

Vegetable grafting is more meaningful under protected cultivation to technique, which increase the productivity and for better use of available resources. The use of precise grafting methods and the selection of suitable rootstocks through breeding are essential to increasing vegetable yield. In some nations, it is more common to graft cucumber-pumpkin, watermelon-bottle gourd, melon-white or wax gourd, or even tomato-tomato or tomato-wild brinjal. Major benefits of grafting include enhanced yield, stress tolerance, and resistance to disease or nematodes.

History of vegetable grafting

Vegetable grafting is an excellent horticultural strategy that has been used for many years in East Asia to overcome the challenges connected with the hard production of vegetable crops. In fact, It's a centuries-old practice, although it's relatively new in the field of vegetable production. Vegetable grafting studies began in Japan and Korea in the late 1920s with the primary goal of preventing fusarium wilt in cucurbits, specifically watermelon (*Citrullus lanatus* L.) on pumpkin (*Cucurbita moschata*) (Leonardi, 2016; Kawaide, 1985). Vegetable grafting techniques spread around the world beginning in the 1920s. The first grafting method in solanaceous vegetables was tried on Brinjal (*Solanum melongena* L.) which was grafted on scarlet aubergine (*Solanum integrifolium* L.) in 1950 (Oda, 1995) and tomato in 1960 (Lee and Oda, 2003). According to Lee (1994), grafted seedlings of Solanaceae and Cucurbitaceae dominated up to 59% and 81%, respectively, in 1990. According to Lee *et al.*, (2010), grafted seedlings are used in 92% and 95% of watermelon growing areas in Japan and Korea, respectively. A private seed business "Thompson and Morgan" introduced a grafted "Pomato" plant in the UK in 2013, then later in 2015, they launched another wonder plant known as the Egg and chips plant.

In India the first report on Vegetable grafting was from the Indian Institute of Horticultural Research, Bengaluru where, Dr. Bhatt and his team (2015) identified vegetable grafting as a tool to select optimal rootstocks for waterlogged conditions. The use of vegetable grafting has resulted in yield increases of up to 80% in Solanaceae and 60-90% in Cucurbits. Cucurbit grafting in *Momordica cochinchinensis* was worked on at the NBPGR regional station in Thrissur, Kerala, to boost production by grafting female plants on male plants. CSKHPKV, Palampur produced the pomato plant another combination of brinjal and potato by researcher at the starting level in the year 2020 and worked on another horticulture wonder plant i.e. "Brimato".

Current status of vegetable grafting

East Asia is the largest market for vegetable grafting especially cucurbits and other vegetables. Grafted transplants yield 99%, 94%, and 40% of watermelon in Korea, Japan, and China, respectively (Bie *et al.*, 2017). In the case of Solanaceous crops, grafted transplants generate approximately 60-65% of tomatoes, eggplants, and 10-14% of peppers. In the Netherlands, all tomato plants grown in soilless circumstances use grafted tomato transplants (Bie *et al.*, 2017). Vegetable grafting is becoming more popular over the world, particularly in Eastern Europe, North and South America, India, and the Philippines. Over 1,500 commercial nurseries in China produce grafted transplants. Because Canada exports grafted transplants to Mexico, international trade in grafted vegetable transplants is quickly expanding (Bie *et al.*, 2017).

Objectives of vegetable grafting

Prime objectives of vegetable grafting is to impart resistance against serious diseases and pests, reduce fertilizer and agrochemical application, resistance against abiotic stresses, quality improvements and quantitative improvements through use of desirable stock plants.

Scope of grafting technique in vegetable cultivation

Grafting is an alternative method for improving resistance/tolerance in current high-yielding commercial cultivars. Grafting allows commercial cultivars to benefit from the generally robust root systems of hardy genotypes belonging to the same or different species, genera (cultivated or wild), to improve the efficiency of commercial cultivars in challenging growth situations through physical reunion through surgical techniques. Grafting is a sustainable method that is now recognized as a quick tool for increasing plant resistance to various biotic or abiotic challenges in significant fruiting crops. Besides, cross incompatibility is a common barrier to transferring resistant traits (genes) into high yielding cultivars, but grafting has the ability to reconnect resistance qualities from even wild genotypes (rootstocks) with commercially viable traits of cultivated genotypes (scions). Furthermore, grafting may eliminate the need for chemicals to treat pathogen-infected soils, making it an environmentally safe practice that can also be used as part of integrated and organic crop management systems.

Although the current method of vegetable grafting involving multiple species or cultivars was first done in the late 1920s by a Japanese farmer who grafted watermelon onto squash to manage Fusarium wilt. Since then, this approach has been applied on a variety of scales. However, since the Montreal Protocol banned the use of the fumigant methyl bromide in 2005, the usage of grafting in vegetables rose tremendously worldwide.

Grafting has become a more preferred approach than others for decreasing crop losses caused by challenges associated with intense controlled production systems, as well as those associated with sub-optimal growth conditions of fragile agro-ecosystems in arid and semi-arid countries. In fact, it has revolutionized the vegetable industry in many countries by becoming an essential part of the vegetable production system in a select group of vegetables such as solanaceous (tomato, eggplant, and capsicum) and cucurbitaceous (cucumber, watermelon, and muskmelon), and more recently, vegetable (pole) beans.

Vegetable grafting for combating biotic stresses

The use of resistant cultivars/varieties is an important disease prevention approach. Simultaneously, developing resistant cultivars/varieties through plant breeding is a laborious and time-consuming Work to combine resistance and desired commercial features. Furthermore, no single plant cultivar/variety is totally resistant to all disease risks. Grafting is more prevalent in fruit and nut production, but it is also becoming increasingly popular in high-value vegetable crops. Grafting vulnerable scions onto disease-resistant rootstocks is an important approach for controlling soil-borne plant diseases. Grafting procedures are used to address soil-borne illnesses such as bacterial wilt and root knot nematode of solanaceous crops and Fusarium wilt of cucurbits.

Cucurbit and solanaceous vegetable agriculture is affected by soil-borne diseases such as Fusarium wilt and bacterial. Grafting is the most effective approach for overcoming such problems in vegetable production (Oda, 1995). When pepper scion Nokkwang was grafted on PR 920, PR 921, and PR 922 lines, it showed resistance to Phytopthera blight and bacterial wilt with the highest success % when Phytophthora capsici and *Ralstonia solanacearum* were employed for causal organism inoculation (Jang *et al.,* 2012).

According to Attia et al. (2003), sensitive pepper scion (cv. Gedon) grafted on stock plants resistant to Rhizoctonia root rot and Fusarium wilt cultivated in disease-infested soil showed less disease infestation than non-grafted plants. The eggplant accessions EG195 and EG203 are recommended by AVRDC (Annonymous, 2009). They are resistant to bacterial wilt, root-knot nematode, and Fusarium wilt in tomatoes.

Grafted brinjal planted in wilt-infected soil yielded higher yields than non-grafted plants (Bletsos *et al.*, 2003). Although grafting suppresses common diseases such as Fusarium wilt in tomato plants (King *et al.,* 2008), the use of *Solanum torvumas* rootstock has been reported to confer resistance to Verticillium wilt, Fusarium wilt, bacterial wilt, and root knot nematode (Sebahattin *et al.,* 2005).

Grafting tomato on Beaufort greatly reduced root galling caused by root-knot nematodes, and this treatment outperformed all others (Kaskavalci *et al.,* 2009). AVRDC (Annonymous, 2009) recommends chilli accessions PP0237-7502, 0242-62, and Lee B for grafting since they are resistant to bacterial wilt and Phytophthora blight damage.

Watermelon grafting onto different cucurbitaceous rootstocks has been quite successful in providing soil-borne disease resistance (Ali, 2012). Cucurbit rootstocks include bottle gourd and *Cucurbita moschata*, *C. maxima* hybrids, both of which are extremely resistant to *Fusarium oxysporum*, which affects and causes severe crop losses (King *et al.,* 2008).

According to a study conducted in AVRDC (Anonymous, 2013), disease susceptible bottle gourd lines can be grafted into Luffa (sponge gourd) or pumpkin to increase crop performance. According to Nisini *et al.,* (2002), controlling races 1 and 2 of *Fusarium oxysporum* and *F. melonis* in melon grafting is the best and quickest way. Verticillium colonization was checked on 'Crimson Sweet' grafted onto 'Shintoza' plants, presumably due to the grafting defense mechanism identified by King *et al.,* (2008). It has been demonstrated that by employing Verticillium wilt tolerant rootstocks, the onset of symptoms can be delayed for three weeks, allowing the watermelon fruits to mature (Paplomatas *et al.,* 2000).

Vegetable grafting to combat abiotic stresses

Climate change has proven significant, with annual temperature increasing about 0.56 degrees Celsius on average over the last 100 years. A rise in global temperature causes glaciers and ice caps to melt, as well as thermal expansion of water. Climate change, such as rising temperatures, shifting precipitation patterns, increased UV radiation, and an increase in the frequency of extreme weather events such as droughts and floods, pose serious challenges to successful vegetable production.

Grafting is considered as a climate resilient technology to alleviate the negative impact of climate change on the productivity and quality of vegetable crops due to its potential to provide resistance to salinity, drought, flood, thermal stress, and heavy metal toxicity. Numerous studies have been published that describe the use of grafting procedures on various vegetable crops to improve tolerance to a wide range of environmental conditions.

Flooding

Excess moisture from unpredictably of heavy rainfall has a negative impact on the productivity of many vegetable crops because of their high susceptibility to flooding, and some vegetables are intolerant of flooded soil conditions throughout their growth and development. Many research groups have documented the application of grafting in various vegetable crops to improve flooding tolerance (Bhatt *et al.,* 2015). Tomatoes are a worldwide produced vegetable that is susceptible to flooding. To improve flooding tolerance, Bhatt et al. (2015) used interspecific tomato grafting. A commercial tomato cultivar, Arka Rakshak, was grafted onto four eggplant rootstocks in this experiment, including BPLH-1, Neelkanth, Mattu Gulla, and Arka Keshav. The findings of this study revealed that grafting had a considerable effect on yield in both flooded and non-flooded environments. Non- and selfgrafted plants died after 5 days of flooding, but two combinations, Arka Rakshak/Arka Keshav and Arka Rakshak/BPLH-1, performed better. Similarly, in watermelon, the commercial cultivar 'Crimson Tide' was grafted onto the landrace Lagenaria siceraria SKP, and chlorosis symptoms were detected on both grafted and non-grafted plants, however symptoms were less severe on grafted plants when flooded.

Drought

Drought is another major water stress issue for global vegetable production, stemming from a lack of water under water-stressed conditions. Despite the fact that breeding and biotechnological interventions have resulted in some novel drought-tolerant crop varieties, these gains have largely been limited to cereal crops. During times of scarcity, grafting could be utilized to reduce production losses and boost water use efficiency (WUE). This could be accomplished by grafting high-yielding vulnerable commercial cultivars onto rootstocks that can mitigate the effects of water stress on the shoot. Tomato hybrids, particularly Solanum spp. and interspecific hybrids, are popular rootstocks for eggplant in Europe. Watermelon (*Citrullus lanatus*) shoots are less stressed when grafted onto pumpkin (*Cucurbita moschata*) rootstocks (Davis *et al.,* 2008; King *et al.,* 2010).

Thermal Stress

Temperature extremes can reduce vegetable yield by inducing wilt and necrosis, slowing the rate of truss development, and influencing fruit ripening timing. Due to the related physiological changes in the grafted plant, grafting can be employed to shield plants against thermal shock and enable plants perform even better in terms of yield (Rivero *et al.,* 2003). Vegetable crops are extremely sensitive to temperature extremes. High-temperature conditions are typically seen during the growing season in a tropical environment, whereas chilling or low temperature is a serious problem for vegetable production in temperate and sub-tropical regions, particularly for tomato, squash, cucumber, and watermelon. Low temperatures also have an effect on seed germination, seedling growth, and plant development, resulting in a loss of economic yield (Venema *et al.,* 2008). *C. ficifolia* is also the main rootstock for cucumbers in Morocco, and it is a great rootstock for low soil temperature tolerance, particularly for winter spring production (Besri, 2008).

Salinity stress

Soil salinity affects around 7% of the global surface and close to 20% of arable irrigated land (Shahid *et al.,* 2018). Because climate change promotes salinization, the amount of saline land is expected to grow under climate change scenarios (Shrivastava and Kumar, 2015). Salinity has a negative impact on plant production and growth. Several solutions have been developed to mitigate the effects of salinity and the use of saline soils for vegetable crop cultivation. Several strategies for reclaiming saline soils are only temporary and relatively expensive to adopt (Machado & Serralheiro, 2017). Similarly, salt-tolerant vegetable crop development has been investigated, but the complicated polygenic feature that triggers salt resistance necessitates numerous cycles of plant breeding (Ashraf *et al.,* 2008). The adoption of resistant genotypes as rootstocks was thought to be a simple and effective method for boosting crop tolerance to salt stress (Koevoets *et al.,* 2016). The salt tolerance of grafted tomato plants has been increased by using interspecific hybrid rootstock (Di Gioia et al. 2013). Watermelon plants salt tolerance increased severalfold when bottle gourd was utilized as a rootstock (Yang *et al.,* 2013).

Heavy metals stress

There have been reports of heavy metal pollution of soil and water, as well as deleterious effects on vegetable plants and, as a result, human health via the food chain. Some vegetable rootstocks can reduce heavy metal uptake and/or translocation to shoots, hence limiting plant harm and lowering pollutants in fruit tissues. Grafting melon and cucumber onto interspecific Cucurbita hybrid rootstocks, tomato onto interspecific tomato hybrids, and brinjal onto wild brinjal were discovered to relieve heavy metal stress in vegetable plants. The rootstock-mediated tolerance was associated with lower accumulation of harmful metals in leaves while maintaining accumulation of good elements, hence assisting in the maintenance of physiological functions. Grafting tomato (Ikram) onto the interspecific tomato rootstock Maxifort was found to effectively mitigate Cd and Ni stress (25 or 50 M) by modifying mineral uptake and improving physiological and biochemical performances of grafted plants when compared to other graft combinations, particularly non-grafted plants.

Role of grafting in improving qualitative and quantitative aspects of vegetable production

The adoption of tolerant/resistant rootstock for vegetable production is considered a sustainable strategy under a variety of biotic and abiotic stress situations. Rootstock has a direct effect on fruit quality (Flores *et al.,* 2010). When the rootstock *Solanum torvum* is used for grafting brinjal, it increases fruit size. Sugar, flavor, color, carotene content, and texture of grafted plants can be affected by rootstocks (Davis *et al.,* 2008). Nicoletto et al. (2013) found that solutes responsible for fruit quality are translocated through xylem and rootstock, influencing quality metrics such as fruit shape, color, smoothness, texture, color (flesh), and TSS. When grafted on *Solanum torvum* and *Solanum sisymbrifolium*, vitamin C and brinjal hardness were reduced (Arvanitoyannis *et al.,* 2005). When Shintosa was utilized as rootstock, Yamasaki *et al.,* (1994) found that grafting delayed flowering in pumpkin, bottle gourd, wax gourd, and watermelon. Flowering in grafted vegetable plants may be delayed due to the age and growth of the scion used for grafting (Maurya *et al.,* 2019).

Application of vegetable grafting in modification of period of flowering and harvest

When rootstock and scion combine, the amount of hormones produced and their influence on grafted plant sections in cucurbits can be adjusted. Flowering is delayed in grafted pumpkin, bottle gourd, wax gourd, and watermelon plants, particularly those with 'Shintosa' rootstocks (Yamasaki *et al.,* 1994). According to Sakata et al. (2007), watermelon grafted onto bottle gourd produces female flowers earlier than other rootstocks. Fruit harvest period is affected by flowering date, which can have a direct impact on quality. There were few reports that could provide more information about the impact of grafting on flowering and earliness.

In the case of solanaceous crops, non-grafted plants blossomed earlier than grafted plants. The late flowering in grafted plants could be attributed to the growth of scion plants being interrupted for about a week owing to grafting and prolonged vegetative growth, as Suthar et al. (2005) documented in brinjal for delayed flowering in grafted plants. It boosts plant vigour while also increasing the duration of economical harvest time. Grafting is also used to investigate the movement of some endogenous flowering substances across the graft union. It has been demonstrated that flower-inducing stimuli controlled by photoperiod moved easily through the graft union, whereas vernalization stimuli did not (Chailakhyan and Khrianin, 1987).

Future prospects

The essential criteria for expanding the use of vegetable grafting are the identification of appropriate disease resistant rootstocks and healthy grafted seedlings at a low cost. To prevent post-grafting losses, more study is needed. Furthermore, the availability of effective grafting machines and grafting robots increases grafting speed, the survival rate of grafted plants reduces the higher price of grafted seedlings, and therefore can boost grafted plant cultivation among small-scale farmers globally. Researchers, extension specialists, and seed firms should collaborate to implement this modernized technology as an efficient tool for producing high-quality veggies. Vegetable breeders and private enterprises in India have an opportunity to create resistant rootstocks. Standardization of grafting abilities and healing environment is required for commercial application. Vegetable grafting can help to increase the supply of organic vegetables, which is a major concern for buyers.

Conclusion

Vegetable grafting has been utilized successfully in Asian countries for many years and is gaining appeal elsewhere. Many worldwide seed companies prioritize the creation and dissemination of rootstock seeds through commercial seed catalogues. Identification of adequate multi-disease-resistant rootstocks with tolerance to abiotic stresses is a critical requirement for long-term success. The emergence of high-quality rootstocks with a wide range of disease resistances, as well as efficient grafting instruments such as grafting robots, will significantly increase the global use of grafted vegetables. A number of typical challenges arise while grafting vegetables and producing seedlings with grafts. Some of these disadvantages include the high cost of rootstock seeds, the labor-intensive nature of grafting and growing grafted seedlings, inexperience with grafting and management of grafted plants, and the possibility of grafting-related physiological disorders. However, there are numerous advantages to using grafted seedlings. These include an increase in income from high yield and off-season growing, a reduction in fertilizer and irrigation water input due to the rootstocks' wide root systems, a significant reduction in agrochemical use due to the rootstocks' high resistance to disease and other physiological disorders, an extension of the harvest season, effective maintenance of well-known cultivars against diseases and other physiological disorders, and a reduction of the demand for lengthy crop rotations.

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40. Exploration of systems for affordable production of Exotic and Underutilized Flower Crops

M. Kannan[1*] and B. Deepika[2]
[1]Retd. Professor (Hort.), TNAU Coimbatore
[2]Assistant Professor (Hort) SRSIAT, Vedasandhur – 624710, Dindigul
*Email: kannanflori@gmail.com

Introduction

India is enriched with diverse agro-climatic conditions such as fertile land, suitable climate, abundant water supply, availability of skilled manpower etc., which are quite beneficial for growing a variety of flowering plants throughout the year. Globally major emphasis has been given to floriculture sector due to its tremendous opportunities in the present scenario.

Over the last few decades this topic has received growing option attention from the Scientific Community due to the fact that it is a possible option expand the area under floriculture sector with more diversification. The production of underutilized flower crops and ornamentals for Landscape use would be able to promote Agro- biodiversity, improve the resilience of the agro -systems toward environmental stressors and provide important local services viz., Environmental, Economic and Socio-cultural. However, there are barriers Continue to hamper the reshaping of production of underutilized flower crops. Apart from many exotic underutilized flower crops native species include Orchids, Musk rose, Lotus, Water lily, Crossandra, Clerodendron, Tabernaemontana, Clitoria and Clematis. In recent times, new underutilized flowers like Iris, Curcuma, Liatris etc. have been introduced.

India is bestowed with varied Agro climate ranging from mid tropical zones to alpine zones and congenial for several types of ornamental plants in different seasons. Worldwide China and India have large total areas under flower cultivation. In view of rapid changing global competition, diversification into under-utilized lesser known potential new ornamental plants play key role in fetching premium prices. Most of the potential ornamentals plants have been introduced from Australia, South Africa, Israel, New Zealand and Eastern USA. There are about more than 60 types of new ornamentals reported to be hold potential for commercial importance. All these newly introduced ornamental plants required different stages of research and development.

Underexploited Jasmine Species

At TNAU, Coimbatore an evaluation trial was conducted with seven jasmine types belonging to ten Jasminum species under open field conditions. Three commercial jasmine cultivars viz., *Jasminum sambac, Jasminum grandiflorum and Jasminum auriculatum* served as standard check *Jasminum multiflorum* was treated as an underexploited species since it is under commercial cultivation in Karnataka but not in TamilNadu. The study revealed that significant variations were observed for vegetative, flowering, flower yield and flower quality parameters indicating that these traits were highly variable among the eleven types of the genus. *Jasminum nitidum* (Acc.JN-1), *Jasminum multiforum (*Acc.JM-2*)* and (Acc.JM-1) possesses special features such as flower production round the year of 12 months with a peak flowering from February to May during which *Jasminum grandiflorum* and *Jasminum auriculatum* underwent off season. Two superior clones of *Jasminum multiforum (*Acc.JM-2 and Acc.JM-1*)* also recorded significantly high mean values for the important quantitative and qualitative traits. The Exploration of non- conventional Jasminum species such as *Jasminum nitidum* (Acc.JN-1) and *Jasminum multiforum* for desirable traits such as year around flowering, good keeping quality have paved the way for identifying useful species which can be commercially exploited.

Other underutilized flower crops

Amaranthus (*Amaranthus spp***):**

The genus comprises of 60 species of annuals or short lived perennial plants from Tropical Asia and they are popular for catkin like cymes of densely packed flowers and colourful foliages and inflorescences. The plants are ideal for annual or mixed borders, pot culture and dry flower purposes. The amaranth requires a warm and moist soil and a sunny situation. The plants perform well in summer and rainy season.

Balsam (*Impatiens balsamina***)**

The plants are 30-75 cm tall with hollow stems and free branches. Leaves are lanceolate, thin, pale green with serrated margins. The flowers are spurred and bome in leaf axils. Flowers may be single or double and lilac, salmon, pink, ruby, orange, scarlet rose or purple in colour. Some of the species have the characteristics of bursting of seed pods and scattering of seeds when touched. They are good for bedding, borders, pot plants and green house plants. The plants survive well in a semi-shaded situation. A well-drained rich soil is ideal. The potting mixture should contain equal parts of loam, leaf mould and sharp sand. They are easily propagated from seeds or cuttings. Seeds of all kinds require light for germination. The plants start flowering 2 to 2.5 months after sowing. They require well aeration and moderate watering for proper growth and flowering. Application of 100 ppm each of N and K at the time of watering is beneficial. Pinching of the apical portion of the plants may be practiced to make them bushy.

Boronia (*Boronia heterophylla*)

These are evergreen, robust shrubs of Australia with scented leaves and flowers. Foliage looks fresh round the year and simple to finely divided. Flowers are waxy, bell shaped, hang on short stalks in cluster of two or three or singly arise from the leaf axils. Flowers are brilliant magenta pink in colour. Plants are susceptible to drought and hot winds. In summer, they need adequate water. They are easily propagated from cuttings using young stem tips at a half ripe stage. A lime free light or heavy soil is ideal for it's growth. Pruning is done regularly to keep up bushy growth. Generally, 40-80 cm long stems are harvested for cut flowers when 50-70% of individual flowers open at the base of the stem. Cut flowers last for 7-11 days. Pulsing with STS improves vase life. A new interspecific hybrid 'Purple Jared' available in this genus. *Boronia megastigma* is popular as source of essential oils due to the presence of aroma compounds such as beta ionone and dodecyl acetate. It is used as food additive for flavourings.

Christmas Bells (*Blandfordia nobilis*)

A wild flower of Australia. Plants are robust, compact clump forming with thick fibrous root and grassy leaves. Flowers are bell shaped, orange to scarlet, blood red tipped with saffron yellow. They are tolerant to heat waves. Plants require a deep, sandy, lime free soil. Plants are raised from seeds. They need full sun and are moisture loving. Usually, 30-60 cm long stems are harvested for cut flowers when all the flowers are fully open.

Dandelion (*Taraxacum officinale***)**

It is a hardy perennial having rosette base bearing several flowering stems and multiple leaves. The common dandelion flower head is arranged with about 150 to 200 yellow ray florets and no disk florets. Leaves, root, and flower are edible. Dandelion leaves are added to a salad or cooked. They can also be dried and stored for the winter or blanched and frozen. Flowers can be made into juice, or added into many recipes. The root can be made into a coffee substitute. The root and leaves can be dried, stored and made into tea. The common yellow dandelion has a long list of powerful healing abilities as well as other health benefits.

Drumsticks (*Isopogon anemonifolius, I. anethiofolius, 1. dawsonii*)

These are upright shrubs of Australia, 2 m tall with divided leaves. Flowers are soft yellow borne at the ends of branches and bloom during November. They prefer well drained soils. Seeds are collected from the cones and left in a bag for raising young plants. Usually 30-60 cm long stems are harvested for cut flowers when outer flowers of each flower head is opening. They are popular as flowers of healings, skill and memory power.

Geraldton Wax Flower (*Chamelaucium uncinatum, C. megapetalum*)

It is medium to large shrub of Australia, 2-3m tall. Leaves are narrow, 40mm long and aromatic. Flowers are circular and light pink in colour. Geraldton is adaptable to wide range of climate ranges from humid temperate to subtropical. They require a well-drained sandy to sandy loam soil and a sunny or semi-shade location. Plants are commercially propagated by cuttings from current season's growth. They need plenty of water. Usually, 50-80 cm long stems are harvested for cut flowers when 5-50% flowers open at the base. Leaves and flowers are rich in globulol and grandinol and they have antifungal properties. Cut flowers last for 7- 12 days. Common varieties are 'Alba', 'CWA Pink', 'Eric john 'Grandiflora', 'Jubilee', 'Lady Stephanie', 'Mullering Brook', 'Purple Pride".

Heath (*Cassinia* spp.)

These are wild shrubs, distributed in New Zealand, Australia and South Africa. Flowers are white and bome along with the stems. The plants prefer a mild climate and a sunny location and a fertile well drained sandy loam soil. They are propagated through cuttings taken from side shoots with a thin heel of old wood during July-August. Used as cut flowers and cut foliage

Hibiscus (*Hibiscus* spp.)

It is a large genus of annual, perennial herbs, evergreen and deciduous shrubs and small trees of tropical, subtropical and warm temperate region. Hibiscus originated from China and is composed of 250 species. The plants are equipped with alternate, palmately lobed or cut leaves; and yellow, white, pink, scarlet, red and pink flowers. They are excellent for shrubbery, groups and pots. The plants are sun loving and they do well in the summer months. They are propagated by seeds, cuttings, layering, budding and grafting depending upon the species and the cultivars. *Hibiscus mutabilis* is propagated by seeds. Cuttings of 2-3 cm diameter and 10 - 15 cm long of *Hibiscus rosa-sinensis*, *Hibiscus schizopetalus* and *Hibiscus syriacus* can be taken from well matured wood and placed in sand after treatment with IBA (5000-6000 ppm) for rooting. Many varieties of *Hibiscus rosa-sinensis* are propagated through grafting by using rootstocks such as 'Single Scarlet', 'Dainty and 'Apple Blossom' during February to April or June to July. T budding or air layerings are practiced during March to April, particularly for those cultivars difficult to start by cuttings.

Hibiscus rosa-sinensis (Shoe flower**):**

Hibiscus rosa-sinensis bear large, single or double red scarlet flowers terminally. The leaves and flowers are found to be promoters of hair growth and aid in healing of ulcers. The varieties are 'Alipore

Beauty', 'Chitra', Daffodil', 'Hawaii White', 'H.D. Maity', 'Juno', 'Kali Jaba', 'Snow Flake', 'Sweet Heart', 'Victory' and 'Viceroy'. The hybrids in this species are 'Aikta', 'Anuradha', 'Bharat Sundari', 'Chitralekha', 'Geetanjali', 'Ratna', 'Smt. Indira Gandhi' and 'Tribal Queen'.

Kangaroo Paw (*Anigozanthos spp*)

The plants are native of Australia, succulent, short, rosette formed and bear underground horizontal rhizome. Leaves are long green or grayish green. Flower buds are tubular, hairy and black to yellow, orange and red in colour. A full grown plant can bear 10-30 flowers at the end of each spike. The plants require a cool and moist climate. They are tolerant to drought. They prefer full sun and a well-drained acidic soils. Higher day and night temperature increases vegetative growth, early flowering and better flower quality with night temperatures at or below 15.5°C. Plants are commonly propagated through seeds although division of rhizome is another easy method of multiplication. Kangaroo Paws are used either as cut flowers or garden plant or potted plants or in flower arrangements. It possesses tuberous roots which contain significant levels of starch and form part of the diet for the Indigenous people in the Yellagonga region of Western Australia. It has weak anti-microbial activity. Common varieties are 'Bush Ochre', 'Bush Ranger', 'Dwarf Delight', 'Harmony', 'Pink Joey', 'Royal Claw', 'Red Cross'.

Lisianthus/Texas Blue Bells (*Eustoma grandiflorum*)

It is a half hardy annual or biennial, native to the Praire from Colorado to Nebraska and Down to Texas. Plants are 15-60 cm tall with bluish green, succulent sessile and glaucous leaves and large funnel shaped flowers of blue lavender or various shades of pink and white. Plants need a sunny location and a calcium rich soil with a pH of 6.7. They respond to micronutrients. Removal of the old blooms encourage more blooms in the season. They require mild low temperatures for growth followed by warmer temperatures for flowering. Seeds are common means of propagation. It may have medicinal significance due to the occurrence of biologically active compounds such as ecoiridoids, flavonoids, and xanthones. Cut flowers last for 8 days. 'Blue Lisa' ''Colorado Blue Bell', 'Little Belle Blue', 'Maurine Blue', 'Misty Blue'are popular varieties.

Lobelia (*Lobelia cardinalis*)

It is a native American plant that is often used as an omamental garden plant. It is found in moist soils, including wet open woods, streambanks, swamps and marshy areas. Cardinal flower produces leafy inflorescences, 90-180 cm tall. Each erect terminal raceme is covered with numerous five-lobed bright red flowers. The flowers open from the bottom to the top over a period of several weeks. Cardinal flowers are used in borders, rain gardens, and native gardens, especially on the edges of streams or ponds.

Manuka (*Leptospermum scoparium*)

These are shrubs or small trees of New Zealand and Australia, 8-10m tall with dense branching. Leaves are evergreen, alternate, simple and with pointed tip. Flowers are white, pink or red in colour. Most of the species are adapted to a variety of soils. They prefer sun but many species tolerate poor drainages and some thrive inundated condition. Tip pruning is useful after flowering to improve vigour of the plants. Propagated through seeds and cuttings. Long shoots are used as cut flowers. Manuka honey produced from the nectar has high therapeutic value due to its non-peroxide anti-bacterial activity known as Unique Manuka Factor. Common varieties are 'Floradora', 'Lavender Queen', 'Red Damask', 'Snow Flurry', 'Winter Cheer'.

Montbretia (*Crocosmia x crocosmiiflora*)

A perennial rhizomatous herb of South Africa with linear or lanceolate leaves. The plants bear racemose or cymose inflorescences of 4 to 20 vivid red and orange sub-opposite flowers on a divaricately branched stem. Flowers are sessile, borne on a flexuose arched spike and hermaphrodite in nature, Crocosmia plants are easy to grow during summer season. They require full sun and a rich garden soil. Plantsare multiplied through corms although they can be started from seeds. Corms are planted 10-12cm deep and 10-15cm apart in pots, also in the flower garden. Used as both cut and dry flowers. In East Africa, leaf sap and a decoction of the corms are used to treat malaria and arthritic rheumatism.

Overberg Pincushion (*Leucospermum* spp.)

This is an erect, rounded shrub, 1 m tall with a single main stem. Inflorescences are bome in clusters of five individual flower heads at the end of branches. Flowers are yellow (*L. oleifolium*), pink orange (*L. lineara*) or golden yellow (*L. cuneiforme*, *L. glabrum*) in colour. The plants require a well-drained soil, sunny location, good ventilation and adequate moisture supply. Mulching with milled bark, rough compost and leaf litter around the plant checks weed growth, keep the soil moist and the roots cool. They are propagated by seeds or cuttings. 6-10cm long cuttings are taken from semi-hardwood current seasons growth. They look attractive when planted in the foreground of a planting with taller plants with *Leucospermum cordifolium*, *Leucadendron tinctum* or *Protea neriifolia* in the background. The flowers are excellent as cut flowers in a mixed arrangement. Cut flowers last for 8 to 10 days. A honey produced from *Leucospermum cordifolium* have anti-microbial activity.

Pink Mulla Mulla/Pussy Tails (*Ptilotus exaltatus, P. obovatus*)

These are perennial herbs or shrubs of Australia. They produce feathery, cylindrical flower spikes of pink flowers.The plants are adapted to dry areas with low incidence of frost. They prefer a full sun and a well-drained acidic soil. Used as cut flowers or dry flowers.

Pot Marigold (*Calendula officinalis*)

This species is native to south Europe, attains a height of 30-60cm and the flowers are generally orange-yellow. These are hardy herbs. Leaves are large, simple and alternate. These free flowering plants bear double or semi-double flowers of brilliant colour, mostly orange, yellow or lemon. A sunny site is best for better growth and flowering. The seeds are sown in the plains in September-October or earlier in July, especially in low rainfall areas. Seeds germinate within four to six days and need total darkness for germination. In the hills, seeds can be sown during autumn or in February-March. Pinching may be practiced for getting bushy plants. Calendula is valuable for sunny or shady beds or borders and also as cut flowers. It is also useful as a pot plant. It contains various phyto-chemicals including carbohydrates, amino acids, lipids, fatty acids, carotenoids terpenoids, flavonoids, quinones, coumarins and other constituents. Common varieties are 'Apricot Queen' (bright yellow), Art Shades' (blend of pastel colours, apricot), Campfire (dark orange), Chrysantha' (yellow), 'Geisha Girl' (reddish orange), 'Indian Maid' (rich orange with black eye), Kelmscoll Giant Orange' (largest flowered), 'Monarch' (orange, long-stemmed), 'Orange Cockage' (largest double), 'Orange Coroner', Orange King', 'Orange Queen', 'Orange Sunshine', 'Pacific Beauty (with different colours), 'Rada'r (good as cut flower), Singlearn' (deep tangerine orange), 'Sutton's Art Shades', 'Sutton's Lemon Queen', 'Sutton's Orange King', 'The Ball' (globular, orange), Yellow Colossal (dear yellow, large flowered), 'Lemon Queen' (lemon yellow), Nova (orange), 'Radar' (orange), 'Radio' (rich orange), ''Golden Gem' (golden yellow).

Protea (*Protea cynaroides, P. repens, P. nerifolia, P. grandiceps, P. latifola, P. compacta, P. sussannae, P. laurifolia*)

These are evergreen shrubs or small trees of South Africa. Plants are tender, evergreen with alternate and entire leaves. Flowers are sessile or sub-sessile, terminal or lateral, solitary and pink or red in colour. Proteas prefer a cool climate and even they withstand freezing temperatures during winter. They need a well-drained fertile acidic soil in full sun. The plants need plenty of water but not water logging. The plants respond well annual pruning. Mulches with leaves, wood chips or shredded garden waste are applied to conserve soil moisture. Proteas are usually propagated through seeds. Both branches and the flowers of the proteas are used as cut omamentals. They can be used as potted plants also and as a component in private gardens and for landscaping of public areas. Cut flowers last for 10 days. Black Mink', 'Green Ice' 'Lime Light', 'Moonshine', 'Peach Sheen' 'Rose Pink' are common varieties.

Rice Flower (*Ozothamnus diosmifolius*)

It is an upright woody perennial shrub of Australia with sessile and alternate leaves. Flowers are head or umbellate corymbs, bisexual and yellow or white in colour. The plants prefer well drained fertile acidic soils. They respond well in phosphorus rich soil also. Rice flowers are propagated through stem cuttings. About 3333-5000 cuttings are required for planting one hectare of land. Adequate water application aids in establishment of new plantings and harvest of good flowering stems and quality flowers. After planting, nipping of young plants help to increase branching. Pruning after harvest encourages regrowth for the next crop. It is used as cut flower crop as well as for bouquet and dry flower for aesthetics. Flowering stems of 30-90cm long can be harvested at an earlier maturity. Cook's Tall Pink', 'Cooks Snow White', 'Coles Pink No-1', 'Dolby White', 'Dolby Pink', 'Redlands Sandra', are the common varieties

St. John's Wort (*Hypericum spp*)

These are annuals, perennial, shrubs or small trees, popular for their showy, attractive golden yellow flowers. Hypericum requires a cool and sunny climate but tolerant to partial shade. A well-drained fertile soil is ideal for good growth of the plants. They are easily propagated through cuttings. Popular as cut flower with a vase life of 8-14 days.

Victorian Lace Flower (*Thryptomene calycina, T. saxicola*)

A native shrub of Australia, 2m tall with small, neat, smooth and clean foliages. Flowers are pure white with a dark eye in case of *T. calycina* and pink hued in case of *T. saxicola*. Plants are moderately drought resistant and need pruning for shaping. Young plants are usually raised through cuttings. They require lime free soil and the full sun or light shade. Usually, 30-60 cm long stems are harvested for cut flowers when the flowers are about 1/3 to fully open Essential oils from these plants.

Wax Flower (*Crowea exaltata*)

These are native shrubs of Australia, dome shaped, 1m tall with narrow leaves and rose purple, waxy, star like flowers. They are frost hardy and suited to cool and moist weather conditions. Plants are propagated by tip cuttings. A partial shady location and lime free light soil are ideal. Pruning is practiced to maintain a bushy growth or a straggly plant. Generally, 30-80cm long stems are harvested for cut flowers when the flowers are just starting to open or buds show full colour. 'Bindalong Compact', 'Ginninderra Falls', 'Green Cape', 'Pink Blush', 'Ryans Star', 'Southern Stars', 'Star of Heaven', 'Whipstick' 'White Star' are popular varieties.

Some selected potential underutilized ornamental species in Sri Lanka

Blue Mist/Iron Wood

Blue mist is an evergreen shrub or small tree, up to 8-14 m tall. Tree bears bright blue color umbellate cymes in young tree branches which adds the floricultural importance for the plant. The flower clusters are consisted with tiny purple flowers which blooms once or twice a year creating a breathtaking view when the petals are al shed to the ground. The crop is listed as an endangered species in Sri Lanka (Fonseka, 2020).

Propagation

Kora kaha can be propagated through seeds and air layering (Fonseka, 2020). Vivipary (Seed germination within a fruit prior to disperse from mother plant) has observed in *M. umbellatum* seeds in some parts of India due to the high moisture accumulation during heavy rainfall. (Thiteet *et al.,* 2016).

Other uses

Memecylon umbellatum including other Memecylon species are used as landscaping plants, as timber to prepare walking sticks, for decorative plant work, to prepare combs, as a mordant in silk and cotton dyeing (Bharati *et al.,* 2016).

Possible value addition

This plant is a potential potted plant when developed to a dwarf structure.

Glory Lily

Glory lily is a climbing herb with a wide natural distribution. The plant is cultivated as a garden ornamental in tropical regions. Glory lily can be commonly seen in forests, grasslands and abandoned cultivated areas. It bears glamorous yellow and red colored solitary flowers which add the ornamental value to the plant. The crop falls under least concern category in Sri Lankan flora red list (Fonseka, 2020).

Propagation

Wine is propagated either by seeds which takes 3 to 4 years to bloom or by tubers which start flowering within 5 to 8 weeks. The branching pattern of the vine is strongly correlate with the tuber weight. More branches can be achieved by targeting the development of the tuber weight and thus more flowers per vine. (Dounias, 2006). But vegetative propagation through tubers reduce the vigor and tolerance to biotic and abiotic stresses (Selvarasu *et al.,* 2013). Therefore, focusing on seed propagation is important to introduce new variability rather than focusing on the only one ecotype in conventional propagation.

Possible value addition

Ornamental value of the plant can be improved by changing flower color and shape through cross pollination. But self-pollination gives better results (Dounias, 2006). *G. superba* can be grown as potted ornamental plant with a dwarf stature and bright colored flowers.

Rough Osbeckia/Bovitiya

Osbekia aspera is a perennial montane shrub with a high floricultural potential. (Prashob *et al.,* 2019). In Sri Lanka, the plant is observed in grasslands, open places and distributed along the roadsides (Fonseka, 2020). The shrub has free flowering nature with contrasting flower color against to its foliage. This shrub falls under least concern category in red list (Fonseka, 2020)

Propagation

It has simple propagation methods and has a good adaptability to grow under greenhouse conditions (*Krishnarajah et al.,* 2002). A mass propagation protocol is valued to generate adequate amount of planting materials for commercial introduction due to the limitation of using stem cuttings.

Possible value addition

This ornamental flowering shrub has a high potential in the Sri Lankan floriculture industry to be introduced as a potted ornamental plant.

Blue Butterfly Pea

Cictoria ternatea is a multipurpose perennial leguminous twiner. The anthocyanin present in the petals of the attractive flowers bring beautiful natural deep blue color which carries an ornamental value to the plant (Mukherjee *et al.,* 2008). Plant is native to equatorial of Asia and to some parts of South East Asia. And have been introduced to Africa, Australia and Africa (Fonseka, 2020). In Sri Lanka, it is a least concerned crop.

Propagation

The plant is normally propagated by seeds and is readily self-seeded. Hand harvested seeds requires scarification prior to sowing (Fonseka, 2020). In vitro regeneration of *C. ternatea* is possible with nodal explants (Mohan *et al.,* 2014).

Possible value addition

Ornamental value of the plant can be improved by developing medium height Sergeants with deep violet, light pink and velvety blue flowers with a smaller Number of leaves (Gomez *et al.,* 2003)

Binara

Binara is an endemic wild plant can be cultivated in low country and up-country wet zone in the island (Dassanayake, 1999). Binara plant grows about 1m height. Flower has blue petals and brilliant yellow anthers which add ornamental value to the plant along with its herbaceous nature (Dissanayake *et al.,* 2015). It is a near threatened valuable ornamental species which requires attention.

Propagation : Binara can be propagated by seeds, stem cuttings and by air layering.

Possible value addition

According to Krishnarajah *et al.,* 2002, Royal Botanical Gardens in Sri Lanka has taken the prior steps to introduce this crop as an ornamental species through ex- situ cultivation strategies.

Marbled Jewel Orchids / Wanaraja

Wanaraja is an endemic orchid species grows mostly in tropical evergreen forests and subtropical montane forests in Sri Lanka (Fonseka, 2020). The plant prefers to grow under tree shades and inside leaf litter growing almost attached to the ground (Hartini *et al.,* 2018). This terrestrial orchid has an ornamental value especially due to the attractive leaves which are dark green to brownish purple and similar to the leaf litter at first glance. Red heart and silvery vein patterns add the attractive nature to the leaves (Hartini *et al.,* 2018)

Propagation

Anoectochilus spp are normally propagated by seeds but the germination percentage is very low and mass propagation through shoot tips and nodal explants is superior to seeds due to the high propagation rate (Ket *et al.,* 2004).

Possible value addition

This orchid type is difficult to find and has a potential to develop as an ornamental potted plant. It can be easily commercialized because of the attractive color pattern of the leaves (Fonseka, 2020).

Wild jasmine

Jasminum angustifolium is a vine with a scented floricultural value. It prominently features white flowers with sweet fragrance. They are solitary or more usually in three (Sulaiman *et al.,* 2012). The plant is endemic to Sri Lanka (Manoranjan *et al.,* 2015). And it is a least concerned crops which requires more attention (Fonseka, 2020).

Propagation

Usual methods of jasmine propagation is through layering and cuttings. But these two methods restrict the quantity of plants produced since it depends on season and climate (Chaitanya *et al.,* 2018).

Possible value addition

The vine can be developed to a dwarf potted wine with big petals while increasing fragrance.

Possible challenges to develop new ornament species

Development of wild species is not an easy task. As the genetic composition and the cultivation practices are little known, their adaptation to new environments will be challenging. Therefore, more research focuses are required to develop protocols for optimum spacing fertilizer programs, irrigation and pest and disease management (Beneragama and Peiris, 2016). When there is less knowledge on genetic diversity of underutilized species, it will lead to many unsuccessful crosses. Therefore, all the genetic aspects of the crosses should be evaluated through basic researches prior to develop new cultivars through genetic modifications.

Conclusion

The above-mentioned underutilized floriculture species are capable of developing as new cultivars through breeding programs targeting the flower color, flower size, fragrance of the flowers, leaf size and number and plant structure etc. After developing into new species, they can be commercialized as potted ornamental plants. However, there are major gaps in our knowledge and capacity to make the best out of these crops because agricultural research has so far paid little attention to these species.

Research to increase the value of these crops and encourage them to be more widely cultivated would broaden the resource base and increase the livelihood options especially for smallholder farmers in marginal areas.

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41. The Current Status of Research in Exotic and Underutilized Flower crops

U. Sreelatha[1]*, Shilpa, P, Rashidha, C.K., Reshma Shaji and Aswathi. S. Vasu
[1]Former Professor & Head, Kerala Agricultural University
*Email: sreelatha.u@kau.in

Introduction

India is bestowed with a traditional background to floriculture where we make use of flowers in many ways thanks to diverse culture and civilisation. However, since decades the floriculture sector has become a commercial industry which is designated as a viable and profitable activity, either as the major or as supplementary source of income generation. This boom to the sector was facilitated by rapid urbanisation and the followed infrastructure development happened in India. A drastic change in the socio-economic situations also enabled the growth of floriculture industry. The presence of diverse agroclimatic situations in different zones of the country further facilitated both exotic and traditional flowers to bloom in India. According to APEDA the country has exported 21024.41 MT of floriculture products to the world worth Rs. 707.81 Crores/ 88.38 USD Millions in 2022-23 and the major export destinations were U.S.A, Netherland, UAE, U.K. Germany and Malaysia. Cut flowers, pot plants, cut foliage, seeds bulbs, tubers, rooted cuttings and dried flowers or leaves contribute to the major share in export market. Important flowers in international trade are Rose, Carnation, Chrysanthemum, Gerbera, Gladiolus, Gypsophila, Liatris, Nerine, Orchids, Archilea, Anthurium, Tulip, and Lilies. When we look into the international market scenario, it is clear that most of the exotic flowers traded in the world market are also being commercially cultivated in India. Of late, momentum has been observed in cut foliage production in states like Karnataka, Kerala, Uttaranchal, Maharashtra, Andhra Pradesh and North Eastern States. Majority of the cut foliage crops are exotics only. Potted ornamentals have also emerged as one of the most sought after floriculture products for interiorscaping. As we spend more time indoors, the desire to create more aesthetic and healthier indoors enhanced the demand for wide variety of indoor flowering and foliage plants.

Market overview by IMARC predicted the market to reach INR 460.6 billion by 2028, exhibiting a growth rate (CAGR) of 131% during 2023-2028. They have attributed the market growth due to advanced technologies and agricultural practices, floriculture-friendly policies and emergence of organised retail markets and e-commerce platforms.

Recently the NE states which have tremendous potential in commercial floriculture, also have stepped into this budding sector. Special attention is being imparted by ICAR to promote floriculture in NE region. Potential areas and flower crops suitable to each area have been identified. However, market infrastructure in the region is still to be developed.

ICAR-DFR has a net-work of research centres across the country and through its budgetary, non-budgetary as well as voluntary centres, intensive research is being carried out in different aspects of floriculture. The different thrust areas are germplasm collection & evaluation, crop improvement, crop management, post-harvest technology & value addition and plant protection.

Among the exotic and underutilised flowers, emphasis is given in this article for lotus, heliconia, tropical ornamental gingers, bird of paradise and native ornamentals.

1. Lotus - *Nelumbo nucifera* Gaertn.

Lotus, a perennial aquatic plant belonging to family Nelumbonaceae comprise of a single genus "*Nelumbo*" having two species namely *N.nucifera* Gaertn (Asian lotus) distributed in Asia and north of Oceania and *N.lutea* Willd. (American lotus) distributed in the eastern and southern parts of North America, as well as the north of South America. Although there are only two species of lotus, very abundant germplasm exist all over the world, which display variable genetic backgrounds and phenotypes.

The Asian lotus /Sacred lotus

Lotus is the national flower of India and Vietnam. It is regarded as sacred and considered as a symbol of beauty, purity and sanctity. Other than China, commercial lotus cultivation practiced in Japan, Korea, and Thailand. The lotus has a close association with Indian culture and religion too. Its references are preserved in Indian arts and crafts, architecture, murals and epics. The commercial cultivation of lotus exists in Chattisgarh, West Bengal and some parts of Odisha. Small scale cultivation also exists in parts of TN (Thovalai) and Kerala (Thirunavaya).

Floral biology

Flowers -Solitary, large, 10-25cm in diameter, white – pinkish or pinkish white fragrant. Peduncle arising from the nodes of the rhizomes, sheathing at the base, 1-2 cm long, green or blackish green, hard & stout, smooth or rough due to the presence of numerous small scattered prickles, sepals, petals & stamens are spirally arranged passing gradually once into another. The flower is protogynous and last for 2-3 days after opening. Study on floral biology taken up at KAU reported that stigma became receptive 32 hours before flower opening and the receptivity was retained for 52 hours even after flower opening. However, pollen dehiscence occurred only after complete opening of the flower. The unique property of floral thermoregulation was also studied and it was reported that the temperature inside the flower bud remained between 30 to 35^{o}C till the fourth day during the period of anthesis despite the changes in environmental temperature between 27 to 33^{o}C. Ruoyi Li et al (2022) reported an increased mitochondrial biogenesis accompanied by notable morphological changes in the mitochondria, including long elliptical, rod-shaped, and dumbbell-shaped morphologies, as well as increased mitochondrial reactive oxygen species (ROS) levels in TM cells. An increase in the expression of alternative oxidase (AOX) during the thermogenesis of *N. nucifera* flowers was also observed. Self-incompatibility prevents pollination upon bagging the flower buds. However, self-incompatibility does not exist in all lotus cultivars(Akhom Khatfana et al.,2014). AICRP on Floriculture KAU Centre has screened one self- compatible lotus genotype, KAU-L-6. Seed set in lotus ranges from 50 – 70%. With regard to flower bud development, Fumiko Ishizuna and Nobuhiro Tsutsumi (2014) reported that floral buds are produced at every node during the growing season from May to October but most of the buds got aborted and only 5-7% of the buds bloomed.

Conservation and breeding

A lot of diversity exists among populations of lotus from different countries. A study by Yang et al(2013) confirmed genetic distinction between *N.nucifera* and *N.lutea* and reported higher genetic diversity among populations studied. They also warned for *in situ* conservation to assure the genetic diversity and evolutionary process of Nelumbo but supplemented with *ex situ* conservation. Mekbib et al., 2020 also confirmed high genetic diversity among populations of India, Thailand and Australia and they concluded that populations found in each country are unique. Geographically separated populations will likely to develop genetic differences due to the adaptation to different habitats. In India lotus germplasm are being conserved at CSRI-NBRI, Lukcnow, KSCSTE- MBGIPS, Kerala and AICRP on Floriculture Centres at Bhubaneswar, Kahikuchi, & Vellanikkara.

Varietal development and evaluation

When we take into consideration of the utility of lotus flowers, there are two criteria for varietal choice like that for loose flower production and for landscaping. Breeding for novel color is a longstanding goal in lotus. There are many hybrids produced by interspecific crossing between *N nucifera* and *N lutea*. China is the major country producing the lotus hybrids. These hybrids are sterile without any seed production. Some of the hybrids are Amiry Camelia, Amiry peony, White Peony, Yellow Peony, Almond Sunshine, Little Rain, Ultimate Thousand petals, Charming Lips, Butter Scotch, Akila etc. Unusual yellow and yellowish -white colored hybrids namely 'Jin Dieyu' and 'Gomoti' have been bred respectively in China and Bangladesh.

A breakthrough in varietal development has been highlighted by release of the improved lotus variety "Namoh 108" from CSRI-NBRI, Lucknow. This particular variety in light pink in color, more weather resilient and with a prolonged flowering period from March to December.

Dedicated lotus breeder in Kerala, Mr. Ganesh Ananthakrishnan has developed many beautiful hybrids like N. Littile Rain, N. Karna, N. Almond Sunshine, N. Miracle, N.Twinkle, N. Akila & N. Butter Scotch. He has registered two of the hybrids namely N. Miracle and N. Twinkle with the IWGS. Passionate lotus breeders from Kerala, Maharashtra & W. Bengal are investigating thoroughly for the development of many more hybrids and of late, one hybrid in pipeline is 'N. Indian Summer' with dark red color.

Evaluation of some hybrids at Coimbatore have shown better performance for Amiry Camelia, Amiry peony, White Peony, Yellow Peony, Almond Sunshine, producing an average number of flowers per plant ranging from 4.33 to 11.33(Gokul et al., 2023). Hybrids like Amiry Camelia, White Puff, Lang Li, Little Rain and KAU-L-6 were found promising at Vellanikkara centre when evaluated for a period of two years, producing more number of flowers ranging from 15 - 44 per container.

Post- harvest handling

Lotus flowers have a short shelf life indicated by petal blackening. If the stems are placed in water, the buds do not open, and the outer petals rapidly turn black. Lotus is a climacteric flower with high respiration rate and ethylene production that ultimately results in rapid senescence. Studies on packaging and storage conditions of lotus flower buds are in progress in various AICRP centres on Floriculture. Pulsing with 0.1% & 0.3% MgO NP respectively of Sattabongkot' and 'Saddhabutra' cultivars increased water uptake, delayed fresh weight decrease, suppressed ethylene production, and reduced petal blackening in the cut flower buds and also extended the shelf life of the cultivars for one more day (Sunpapao et al., 2019).

Value addition

The flowers are used for garland making, religious purposes and the dry pods contribute to excellent materials for dry flower arrangements.

Lotus is a crop of which almost all the plant parts are reputed as functional foods or nutraceuticals. All the parts were used for various therapeutic purpose since ancient times. There many herbal formulations with any of the lotus plant part as an ingredient in Ayurvedic system of medicine. Innumerable studies have been carried out regarding the bioactivity of various lotus plant parts for anti -cancer, anti-inflammatory and for treatment of cardiovasular diseases and nervous disorders.

Other than the traditional uses, works have been carried out for alternate uses of lotus in various food items. Process for many value added products namely bread, biscuits, cookies, noodles, etc. have been standardised. Tarts prepared using 75% lotus seed powder + 25% wheat flour along with butter and honey, have been assigned with excellent organoleptic and other nutritional contents (Jyoti Kumari and Arivuchudar, 2021). Cookies made up of 10% lotus rhizome flour + 90% wheat flour excelled in organoleptic qualities along with richness in nutrients and also recorded low glycaemic index (Sruthi et al., 2022). Longer shelf life due to low moisture content and dehydration ratio for lotus stem powder was reported by Aamena Zaidi et al (2023). They suggested the lotus stem powder as a substitute or replacement in a variety of food items.

Other than the edible products, lotus stem is being used for fibre extraction for fabric weaving. Studies by Pandey et al (2018) revealed that lotus fibre is one of the finest (0.22 tex) natural fibres with helical structure and promising quality. Chemical characterization of the lotus fibre shows presence of cellulose and similarity with cotton fibres.

Flowers are used for extraction of concrete and absolute. The perfume brand “Frotrus’ may be the first of such kind from lotus flower, developed by a public sector.

Environmental and phytoremediation

Silver nanoparticles synthesized using *Nelumbo nucifera* extracts (Leaf, Stem and Flower) exhibits excellent antimicrobial activity and can be used in biofilms degradation in water distribution systems, its anticorrosion activity can be used in prevention of corrosion formation by applying coatings and Photo-catalytic dye degradation activity against methylene blue dye molecules. The silver NPS can be used in water purification systems and for dye production industries (Supraja et al., 2017).

Lotus flower is reputed as a symbol of purity; in spite of its muddy origin, the leaves and flowers come out of water without any stains. Studies on the potential of lotus plant in treating surface water revealed that after 30 days the lotus treated water showed reduced BOD& COD by 97% and 55% respectively (Abd Rasid et al., 2019). They attributed this due to the thermo osmotic transport mechanism that equipped lotus plants to provide sufficient oxygen to the buried rhizomes and thus it could improve the water quality in the ecosystems.

***2. Heliconia* spp. – Lobster claws**

Heliconias belonging to family Heliconaceae and native to South & Central America, are popular ornamental having multiple uses as cut flower, landscape plants as well as for floral decorations. Easiness in cultivation, spectacular field presence of plants and prolonged shelf life of flowers contributed to the multifaceted application of this particular crop in floriculture. A genus with nearly 200 species, the heliconias are commonly called as ‘Lobster-claws’. The flowers are produced on erect or drooping inflorescence with brightly colored bracts which are the major attraction of the flower. Flowers are available in wide array of colors and shades of red, orange, yellow, pink & green.

Based on the orientation of the inflorescence, heliconias are mainly classified into two types namely erect and pendent/drooping type. These are again divided into four subtypes as the following;

1. Erect inflorescence with flowers arranged in single plane –*H.burleana, H.bihai, H.caribea, H.humilis, H.psittacorum, H.stricta & H.wagmeriana*

2. Erect inflorescence with flowers arranged in different planes – *H.aurantiaca, H.angusta, H.indica, H.metallica, H.latispataha*

3. Pendent inflorescence with flowers arranged in single plane – *H.rostrata, H.catheta, H.laxa, H.flabellata, H.villosa, H.mariae, H.stilesii, , H.reptans*

4. Pendent inflorescence with flowers arranged in different planes – *H.collinsiana, H.ramonensis, H.fernadnezii, H.platystachys, H.juranta, H.rauliniana, H.colgantea, H.trichocarpa, H.mutans, H.pendula.*

Production technology

Heliconia is easily propagated by rhizomes or suckers. Spacing and nutrient management vary according to agroclimatic situations. It comes under both open and shade. In tropical situations, partial shading is found better for good performance of the crop and thus make it as a suitable intercrop in coconut plantations. Studies in this respect undertaken at KAU has reported *H. stricta* cv. Iris Red as suitable for intercropping in coconut gardens. It was also observed that the plants had a superior vegetative growth and inflorescence production in sandy soils with low nutrient and water holding capacity by supplying cow dung @ 1 kg/plant + bone meal @250 g/plant basally and topdressing equal doses of Vermicompost @ 200g/plant + Neem cake @ 100 g/plant at quarterly intervals from three months after planting. Planting of heliconia cv. Golden Torch under 50 % shade net at a spacing of 50 x 40 cm and supplemented with 300 kg N/ha and 100 kg P2 O5 /ha enhanced growth, yield and quality parameters (Aklade *et al.*, 2016) at Navsari, Gujarat. Among the 38 cultivars tested for Shevaroy conditions of Eastern Ghats, revealed that Lady Di, Strawberry Cream. Alancarli, Tropics, Dwarf Jamaica, Kenya Red, Alex Red, Andromeda, Petracover and Gyana performed well showing year round blooming with floral quality and yield required for commercial cut flower production (Sankari *et al.,* 2016). Evaluation of different genotypes under shade house at Dharward conditions reported that the genotypes *H. latispatha* 'Orange', *H. psittacorum* x *H. spathocircinata* 'Golden Torch', *H. psittacorum* 'Kenea Red' and *H. psittacorum* x *H. stricta* 'Tropica' produced maximum number of spikes with excellent visual appearance and good vase life (Dalawai *et al.*,2017). The heliconia genotypes *H. bihai* cultivar Caribea, H. bihai cultivar Iris red, and *H. rauliniana* cultivated in full sun in the Brazilian Midwest region presented agronomic characteristics according to the standards required for commercialization (Auclar Felipe Botini *et al.*, 2022). Studies on irrigation requirement of Heliconia cv. Golden Torch in pot culture under 50 % shade net in Brazil reported an irrigation level of 75% to 15 & ECA for better performance (Alcilane Arnaldo Silva *et al.,* 2018).

Postharvest handling

Stage of harvest significantly influenced the vase life of flowers. The flowers are harvested when one or two bracts are fully opened; harvested with a peduncle of 70 – 100 cm length. These are precooled at 20°C for 4 hrs., pulsing with 5% sucrose + HQ 200 ppm, plugging the stem end with wet cotton, covering with polythene sheet, packing in cardboard boxes with KMNO4, storage at 17°C and holding with 2% sucrose + HQ 100 ppm (KAU, 2010).

Chitosan (1%) coated on the stem of *H.bihai* cv.Halloween was found to be effective for enhancing the vase life of flowers by 10 more days than the control without chitosan treatment (Bañuelos-Hernández *et al.,* 2017).

Phytoremediation and other uses

Efficient phyto remediation using *H. psittacorum* has been reported by Baharuddin et al. (2020). They attributed this effect due to the high concentration of three gram positive bacteria namely *Staphylococcus aureus, Staphylococcus xylosus, and Staphylococcus lentus* in the root zone of the plant, which is having high impact on metal degradation in the effluent.

Biogenic copper nanoparticles synthesized using *H.psittacorum* leaf extract has been reported with potent antibacterial activity against *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas putida* (Roy *et al*., 2016).

3. Bird of Paradise – *Streltzia reginae*

Bird of Paradise (BOP) is an evergreen perennial suitable for cultivation in subtropical situations. The unusual floral features and the brilliant color combinations have made this unique flower popular for cut flower production. Bird of paradise a member of Streltziaceae, is a native to South Africa. The plant grows to a height of 2 meters. Leaves are large, up to 70 cm long and 30 cm wide on petioles up to 1 m long. Leaves are evergreen, arranged in two ranks in a fan-shaped crown. Flowers stand above the foliage at the tips of long stalks. The spathe from which the flower emerges is perpendicular to the stem giving the appearance of a bird's head and beak. Flowers are showy with three brilliant orange sepals and three purple or blue petals. Seeds with black with vivid orange arils. Biochemical analysis of the seeds have shown high contents of starch (15.77%) and proteins (10.24%) in seeds (Marisa Taniguchi *et al.,* 2022).

Production technology

BOP prefers a moderate cool climate with temperature ranging from 17 -27°C. It can be grown in full sun or in partial shade. The plant is propagated by division of clumps, suckers or seeds. Seedlings show prolonged gestation period of 4-5 years to attain flowering. Micropropagation using rhizome explant in MS medium supplemented with 2.0 mg/l BAP + 0.1 mg/l NAA showed best results for establishment (53.33%) of explants and shoot proliferation rate of 1.55 (Osin Rai *et al.*, 2021).

Planting is done in pits of 60 x60 x 60 cm spaced at 1.25 m x 1.25 m. Composted organic manures @ 2-3 kg/plant applied basally. Studies have been reported on integrated nutrient management and fertigation in BOP. Monthly fertigation at 19.2:13.2:7.2 g NPK/plant and daily irrigation with 12 L of water resulted in the best performance of the crop in terms of growth and yield (Jainag et al., 2011) in Bengaluru conditions. Studies on the effect of varied doses of nitrogen & phosphorous at Navsari revealed that nitrogen @ 30 g and phosphorus @ 15 g/plant/year recorded significantly higher vegetative as well as flowering attributes. The same treatment also improved quality and yield of flowers of bird of paradise

(Dishaben *et al.*, 2017). Anand et al. (2021) reported the best dose of fertilizer as 37.5: 20:37.5 g NPK per plant/year which effected in terms of good vegetative and yield characters in Bird of Paradise under Nilgiris conditions.

Harvesting & Post harvest handling

For the domestic markets, flowers are cut when the first floret opens. For distant markets, the flowers harvested when they are showing orange-yellow colouration but have not yet emerged from the sheath. The cut stems of Bird of paradise are trimmed 60-80 cm length, dipped in the solution of 10 % sucrose + 250 ppm 8-HQC + 150 ppm citric acid for 48 hours. This practice greatly enhanced the longevity and floret opening both unstored and stored (22^0C) flowers. The flower stem of Bird of paradise is separately wrapped each stem with polyethylene sheet or butter paper and stems are packed in 120 X 30 cm cardboard box and stored at an 8°C temperature.

Leaves of BOP are also used as cut greens as well as for padding and support in floral arrangements. Dipping the leaves with 12 cm long stem in 20% carnauba wax + vegetal resin for 14 seconds retained the quality of the leaves upto 24 days (Paula *et al.*,2021).

4. Ornamental gingers

Plants with ornamental value belonging to the families Zingiberaceae and Costaceae are commonly described as ornamental gingers. These families are represented by about 60 genera and more than 1500 species. Ornamental gingers are natives of Natives of South East Asia, South Asia and East Asia. In India, around 200 species of gingers are reported under 22 genera, distributed mainly in North East India, South India as well as the Andaman and Nicobar Islands. The important genera grown as ornamentals are Alpinia, Boesenbergia, Curcuma, Etlingera, Globba, Hedychium, Kaempferia, Larsenianthus, Zingiber, Costus, Dimerocostus, Monocostus and Tapeinochilos.

These are grown widely under tropical regions of the world. In recent years, ornamental zingers are gaining popularity in cut flower markets and in the landscape industry. Ornamental gingers also have great potential as potted plants due to their ease of production, unique foliage, colourful and long-lasting inflorescences. The demand and use of ornamental gingers have been increasing in recent years, making the development of such ornamental types an alternative for different floricultural segments.

Ornamental gingers are rich source of various phytochemicals with diverse pharmacological activities which are obtained from plant extracts and essential oil. Anti-oxidant, anti-inflammatory, and various other bioactivities are reported in *Alpinia purpurata*, *Alpinia zerumbet* , *Hedychium coronarium*, and other gingers also.

Gingers are also accredited as a source of nutrients like vitamins, minerals, etc. Flowers of some species of ornamental gingers are edible and their nutritional value is now well recognized in the food and nutraceutical industries, for instance, the inflorescences of *Etlingera elatior* and the flowers of *A. galanga* are cooked in traditional Thai meat dishes. *Hedychium coronarium* flowers are consumed as vegetables and give a distinctive aroma in scented tea, *Zingiber zerumbet* flower buds are also consumed as vegetables and also used as a spice.

Ornamental gingers are also utilized for extraction of essential oil, natural fibre and natural dye. Essential oils from different gingers are known to possess strong antibacterial, antifungal, antioxidant and insecticidal activity due to the presence of several bioactive compounds.

5. Native ornamentals

India is bestowed with as a centre of mega biodiversity with respect to diverse ecosystems, genetic as well as species diversity. The diverse ecosystems present in the country are forests (tropical rain forest, dry deciduous, montane temperate, montane sub-tropical, alpine, mangroves), grasslands (wet & dry), wetlands and desert. India represents about 11% of world flora and 28% of the Indian flora endemic to the country. Endemism is restricted to Western Ghats, Eastern Himalaya and Western Himalaya. The diverse plants show varieties of structure, texture, color and form ascribing scope for these plants for commercialisation in aspects like landscaping, interior scaping, cut greens, potted ornamentals, dry flower industry, ecological engineering, etc.

Plants with edible parts like leaves /flowers/fruits add to the sustainability by augmenting nutritional resources. Majority of the native plants are also renowned home remedies to various ailments thereby assist for a holistic treatment for many health issues. Acceptance by pollinators is again an advantage of the natives intended for landscaping purposes. Majority of the native flora act as either sources of nectar, pollen or fruits and thus provide food for fauna especially bees, butterflies and birds.

Some native species have difficulty in home landscapes because the environment is very different from their natural growing conditions. Also, even with natives, it is important to find the right plant for each specific location in the landscape to be created. Focused research in native ornamentals have been given impetus by ICAR and the centres of AICRP on Floriculture representing the mega diversity hot spots, are putting effort for collection , conservation, evaluation and commercialization of native ornamentals.

Native ornamentals for landscaping have been identified at centres like Hessaraghtta, Vellanikkara, Solan, Kahikuchi and Port Blair. Plants like *Artemisia japonica, Artemisia niligiriaca, Senecio belagumensis, Senecio bombayensis, Jasminum malabaricum* were identified by IIHR for landscaping purposes. Vellanikara centre has given focus to endangered and endemic flora of the hillocks of Kerala. Thrust areas are habitat mapping, domestication, proximate analysis, phytochemical analysis and value addition. Value added epoxy resin encapsulated pendants, key chains, gel candles, paper weight, etc. using native ornamentals have been prepared at Solan & Vellanikkara centres. Indigenous ornamental palms and ferns of Andamans & Nicobar Islands have been enumerated by the Port Blair centre. Appreciable efforts are also put by JNTBGRI, Kerala for conservation and improvement of native orchids & wild ornamentals.

Native plants may be specific to each agroclimatic situations and the different ecosystems. Hence region wise conservatories will be needed for the conservation of these valuable firal wealth. Other ways forward are popularizing the potential natives in botanical gardens, highway median, road sides, airports, golf courses, public institutions and home gardens.

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42. Production management of exotic and underutilized flower crops

Bharati Kashyap*, Dixit Chaudhary and Sita Ram Dhiman
Department of Floriculture and Landscape Architecture,
Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP
*Email: kashyapbharati057@gmail.com, bhartifls@yspuniversity.ac.in

Introduction

Ornamental plants are grown usually for the purpose of beauty, for their fascinating foliage, flowers and their pleasant smell (Swarup, 1998). In the competitive export market of cut flowers and pot plants, new ornamental plants play crucial role in stabilising and expanding market share.

The Indian floriculture industry is valued at INR 231.7 billion. With a whooping production of 2815 thousand tonnes flowers from an area of 283 thousand hectares in 2022, India has paved its way into the international flower market. Although the assortment of ornamental crops is already very large, there are still possibilities for new crops as the market is always asking for something new.

Under-utilized ornamentals

To break the monotony and to bring newness into the market, exotic and under-utilized crops play an important role. These ornamentals are relatively new to the market. A lesser-known ornamental crop may be defined as:

i. An ornamental species or variety about which little or no information is available.

ii. A species which is not found within a particular agro-climatic region but is grown in other parts of the world.

iii. A completely new variety or species of a genera.

iv. Wild relatives of the domesticated species.

v. Some native or indigenous crops.

vi. Newly introduced cultivars of plants grown in earlier years, but forgotten or without complete cultural information.

vii. Crops that can be produced with new production technologies that can enhance crop quality and shorten the total production time.

Today, floriculture has transformed into a viable agri-business. Ornamental industry is unique among agricultural industries in a way that novelty is an important attribute. Consumers always seek '*something new*'. The consumer demand for cut flowers with new, showy traits, in addition to the desire for a large choice of flowers, makes the introduction of new species an important task. India with varied agro-climatic conditions provides tremendous scope for diversification of novel ornamental crops, which fetch premium prices and possess a huge potential for the future global floriculture industry. Under-utilized flowers may be profitable for their unique qualities and faster harvest to consumer transition, resulting in a longer post-harvest vase life.

Objectives for classifying novel plant species as new age cut flowers

a. Overall attractiveness as a cut flower stem length
b. Uniformity of individual flowers
c. Flower colour and its range
d. Use potential (centerpiece or filler use)
e. Shipping life (need for preservatives, temperature requirements, ethylene tolerance)
f. Vase life
g. Harvest (timing and duration)
h. Ease and cost of production
i. Cost of propagation material
j. Production methods (green house or open field)
k. Hardiness
l. Pest and disease tolerance
m. Uniqueness

Some new generation cut flower crops

I. Sugar bush (Proteaceae)
II. Calla Lily (*Zantedeschia* spp.)
III. Zingiberaceous cut flowers
IV. Ornamental Curcuma (*Curcuma* spp.)
V. Kangaroo Paw (*Anigozanthos* spp.)
VI. Guzmania (*Guzmania* spp.)
VII. Chinchirinchee (*Ornithogalum* spp.)
VIII. Wax Flower (*Chamelaucium uncinatum)*
IX. Craspedia (*Craspedia globosa*)
X. Statice (*Limonium* spp.)
XI. Baby's Breath (*Gypsophila* spp.)
XII. Lisianthus (*Eustoma* spp.)
XIII. Ornamental Kale (*Brassica* spp.)

I. SUGAR BUSH

Family : Proteaceae

Origin : South Africa and Australia

Horticulturally Important Genera: Protea, Leucadendron, Leucospermum, Banksia,Serruria, Isopogon, Telopea, and Macadamia

The Proteaceae of Southern Africa provide an interesting floriculture product to use to review the challenges that arise from developing an undomesticated plant into an economically viable, cultivated fresh cut flower.

An accommodating characteristic of the family is the presence of proteoid roots. Another important taxonomic feature of the family is that its flowers do not have separate sepals and petals. The perianth is made up of a single set of four segments called tepals.

Protea Flowers:

The capitulum, in which the flowers are borne on a flat or pointed receptacle, is the most common type of flowerhead.

The flowers are large, mainly oval in shape and the colour varies from light pink, pinkish-red to white. Flowers are surrounded by brightly coloured bracts, covered in silky hairs which are very attractive. Main advantage of *Protea* flowers is their conspicuous and showy nature, which renders them ideally suited as standard blooms which form the focus or centerpiece of large floral arrangements.

Climate

Proteas prefer a mild Mediterranean climate with low humidity. They can tolerate slight frosts, but the young foliage and flowers of some species, such as *P. nerifolia* and *P. cynaroides*, may be slightly damaged. Leucadendrons and Leucospermums are generally unaffected by high summer temperatures. Flowering proteas can be damaged by persistent high temperatures, although adequate irrigation can reduce the damage.

Soils

Proteas prefer deep, well drained sand with pH 5.0 to 6.0 for optimum growth and production. Avoid alkaline soils for most species. A site with low phosphorus (20 mg/kg soil) is preferred.

Some horticulturally important genera in the genus Protea are:

- **i. PROTEA:** The most widely recognized species in the genus is *Protea cynaroides*, the King Protea, the national flower of South Africa. A serious problem with marketing several species of Protea is the undesirable discoloration of leaves soon after harvesting.
- **ii. LEUCOSPERMUM:** The genera has the greatest potential to be used as potted plants due to attractive floral display and relative ease of rooting.
- **iii. LEUCADENDRON:** Highly colorful, easily packaged, long and long-lasting cut stems and have a potential of very high yields. Although more widely known as commercial cut foliages and landscape plants, most Leucodendrons can be planted as colourful potted plants.
- **iv. BANKSIA:** Widely grown for cut flowers and foliages.
- **v. GREVILLEA:** Used for landscape plantings and cut foliages, but their use as cut flowers is limited because of short vase-life and tendency of floret abscission.
- **vi. ISOPOGON:** They offer some interesting, hardy plant materials for the landscape, and possibly for the cut flower trade.
- **vii. TELOPEA:** The most important species, *T. speciosissima* is known as the Waratah and is the floral emblem of New South Wales, Australia.
- **viii. SERRURIA:** Serruria potted plants have good floral display qualities. Vase life: 7-10 days following cutting.

Propagation:

Most commercial protea varieties are propagated by using approximately 20 cm long terminal semi-hardwood cuttings. A 5 second basal dip in IBA (4000 ppm) is used and cuttings are planted in a well aerated medium with intermittent misting. The cuttings take six to sixteen weeks for rooting.

Pruning:

Pruning by thinning-out poor growth and heading-back to encourage re-sprouting will maintain active growing tips, flowers and sturdy branches, as well as general good form of the bush. Three years after planting, prune back 10 to 15 cm of each stem on the plant in late winter, and then every year after flowering.

Plantation Design:

Plant proteas 1m apart in the rows and 1.5 - 3.5m between the rows depending on the plant size. A rough guide for planting is 3.5m between rows for large proteas (e.g. *P. repens and eximia; Leucodendron xanthoconus* and *eucalyptifolium, Leucodendron 'Goldstrike*') and 1.5 m between rows for smaller proteas (*Protea cynaroides*). Space is important to allow adequate aeration to prevent disease and space for root and canopy development.

Post harvest handling: The recommended developmental stage for harvesting most Protea, to ensure market quality and acceptable postharvest life, is the so-called soft-tip stage when bracts have lost their firmness and begin to loosen but still cohere. Flowers are cut preferably in the morning or late afternoon when they are fully mature and remain in good condition for upto 4 weeks, depending upon cultivar. Long vase life coupled with unique beauty and hardiness of *Protea* flowers make them valuable as cut flowers. The vase life of Protea is generally three to four weeks, but postharvest leaf blackening reduces the vase life to approximately one week. In the genus Protea, vase life reduction is associated with the phenomenon of leaf blackening due to oxidation of phenolic compounds in the leaves. Removal of the inflorescence, placing the flowers in high light conditions, or girldling the stem immediately below the inflorescence delayed or eliminated leaf blackening. Pulsing cut Protea stems in a 1% sucrose solution, or a floral preservative solution, before packing and especially post unpacking is an effective treatment to delay the onset of leaf blackening.

II. CALLA LILY

Scientific Name: *Zantedeschia aethiopica*, *Zantedeschia rehmanii*

Family: Araceae

Origin:Southern Africa in Lesotho, South Africa, and Eswatini

Other Names: Arum Lily, Lily of the Nile, Pig Lily

New Zealand is the largest exporter of colored calla hybrids. The striking arum lily "flower" is actually many tiny flowers arranged in a complex spiral pattern on the central column (spadix). These spectacular flowers are beginning to rival the rose in popularity for bridal bouquets. The spathes are used as cut flowers while the leaves are very elegant and used for flower arrangements. Callas are also used for planting along ponds and lakes as border plants.

Calla lilies prefer a warm head and cool feet and therefore, temperature is important to their performance. An ideal day temperature would be 18 to 25°C and nights of 12 to 18°C. It can be propagated by seeds, rhizomes/tubers and micropropagation. They are planted at 30-45 cm apart in beds during spring to early summer. It takes 10-12 weeks to come to flowering from the time of planting.

The flowers should be harvested when the spathes are fully open and about one day before the flowers shed pollen in the cool of the morning or evening. To ensure the longest possible stem length, flowers are pulled rather than cut when the plants are turgid. In the second year, 10 to 20 flowers can be harvested per grown up plant. By the 3rd year at least 24 long stemmed flowers appear in a plant

The post-harvest life of *Z. aethiopica* is about 5 days. Re-cut the stems before they are placed in the condition solution. Gibberellic acid is known to increase the vase life of cut calla stems.

III. ZINGIBERACEOUS CUT FLOWERS

Scientific Name: *Alpinia purpurata, Zingiber spectabile, Etlingera elatior, Hedychium* spp., *Kaempferia* spp.

Family: Zingiberaceae

Origin: Southeast Asia

Other Names: Red ginger, Beehive ginger, Torch ginger, Butterfly ginger, Peacock ginger

Ornamental Gingers are iconic tropical and subtropical plants that have spectacular, brightly coloured flowers. The *Hedychiums* (butterfly gingers) are the most fragrant types of ginger. Good flowering requires proper sunlight. The varieties that prefer shadier conditions tend to perform best indoors. The species of genera *Etlingera* and *Zingiber*, of the family Zingiberaceae, are examples of exotic tropical flowers that present interesting features that led several producers and nationals to market them as cut flowers and as plants for landscaping.

Among the tropical floriculture products, ornamental gingers, species belonging to the families Zingiberaceae and Costaceae, have high potential for ornamental use, both for landscaping, for cut and potted flower and foliage. The species of Zingiberales are sources of globally important spices and ornamental plants, and have long been used in Asian traditional medicine, cuisine and as herbs. Some species have high ornamental value due to their attractive foliage or flowers, including *Zingiber spectabile* Griff, Alpinia, and Costus that had been commonly used as cut flower. These are popular cut flowers and have been promoted as a promising potted flower crop because of unique foliage, long-lasting colorful bracts, and few pest problems.

i. ALPINIA: *Alpinia purpurata*

Alpinia purpurata is one of the species cultivated in gardens for ornamental purposes for its attractive and long-lasting flowers. These gingers are frost-sensitive, and warm-temperatures are needed for good production. It grows well in rich soil and in wet habitats, but it few at a time. can grow in dry areas as well.

Post harvest vase life is reported to be around 10-16 days but it has been reported that it tends to be greater with thicker stems. Harvest is normally done when about ½ to ⅔ of the bracts have opened. The flowers should be held at temperatures above 10°C (15°C is preferable, with high humidity) as colder temperatures cause bract discoloration. Postharvest life is increased by use of floral preservatives containing 2% sucrose and 8-HQC (8-hydroxyquinoline citrate), antitranspirants, or simply recutting the stems.

ii. HEDYCHIUM: *Hedychium coronarium*

The common name, butterfly ginger, is often applied to the flowers of *Hedychium coronarium,* because the flower resembles a butterfly, and many species attract butterflies and moths. In Hawaii, commercial growers use lights for winter flower production, suggesting that *H. coronarium*, at least, is a long day plant. Current recommendations call for using fresh cut stems without storage and the buds just beginning to open and showing color.

iii. ETLIGERA: *Etlingera elatior*

Etlingera elatior (formerly *Phaeomeria* or *Nicolaia*) is the most widely grown of the genus and finds use as a vegetable (the young inflorescence), cut flower and in the landscape. Propagation of *Etlingera* is by seed or division of the rhizome mass.

Torch ginger inflorescences have rather long vase life of about two weeks after full bloom. The large inflorescences of *E. elatior* are heavy and difficult to ship without damage to the bracts, and vase life is only about 4-5 days before discoloration sets in. It is also reported that sucrose in the holding solution improved water uptake, but caused some bract browning; they suggested that a low energy reserve prevented further development and improved vase life.

iv. ZINGIBER: *Zingiber spectabile*

While the green inflorescence of *Zingiber officinale* can be used as a cut flower and *Z. mioga* buds are consumed as vegetables, species such as *Z. spectabile* and *Z. zerumbet* are more widely grown for their cut flowers. *Zingiber spectabile* is a short-day species; it requires at least nine weeks of consecutive short days in order to initiate and develop flowers, Propagation is primarily by rhizome division or seed. The floral stems of ice cream can be harvested from the point at which the inflorescences have a diameter greater than the length or when they are long, longer than the diameter. The postharvest vase life of *Z. spectabile* has been variously shown to be 10 to 15 days.

v. KAEMPFERIA: *Kaempferia* spp.

Exquisitely beautiful, the purple and white flowers, resemble large ornate butterflies and are borne one or two at a time, each flower lasting several days, with more following on in succession over a period of weeks in summers. Flowers are very fragrant. Kaempferia species have short lived flowers with attractive, colored/patterned leaves that vary in size and shape. Its relatively small size ginger that is best suited for growing in a container and kept at table-top height. Peacock ginger adds cool color to a shady oasis.

IV. ORNAMENTAL CURCUMA

Scientific Name: *Curcuma alismatifolia*

Family: Zingiberaceae

Origin: Thailand

Other Names: Queen Lily, Siam Tulip

Curcuma family has quite an interesting and unique group of flowers. They come in many forms, shapes and colours. Thailand is one of the leading producers, although Israel also has also good cultivation using tissue cultured plants. *Curcuma alismatifolia* is a new flower crop with potential for expansion in the markets. The inflorescence comprises a number of pink coma bracts in the upper part and green coma bracts in the lower part, with small true flowers.

The propagation is through rhizomes and several storage roots termed as t-roots. Most species can be found in rich, well drained soils, in full sun to partial shade, and favoring humid habitats. It was observed that flowering of *Curcuma alismatifolia* was enhanced when the plants were subjected to a daylength of 20 hours, indicating that it is a quantitative long-day plant. Curcuma species or cultivars that have showy bracts and a long post-harvest vase-life are produced as cut flowers, while some dwarf forms are used as potted plants.

V. KANGAROO PAW

Scientific Name: *Anigozanthos* spp., *Macropidia* spp.

Family: Haemodoraceae

Origin: Australia

Other Names: Kangaroo Paw, Cat Paw Flower, Black Kangaroo Paw

A wide range of colours is available, which has increased the popularity of the genus on the international cut flower market. Flower evocation is directly related to the temperature, as temperatures rise, more flowers appear. While planting, the spacing is usually kept 50-75 cm between plants and 100-140 cm between rows. *Anigozanthos* is propagated by seed, each capsule containing many seeds, but germination is usually low. *Macropidia* has only three seeds per capsule and germination is difficult. Division of the rhizomes is also used with both genera.

Anigozanthos is usually harvested when two lower florets on the spike open. Cut kangaroo paw (*Anigozanthos* spp.) inflorescences are regarded as having poor storage potential. Between 2 and 5°C is a relatively safe storage temperature range for cut kangaroo paw flowers.

VI.GUZMANIA

Scientific Name: *Guzmania* spp.

Family: Bromeliaceae

Origin: Central and South America

Other Names:Scarlet Star

Guzmanias produce showy and long-lived inflorescences. What is commonly mistaken as the flower on the plant is actually a grouping of modified leaves, called bracts. The true flowers are white and do not rise above the colorful bracts. The range of colors for Guzmania is generally from yellow through orange but may also include flame red and red-purple. These may be advantageously grown as pot plants for greenhouse or home use. With 60 million plants sold each year as ornamentals, 65% being Guzmania hybrids, bromeliads are well-established in the flowering potted plant industry.

Guzmania are predominantly epiphytic with a few terrestrial species. Asexual propagation of Guzmania is frequently done through the use of tissue culture practices. Propagation can also be from off-shoots produced by the plant which may then be rooted. The resulting plantlets are detached from the mother plant and may be potted up in a suitable growing mixture.

In guzmania cultivation, tubing is a problem related to water uptake which causes great economic losses. Instead of arranging their leaves into a typical open bromeliad rosette, the leaves form an upright, twisted structure rendering up to 10% of plants worthless for sale. A little is known about the mechanism and factors leading to tubing. Prestorage spray with 60 μM BA could significantly improve the post-storage quality or post-shipment quality of Guzmanias.

VII.CHINCHIRINCHEE

Scientific Name: *Ornithogalum dubium*

Family: Asparagaceae

Origin: Cape Province in South Africa

Other Names: Star of Bethlehem

Ornithogalum is mainly grown for cut flower and flowering pot-plant production. It generally produces 10-25 cm-long flowering-stems, bearing 5-25 yellow to orange flowers with a dark green/brown center. It is in great demand in Europe and North America as a cut flower and a flowering-house pot plant.

It is commercially propagated through bulbs which are planted in spring or autumn to a depth of 5-10 cm in fertile loose loamy soil. It is comparatively frost tolerant and can withstand harsh winters. The flowers are harvested when the lowest first buds in the inflorescence open. The flowers retain freshness for a long time (from 2 to 4 weeks).

VIII. WAX FLOWER

Scientific Name: *Chamelaucium uncinatum*

Family: Myrtaceae

Origin: Western Australia

Other Names: Geraldton Wax

Wax flower is commonly used as a cut flower due to the showy blooms and their longevity once removed from the plant. Flower colours from white through to purple/red are known. It is regarded as an environmental weed in those parts of Western Australia where it has become naturalised outside its native range. A highly ornamental yet hardy foliage plant. Although used as filler in flower arrangements, Geraldton waxflower makes a striking display alone. Wax flower tolerates a wide range of conditions. In high rainfall areas Botrytis flower blight may be an ongoing problem.

Harvesting of waxflower is very labour intensive, as stems are cut by hand, when the number of flowers open is between 30-70%, depending on variety, time of season and market requirements. The most important export markets for Australian wildflowers, foliage and native plants are Japan (36%), the Netherlands (30%), the United States (16%), Germany (6%) and Canada (4%). Western Australia accounted for 34% of the total value of exports in this period, Queensland 28%, Victoria 24%, and New South Wales 13%.

IX. CRASPEDIA

Scientific Name: *Craspedia globosa*

Family: Asteraceae

Origin: Australia and New Zealand

Other Names: Billy buttons and Woollyheads

Adaptable and drought resistant, *Craspedia* forms a clump of silvery-green foliage topped by yellow, drum-stick blooms. It is very popular with florists for both fresh and dried flower arrangements as the bright-yellow, spherical flower heads are long lasting and form on long, stiff stems up to 90cm tall. The Australian drumstick flower has the potential as a speciality cut flower because it has an acceptable vase life, long sturdy scapes, flowers that are suitable for drying, and a unique flower shape because the individual flowers form a globular head.

The sulphur yellow golf-ball-shaped flowers will appear all year round in temperate climates and are said to symbolise good health. *Craspedia* is very popular for drying and can be used to dramatic effect when clustered closely together in flower arrangements. In 2011, craspedia was in big demand for its use in wedding flowers. It requires good drainage. Do not overhead-irrigate. Harvest period-Spring/summer. Stage of development- Yellow flowerheads fully developed. Floral preservative helpful but not necessary. Hang to air-dry.

X. STATICE

Scientific Name: *Limonium sinuatum and Limonium sinensis*

Family: Plumbaginaceae

Origin: Europe, Mediterranean and Central Asia and Canary Islands

Other Names: Sea Lavender, Notch Leaf Marsh Rosemary and Marsh Rosemary

Limonium sinensis: Annual statice is an important cut flower and is used as a filler material in floral art or as a dried item. It is an annual plant which has a rosette plant habit. The 12 to 24″ flower stems have colored bracts which surround the white flower. The bract colors include white, yellow, lavender, peach and shade of blue.

The soil should be well drained; sandy or sandy-clay soils are recommended. The advised planting distance between each plant is 30 cm×30 cm. A day length of 14 hours or more promotes earlier flowering and better quality of flowers. The plants are sensitive to high moisture content. Statice is also known as an 'everlasting flower' because its pretty calyx stays on much after the flower has dried. The tiny funnel shaped statice flowers have a delicate, airy, hazy appearance, almost like smoke.

The flowers are perfect for drying, for use in bouquets. They are ideal for beds, borders in any garden. For pot culture: statice can be sown directly into pots. This annual species is propagated from seeds. Seedlings emerge in 1 to 2 weeks at ambient temperature, and are ready to transplant in 4 to 5 weeks. The optimal stage of harvest: Almost fully open flowers

Postharvest Handling: Most varieties will last 1 to 2 weeks in the vase in water, and also maintain excellent color when dried. Extended leaf-like projections along the stem are common with many varieties, and tend to shorten vase life if not stripped away at harvest.

Limonium sinensis: It is an essential filler for bouquets, corsages and other flower arrangements which is suitable for cut flower greenhouse or field production. This species is specifically selected for absence of fragrance, high-quality and strong stems, bright flower colors, high productivity, and multiple flushes.

Limonium sinensis is suitable for bouquets and solid bunches due to its wide availability of colors. The long-lasting snow-white and yellow Limonium is perfect for tinting

Crop time: From planting to harvest: 16 weeks, thereafter, production starts every 14 weeks.

Netting is provided at 2-3 levels in order to give support to the plants. In order to stimulate the basal sprouting of new stems, pinch when the first stem is induced. Handle with care to avoid damaging the growth points.

Harvest: Harvest when minimum 50% of the flowers are open. Flowers do not open once harvest.

Post harvest treatment: Hydrate in an initial solution of Chrysal 0.3 cc/lt for 4 hours.

XI.BABY'S BREATH

Scientific Name: *Gypsophila paniculata*

Family: Caryophyllaceae

Origin: Eurasia

Other names: Poor man's Rose

The small, white blossoms of baby's breath are a classic addition to floral arrangements, from wedding centerpieces to baby showers to florist wreaths. Despite its delicate-sounding name, baby's breath is an incredibly hardy and low-maintenance flower that is great for adding an airy, billowing element to your flower garden or rock garden. The flower inducement is more effective after 45 days of vernalization & 16 hours of photoperiod indicating that it is a long-day plant.

Light is critical factor in flower production during winter of gypsophila. It does best in full sun in cool summer areas or partial sun in warm summer areas. The optimum growing temperature is 15°C. Higher temperature (30°C) will reduce the number of flowers.

While its blooms are only about a pencil eraser's size, each baby's breath plant can grow hundreds of blooms, making them a spectacular addition to a flower garden. It is propagated sexually as well as asexually. Sexual propagation is through seeds while asexual methods involve cuttings, grafting and micropropagation. After the second flush, the plants are pruned usually 2-3 cm above ground level.

Post-harvest handling: The vase life: 14 days, the flower can be stored for 1-2 days at 4°C. The dried flowers last for >1 year

Bud opening solution: Improve the water balance of cut inflorescence during transport (200ppm 8HQC + 25 ppm silver nitrate + 5-10% sugar for 72 hours).

Pulsing solution: 5% sucrose + 510 ppm Benzalkonium chloride + 300 ppm 17 GA at 21°C results the longest vase life with 99% flower opening.

Storage of cut flower: Gypsophila flowers with about 50% flowers in open condition kept in a preservative solution. Can be stored for >2 weeks at 2°C. It should not be stored dry as the flowers will fail to open.

Drying of flowers:

Two methods are employed:

1. Flowers are air dried & kept upright in a container of water covering only the cut ends, at a temperature of 10°C
2. Flowers are dipped in a solution of 1 part of glycerine & 2 parts of water. The flowers should be removed from the glycerine solution when drops of water accumulate on the leaf surface. Stem should be dried keeping the flowers hanging down in a well aerated room.

XII. LISIANTHUS

Scientific Name: *Eustoma grandiflorum*

Family: Gentianaceae

Origin: Warm regions of the southern United States, Mexico, Caribbean and northern South America

Other names: Poor Man's Rose, Prairie Gentian

Lisianthus, ranks high among ornamental cut flowers, and is popular for its bright, colourful petals, long post-harvest life, and the ease at which it can be shipped worldwide. Flowers of various colours (purple, pink, white, yellow, lavender and pink or purple edged white) and forms (bell and funnel shaped corollas) with excellent vase-life are produced. This plant is attractive both as a cut crop and as a potted one. In European and Asian markets, it is already listed among the top selling cut flowers. Double- and even triple-petal lisianthus have resulted in luxurious blooms.

It prefers moderate climate and for better growth and quality flower production, the optimum day and night temperatures should be maintained between 20-24°C and 16-18°C, respectively. Higher temperatures (above 28°C) during the first four weeks of transplanting can induce rosetting in susceptible varieties. The optimal light levels for lisianthus flower are 4,000 to 6,000 ft candles.

Lisianthus is mainly propagated through seeds. Sown in mid-December to February in the hills. Seedling growth is very slow. For this reason, it is advisable to purchase plug seedlings from commercial nurseries. Vegetative propagation through rooting of cuttings and micro-propagation are the alternative methods for propagation of this crop. Some growers perform single pinching after 20-25 days of transplanting.

Harvesting: The Lisianthus cut flowers are harvested when one or more flowers are open. Lisianthus is not known to be sensitive to ethylene. However, pulsing with 10% sucrose for 24 hours after harvest has been reported to increase vase life of this flower. The vase life of cut Lisianthus ranges from 12-15 days depending upon cultivars.

XIII. ORNAMENTAL KALE

Scientific Name: *Brassica oleracea var. acephala*

Family: Brassicaceae

Origin: Mediterranean Region

Other Names: Ornamental Cabbage, Ornamental Kale

The potential to expand the production of ornamental kale as a specialty cut flower appears promising, especially for the winter holidays. Special varieties are available in the market which are grown only for cut flower purposes. Tinting of kale in various food dyes results in variously coloured cut flowers. It is a cool-weather biennial usually grown as an annual in the cool gardens of fall, and winter.

Landscape use and Planting:

It can be added to seasonal colour areas of a landscape because of its large rosettes of white, pink, purple or red leaves. Kale is used as bedding plants for colour and landscape contrast. They can be planted in between other plants for a change in the landscape. Kale performs best when set out in full sun in early October through November, and planted 10 to 12 inches apart.

Soil: Plants can be grown in any good quality soilless substrate that has good water holding capacity. The colors begin to develop once nighttime temperatures dip below 15°C. As a matter of fact, a chilling frost suppresses chlorophyll production and intensifies rosette colors. It is propagated by seeds. The seedlings are then transplanted to pots or to the fields. For tall cultivars, staking is required to maintain an erect posture. Summer gardens transition beautifully to fall and winter when you clear away plants that have finished blooming, and replace them with ornamental kale rosettes.

Postharvest Handling: The heads will last 1 to 2 weeks in water after harvest. Head color may change gradually to green if plants face warm conditions.

Future strategies

(i) Introduction and acclimatization of new cut flowers.

(ii) Need for providing research support on new cut flowers.

(iii) Exploration and exploitation of indigenous new ornamentals.

(iv) Information on consumer attitudes which influence floral purchasing needs to be collected.

(v) Prioritizing coordinated well-focused research programme and policy for development of new crops.

The increasing consumer demand for versatility, durability and low cost of flowers in the last few years, has made markets constantly seek out for new products. Thereby, new varieties are constantly introduced into the flower market every year, contributing to its renewal. Although the assortment of ornamental crops is already very large, there are still possibilities for new crops as the market is always asking for something new. The novelty in market can not only be achieved by introduction of exotic germplasm, but also by the introduction of indigenous and wild ornamentals and also by the development of new varieties of the already existing ornamental germplasm in the country.

Conclusion

Although traditional cut flower crops will continue to play key role in the floriculture trade, to break the monotonous nature of the ornamental market, introduction of lesser-known new potential crops is very important. These new cut flowers would normally fetch higher prices than traditional crops for a certain period but quite often the prices will drop when market is saturated. By that time new cut flowers should be ready to enter the market. In this context, introduction of new cut flowers is of paramount importance.

43. Sustainable agro technology development and healthy planting material production of under exploited and exotic spices

K. Kandiannan*, V. Srinivasan and R. Dinesh
ICAR – Indian Institute of Spices Research, Kozhikode, Kerala
*Email: Kandiannan.K@icar.gov.in, kandiannan@gmail.com

Introduction

Spices played a pivotal role in the human history and civilization. Spices are considered as "Divine Crops", and they are low volume and high value commodities, human food is incomplete without spices. Spices primarily used to flavor food and to provide aroma, texture, and color. Spices are also useful in preservative, nutritional, and health benefits. The word "spice" came from the Latin word "species," meaning specific kind. The name reflects the fact that all plant parts have been cultivated for their aromatic, fragrant, pungent, or any other desirable properties including the seed (e.g., aniseed, caraway, and coriander), leaf (cilantro, kari, bay, and mint), berry (allspice, juniper, and black pepper), bark (cinnamon), kernel (nutmeg), aril (mace), stem (chives), stalk (lemongrass), rhizome (ginger, turmeric, and galangal), root (lovage and horseradish), flower (saffron), bulb (garlic and onion), fruit (star anise, cardamom, and chile pepper), and flower bud (clove) (Susheela, 2006).

The term "spice" is defined in the U.S. Code of Federal Regulations for specific labeling requirements. "Spice" is defined under 21 CFR Sec. 101.22(2) (2) The term spice means any aromatic vegetable substance in the whole, broken, or ground form, except for those substances which have been traditionally regarded as foods, such as onions, garlic and celery; whose significant function in food is seasoning rather than nutritional; that is true to name; and from which no portion of any volatile oil or other flavoring principle has been removed. Many other definitions for spices are exist from ASTA, FAO, ISO etc. In simple terms "Spices are products of plant origin, used primarily for adding taste, flavor, colour or all such qualities to foods and beverages during the process of their preparation or manufacture (Ravindran, 2017). Seidemann (2005) has listed over 1400 spice and aromatic plants in his book, whereas, Ravindran (2017) described 260 plants used as source of herbs and spices by humankind globally.

Nowadays, food professionals continually search for "new" and unique spice flavorings because of the growing global demand for authentic ethnic and cross-cultural cuisines. Consumers are also seeking natural foods and natural preservatives for healthier lifestyles and natural ways of preventing ailments. So, spices are also being sought for their medicinal value, as antioxidants, and as antimicrobials. These herbs and spices constitute an important agricultural commodity; many are traded globally and are indispensable for pharmaceuticals, flavouring foods and beverages, and in the perfumery and cosmetic industries. More recently, they are increasingly being identified as having high nutraceutical potential and important value in human healthcare. When we discuss about under-utilized spices, first we should know about what are the spices produced commercially and utilized or consumed and exported. Spice trade is ancient, it was Arab trader sourced from Asia-Pacific Regions and sold to European market via "Spice Route".

Area and production of spices

Spices are important group of horticultural crops, ISO approved list of spices are 109, whereas, in India, we recognized 52 spices under Spices Act 1986. All of them are not cultivated in large commercial scale; only around 20 of them are grown in large scale (Table 1). On an average (four years average 2018-19 to 2021-22), spices are grown in 4.2 million ha with a production of 10.43 million tonnes. Spice crops account 15.91% area and 3.19% production of total horticultural crops in India. Cumin, chillies and coriander alone occupy around 55.0% of total spices area, whereas, garlic, ginger, chillies and turmeric shared 78.4% of spices production. The share of clove, vanilla and saffron to the total spice area and production is comparatively less

Table 1. Area and production of spices in India

Sl. No.	Crops	Area ('000ha) Mean (2018-19 to 2021-22)	% Share to total	Production ('000 tonnes) Mean (2018-19 to 2021-22)	% Share to total
1	Pepper	274.171	6.40	119.207	1.14
2	Ginger	190.012	4.44	2110.665	20.22
3	Chillies	728.18	17.01	1810.55	17.35
4	Turmeric	295.97	6.91	1123.192	10.76
5	Garlic	382.398	8.93	3139.682	30.08
6	Cardamom	84.867	1.98	28.492	0.27
7	Coriander	552.033	12.89	731.083	7.00
8	Cumin	1065.105	24.88	740.947	7.10
9	Fennel	80.22	1.87	137.4	1.32
10	Fenugreek	142.737	3.33	214.832	2.06
11	Ajwan	39.303	0.92	30.981	0.30
12	Dill/Poppy/Celery	27.73	0.65	30.777	0.29
13	Cinnamon/Tejpat	2.412	0.06	5.991	0.06
14	Nutmeg	23.935	0.56	16.266	0.16
15	Clove	2.016	0.05	1.191	0.01
16	Tamarind	42.82	1.00	154.953	1.48
17	Vanilla	0.111	0.00	0.055	0.00
18	Mint (Mentha)*	343.576	8.03	40.691	0.39
19	Saffron	3.558	0.08	0.004	0.00
	Total	**4281.152**	**100.00**	**10436.959**	**100.00**

Note: 1. Ginger production are in terms of FRESH, 2. Turmeric production in terms of DRY, Cardamom includes both small and large cardamoms; * *Mentha species*

Export and import of spices in India

India is the largest producer, consumer and exporter of spices in the world. Indian Spices are renowned across the world for their rich intrinsic qualities, since time immemorial despite the global pandemic situation. India's spice exports, with a volume of 17,58,985 tons valued Rs.30973.32 crores during 2020-21, scaled the landmark level of 4.1 billion US$ in value realization, besides recording a growth rate of 37% in volume, 16% in rupee terms and 11% in dollar terms of value over the previous year. The Indian spice sector has a strong exporter base with over 7000 registered exporters, who export spices and value-added spice products to over 180 destinations worldwide. India is the global leader in spice oils and oleoresins, curry powders, turmeric, chilli, cumin etc. and a strong supplier of a wide range of spices and spice products worldwide. On an average (five-year mean (2017-18 to 2021-22), India export 1.3 million tonnes of spices to the value of Rs 24169.28 crores (Table 2). The top destinations among them were China, USA, Bangladesh, Thailand, the UAE, Sri Lanka, Malaysia, the UK, Indonesia and Germany. These ten destinations comprised more than 70 per cent of the total export earnings in 2020-21. India exports only 12.69% of the spice production.

Table 2. Item-Wise export of spices from India (Qty.in tonnes & value in Rs. Lakhs)

Sl No.	Item	QTY	% Share to total	VALUE	% Share to total
1	Pepper	17,845	1.35	65743.478	2.72
2	Cardamom(S)	5,487	0.41	77396.766	3.20
3	Cardamom(L)	1,226	0.09	8785.344	0.36
4	Chilli	523,071	39.47	684019.318	28.30
5	Ginger	78,963	5.96	52549.718	2.17
6	Turmeric	143,035	10.79	139916.154	5.79
7	Coriander	47,447	3.58	40037.956	1.66
8	Cumin	210,711	15.90	324521.368	13.43
9	Celery	6,765	0.51	7834.516	0.32
10	Fennel	31,780	2.40	28814.918	1.19
11	Fenugreek	31,148	2.35	19042.924	0.79
12	Other Seeds (1)	40,986	3.09	27987.432	1.16
13	Garlic	27,708	2.09	19754.996	0.82
14	Nutmeg & Mace	3,822	0.29	18260.7	0.76
15	Other Spices (2)	56,625	4.27	88496	3.66
16	Curry Powder/Paste	41,239	3.11	90053.818	3.73
17	Mint Products (3)	26,271	1.98	378365.632	15.65
18	Spice Oils & Oleoresins	16,373	1.24	303709.524	12.57
	TOTAL (Incl Others)	**1,325,271**	**100.00**	**2416928.35**	**100.00**

(1) Include Bishops Weed (Ajwan seed), Dill Seed, Poppy Seed, Aniseed, Mustard etc.

(2) Include Asafoetida, Cinnamon, Cassia, Cambodge, Saffron, Spices (Nes) Etc.

(3) Include Menthol, Menthol Crystals And Other Mint Oils.

India also import spices, on an average (five year mean (2017-18 to 2021-22), India imported 2.16 Lakhs tonnes to the value of ₹ 6364.63 crores (Table 3). Major spice items in terms of quantity imported are cassia (14.02%), black pepper (13.63%), turmeric (11.69%), clove (10.48%) ginger (10.33%) and coriander (7.18%); whereas, in terms of value, spices such as clove (15.58%), black pepper (14.51%), asafoetida (10.88%), spices oils & oleoresins (9.66%) and cassia (8.82%) are in the top.

Table 3.Item-Wise import of spices into India (Qty in Tonnes &Value in Rs. Lakhs)

Sl. No.	Crop	Quantity	% Share to total	Value	% Share to total
1	Pepper (1)	29486.6	13.63	92370.8	14.51
2	Cardamom (Small)	431.8	0.20	4654.55	0.73
3	Cardamom (Large)	6031.4	2.79	32303.3	5.08
4	Chilli / Paprika	1667.8	0.77	3359.79	0.53
5	Ginger Fresh / Dry	22349	10.33	12795.6	2.01
6	Turmeric	25293.4	11.69	24090.7	3.79
7	Coriander	15530	7.18	9272.77	1.46
8	Cumin Black / White	3771.2	1.74	6274.66	0.99
9	Others Seeds (2)	1959.8	0.91	2157.55	0.34
10	Poppy Seed	9561.8	4.42	18256.3	2.87
11	Garlic	2509.6	1.16	1421.25	0.22
12	Clove	22665.4	10.48	99139.2	15.58
13	Nutmeg	1109.6	0.51	4098.6	0.64
14	Mace	1856.2	0.86	18545	2.91
15	Cassia	30341.6	14.02	56123.9	8.82
16	Star Anise	6601	3.05	26037.5	4.09
17	Spices Oils & Oleoresins	3506.25	1.62	61508.4	9.66
18	Mint Products (3)	3100.21	1.43	32898.9	5.17
19	Caraway/Fennel	5685	2.63	13241.5	2.08
20	Tamarind	2303.2	1.06	2096.69	0.33
21	Cinnamon	1857.6	0.86	5777	0.91
22	Asafoetida	1429.4	0.66	69244.4	10.88
23	Curry Powder/Paste	3110.4	1.44	6776.9	1.06
24	Herbal Spices (4)	6523.4	3.02	7642.57	1.20
25	Other Spices(5)	7668	3.54	26374.8	4.14
	Total	**216350**	**100.00**	**636463**	**100.00**

Source: DGCI&S, CALCUTTA/DLI FROM CUSTOMS UPTO 2019-20 and 2020-21/2021-22 figures are taken from only DGCI&S, Kolkatta and include re-import also)

(1) Include White Pepper, Light Pepper and Black Pepper

(2) Include Mustard, Celery, Ajwan, Juniper Berry, Fenugreek, Dill and Badian Etc.

(3) Include Menthol, Menthol Crystals and Other Mint Oils.

(4) Include Basil, Hyasop, Rose Mary, Sage, Savory, Mint, Incl. Leaves (All Species), Garcinia and Greater Galangal Etc.

(5) Include Saffron, Kokam, Vanilla, Spices Husk/Spent and Spices Nes

Note: Spices statistics are collected from DASD, Kozhikode and Spice Board, Kochi websites

Under-utilized spice crops

Some of the spices and herbs are widely grown and widely used; some are extremely restricted and are used only in few limited locations or regions; some are produced on a large scale and traded widely and globally; and some are not cultivated or traded but instead the wild-grown plants are collected and used, while others are less known and are under-utilized. Such under-utilized herbs and spices are indeed valuable, not only as spices for flavouring dishes, but also as medicinal plants of great importance (Ravindran *et al.*, 2004; 2006). A list of such under-utilized herbs and spices 55 numbers is given in Table 4. Sanwal (2008) has included (i) bird eye Chilli or King Chilli (World's Hottest Chilli) also called "Bhut Jolokia" (*Capsicum chinense* Jacq.), (ii) mango ginger (*Curcuma amada* Roxb.); (iii) black ginger (*Kaempferia parviflora* Wall.) and Long coriander (*Eryngium foetidum* L.) in under-utilized spices. There is no data on area, production and other statistics for this group of crops.

Exotic spice crops

Spices and herbs such as black pepper, cinnamon, turmeric, and cardamom have been used by Indians for thousands of years for both culinary and health purposes. Spices indigenous to India (such as cardamom and turmeric) were cultivated as early as 8thcentury BC in the gardens of Babylon (Duke *et al.*, 2003). Sushruta, an ancient surgeon (around 4thcentury BC), used white mustard and other aromatic plants in bed sheets to ward off malignant spirits. He also applied a poultice from sesame to postoperative wounds which may have acted as an antiseptic. Medical writings of Charaka(1stcentury) and Sushruta-II(2ndcentury) referenced spices and herbs. Sushruta II also used spices and herbs such as cinnamon, cardamom, ginger, turmeric and pepper for healing purpose. Spices such as cardamom, ginger, black pepper, cumin and mustard seed were included in ancient herbal medicines for different types of health benefits. In Ayurvedic medicine, spices such as cloves and cardamom were wrapped in betel-nut leaves and chewed after meals to increase the flow of saliva and aid digestion. Though India is considered as 'Land of Spices' many are exotic spice crops e.g. chilies, tamarind, clove, nutmeg, vanilla, cassia, seed spices, herbal spices etc., however, they are all naturalized to agro-climatic conditions in India.

Healthy planting materials production

Seed / planting material is an important input for successful and sustainable production of all the crops. This group of crops has different life span viz., seasonal, annual and perennial, some are seed propagated and others are through vegetative means and some crop can be multiplied both the modes ie., through seed as well as vegetative methods. The tree spices can be propagated through cuttings, layering, grafting and budding. Micro-propagation is also an important technique to generate quality disease free planting materials. Simple structures to hi-tech poly houses can be employed to produce quality planting materials. Sourcing mother plants, ideal potting mixture, solarization / sterilization, fortification with bio-control agents, regular irrigation and periodical plant protection are essential operations in the process of healthy planting material production. Different type and size of poly bags, pro-trays and containers are used in the nursery. Depending upon the nature of crop, nursery duration may vary from few days to two years, if it is kept for long time, repotting is required for better and healthy growth. There is no set of 'Seed / planting materials Certification Standards' for this under-utilized herbs and spices, developing such guidelines would help to strengthen systems of seed supply chain for these crops.

Table 4. Under-utilized Spice Crops

Sl. No.	Common name	Botanical name	Family	Edible part(s)
1	Ajowan/Bishop's weed	*Trachyspermum ammi* L.	Apiaceae	Fruit
2	Aniseed	*Pimpinella anisum* L.	Apiaceae	Fruit
3	Asafoetida	*Ferula asafoetida* L.	Apiaceae	Dried latex from the rhizome or tap root
4	Balm	*Melissa officinalis* L.	Lamiaceae	Leaf
5	Basil	*Ocimum basilicum* L.	Lamiaceae	Leaf
6	Bay Leaf	*Laurus nobilis* L.	Lauraceae	Leaf
7	Betel leaf	*Piper betle* L.	Piperaceae	Leaf
8	Black caraway	*Bunium persicum* (Bosis) B Fedtsh.	Apiaceae	Seed, tuber
9	Black caraway	*Carum bulbocastanum* L	Apiaceae	Fruit, Bulb
10	Black cumin	*Nigella sativa* L.	Ranunculaceae	Fruit
11	Black mustard	*Brassica nigra* Koch.	Brassicaceae	Seed
12	Cambodge	*Garcinia cambodgia* Desr.	Clusiaceae	Pericarp lobes
13	Caper	*Capparis spinosa* L.	Capparaceae	Unopened flower bud
14	Caraway	*Carum carvi* L.	Apiaceae	Fruit
15	Cardamom (large)	*Amomum subulatum* Roxb.	Zingiberaceae	Seed
16	Cassia	*Cinnamomum cassia* Blume	Lauraceae	Bark
17	Celery	*Apium graveolens* L.	Apiaceae	Seed
18	Cinnamon	*Cinnamomum zeylanicum* Breyn	Lauraceae	Bark
19	Common juniper	*Juniperus communis* L.	Cupressaceae	Fruit
20	Curry leaf	*Bergera koenigii*, Syn.: *Murraya koenigii* (L) Sprengel	Rutaceae	Leaf
21	Dill	*Anethum graveolens* L.	Apiaceae	Fruit
22	Fenugreek	*Trigonella foenum- graecum* L.	Fabaceae	Seed, leaf
23	Galangal	*Kaempferia galanga* L.	Zingiberaceae	Rhizome, tubers
24	Garden angelica	*Angelica archangelica* L.	Apiaceae	Root
25	Greater galangal	*Alpinia galangal* Wild.	Zingiberaceae	Rhizome
26	Guinean pepper	*Xylopia aethiopica* (Dunal) A. Rich.	Annonaceae	Fruit
27	Horseradish	*Armoracia rusticana* Gaertn.	Brassicaceae	Root
28	Hyssop	*Hyssopus officinalis* L.	Lamiaceae	Leaves
29	Indian cassia/Tejpet	*Cinnamomum tamala* Nees and Eberum	Lauraceae	Bark, leaf
30	Indian mustard	*Brassica juncea* Czen and Cross.	Brassicaceae	Seed
31	Japanese pepper	*Zanthoxylum piperitum* (L.) DC	Rutaceae	Fruit and rind

32	Kokum	*Garcinia indica* Choisy	Clusiaceae	Peel of fruit
33	Lovage	*Levisticum officinale* Koch.	Apiaceae	Fruit, root
34	Malabar tamarind	*Garcinia gummi-gutta* (L.) N. Robson	Clusiaceae	Pericarp lobes (fruit rind)
35	Mango	*Mangifera indicia* L.	Anacardiaceae	Unriped fruit
36	Mint	*Mentha piperita* L.	Lamiaceae	Leaves
37	Nutmeg and mace	*Myristica fragrans* Houtt.	Myristicaceae	Seed and aril
38	Oregano	*Origanum vulgare*	Lamiaceae	Leaf, flowering top
39	Pandan wangi	*Pandanus amaryllifolius* Roxb.	Pandanaceae	Leaf
40	Parsley	*Petroselinum crispum* Mill.	Apiaceae	Leaf
41	Pepper long	*Piper longum* L.	Piperaceae	Berry
42	Pomegranate	*Punica granatum* L.	Punicaceae	Seed
43	Poppy seed	*Papaver somniferum* L.	Papaveraceae	Seed
44	Rosemary	*Rosmarinus officinalis* L.	Lamiaceae	Leaves
45	Saffron	*Crocus sativus* L.	Iridaceae	Stamen
46	Sage (Garden sage)	*Salvia officinalis* L.	Lamiaceae	Leaf
47	Star anise	*Illicium verum* Hook.	Illiciaceae	Fruit
48	Summer savoury	*Satureja hortensis* L.	Lamiaceae	Stem, leaf, flowering top
49	Sweet flag	*Acorus calamus* L.	Araceae	Roots
50	Sweet marjoram	*Marjorana hortensis* Moench.	Lamiaceae	Leaf, flowering top
51	Tamarind	*Tamarindus indica* L.	Fabaceae	Pulp, seed
52	Thyme	*Thymus vulgaris* L.	Lamiaceae	Leaves, flowers
53	Vanilla	*Vanilla planifolia* Andr.	Orchidaceae	Pod
54	White mustard	*Sinapis alba* L.	Brassicaceae	Seed
55	Winter savory	*Satureja Montana* L.	Lamiaceae	Leaf, flowering top

Source: Ravindran *et al.* (2004; 2006), and Sarangi *et al.* (2018)

i. Serpentine layering technique

Serpentine method can be used for production of rooted cuttings of black pepper in a cheap and effective manner. In a nursery shed with roofing sheet or shade net, rooted black pepper cuttings are planted in polythene bags holding about 500 g potting mixture, which will serve as mother plants. As the plant grows and produces few nodes, small polythene bags (20 ×10 cm) filled with potting mixture may be kept under each node (Fig. 1). The node may be kept gently pressed in to the mixture assuring contact with the potting mixture with the help of a flexible twig such as mid rib of a coconut leaflet. Roots start growing from the nodes and the cuttings keep on growing further. The process of keeping potting mixture filled polythene bags at every node junction to induce rooting at each node is repeated. In three months the first 10 to 12 nodes (from the mother plants) would have rooted profusely and will be ready for harvest. Each node with the ploythene bag is cut just below the rooted node. The cut end is also buried into the mixture to induce more roots. Polythene bags used are filled with solarized potting mixture fortified with biocontrol agent. The Potting mixture is prepared by mixing two parts of fertile topsoil, one part of river sand/granite powder and one part of FYM (2:1:1). The rooted nodes will produce new sprouts in a week time and will be ready for field planting in 2-3 months. The growing vines are to be irrigated every day with a rose can or sprinklers. By this method, on an average, 60 cuttings can be harvested per mother plant in a year. Similar technique can be used other under-utilized spices which are vines like type of long peppers, vanilla, etc..,.

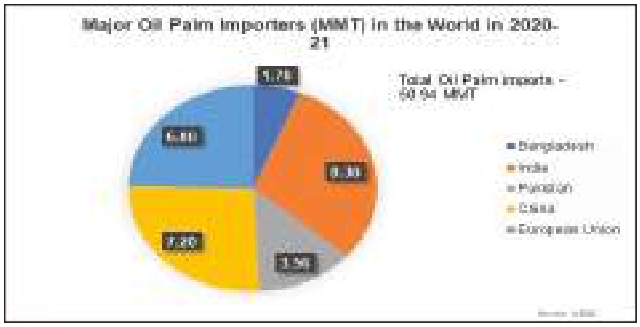

Fig. 1. Serpentine layering technique

i. Transplanting technology

Transplanting is not common in ginger and turmeric, it is found profitable. A transplanting technique in by using single bud sprouts (about 5 g) has been standardized to produce good quality planting material with reduced cost. The yield level of transplants is on-par with conventional planting system. The technique involves raising transplants from single sprout seed rhizomes in the pro-tray and planted in the field after 30-40 days (Fig. 2). The advantages of this technology are production of healthy planting materials and reduction in seed rhizome quantity and eventually reduced cost on planting material. This can be used for other rhizomatous crop like galangal, mango ginger etc.

Fig. 2. Ginger seedling from single buds in a pro-tray

i. Micro Propagation and micro-rhizome technology

Plant tissue culture facilitates rapid production of true to type plantlets which are disease free. The protocols for micro propagation were standardized by many workers (Nirmal Babu *et al.*, 1997). But tissue culture derived plantlets of ginger are not used for commercial planting due to its long time taken for rhizome formation and to get good normal sized rhizomes as that of conventional propagation. Production of pathogen free seed rhizomes under *in vitro* conditions by micro rhizome technology can be capitalized to ensure healthy crop. Micro rhizomes resemble the normal rhizomes in all respect, except for their small size. The micro rhizomes consist of 1 to 6 buds and 2 to 4 nodes. They have the aromatic flavour of ginger and resemble the normal rhizome in anatomical features in the presence of well-developed oil cells, fibres, and starch grains. *In vitro* formed rhizomes are genetically more stable when compared to micro propagated plants. Generally seed rhizome weight of micro rhizome was 2-8 g as against 20-30 g or even more in case of conventionally propagated plants. Micro rhizomes can be easily stored and transported to a long distance without much disturbance. It's often used for germplasm conservation due to longer storage possibility and efficiency in synthetic seed production. It is non-seasonal and is available for year-round crop production. This technology can be utilized for the multiplication of many under-utilized and exotic spices.

AGRO TECHNOLOGY

i. Identification of cropping zones:

Under-utilized spices are grown in limited area, by personal field visits, survey or from official statistics, we have to map the growing area, not only that, suitable growing conditions like climate, weather, soil, elevation etc.., need to be studied to expand the area of these crops. The GIS, climate analogue tools etc.., may be employed to delineate the cropping zones for under-utilized crops.

In India, the production of saffron from J&K is 3.83 tonnes whereas its annual demand is approximately 100 tonnes. In this country, there are geographical regions that have similar environmental and ecological conditions to J&K and possess the possibility of introducing this crop. Identification of such regions was made using Ecological Niche Modelling (ENM) (Kumar *et al.*, 2022). Therefore, 'MaxEnt' ENM was carried out using 103 environmental variables, 20 presence data and topographic parameters (elevation, slope and aspect) to find suitable regions for saffron production in unconventional areas of India. The achieved area under the curve for the model was 0.99. The precipitation and temperature were the main environmental variable influencing its cultivation. To increase the production of saffron, crop was sown in new modelled locations in India representing its various states such as Himachal Pradesh, Uttarakhand, Arunachal Pradesh, Sikkim, Manipur and Tamil Nadu. The quality, as well as yield of saffron produced in some of these regions, were evaluated and found at par with the saffron grown traditionally in India. Based on the promising results obtained in this work, expanding saffron cultivation to more modelled areas in India to meet our national demand is underway. The rosemary is suitable to grow in Himalayas and The Nilgiris. With rosemary herb cultivation yielding substantial income, more farmers are involved in raising the crop in Talavadi hills in the Erode district of Tamil Nadu is located along the border with Karnataka is a hill located at an altitude of 823 metres above the sea level favouring this crops. Similar locations can be found out to expand the area for this crop and other under-utilized crops.

ii. Improved varieties

Many crops in this category have no or less number of improved varieties, an effort is required to develop and popularize improved varieties.

iii. Plant health management

The production hampered by many disease causing pathogens like in black pepper - *Phytophthora* foot rot caused by *Phytophthora capsici*. The talc based bioformulation based on *Trichoderma harzianum* can be used successfully to manage *Phytophthora.* It can be used in Integrated Disease Management as well as under Organic farming system in crops like black pepper, ginger, cardamom and turmeric. There is a great demand for the product and IISR has already issued several licenses for its commercial production.

Plant parasitic nematodes, especially root knot nematodes (*Meloidogyne* spp.), are widely prevalent in

South India in black pepper growing soil and cause significant damage to the plants. Currently they are managed through application of nematicides like phorate and carbofuran. Biological control of root knot nematodes using *Pochonia chlamydosporia*, a known nematode biocontrol agent, therefore, is highly relevant in this context.

iv. Novel delivery of biocontrol agents

The bio agents like *Bacillus amyloliquefaciens* specific to ginger and consortium of three micro-organisms namely *Micrococcus luteus*, *Enterobacter aerogenes* and *Micrococcus sp*. for black pepper are successfully encapsulated and the delivery of a plant growth promoting rhizobacteria are made in to bio capsules by ICAR-IISR. The encapsulation process is simple, reduced cost and easy handling and transport, no harmful by products, storage at normal temperature with enhanced shelf life. Besides, this encapsulation technique can be used to deliver all kinds agriculturally important microorganisms. Patent for this delivery process has been filed and the technology has been commercialized by providing non-exclusive licenses to private companies. Such technology can be used for under-utilized spices as well.

v. Seed coating using PGPR

PGPR technology is a novel process of coating efficient strains of PGPR on seeds. Seed spices such as coriander (*Coriandrum sativum* L.), cumin (*Cuminum cyminum* L.), fennel (*Foeniculum vulgare* M.) and fenugreek (*Trigonella foenum-graecum* L.) cultivated predominantly in states of Rajastan and Gujarat have major constraints like low germination, slow initial growth and high susceptibility to diseases and frost. The seeds coated with PGPR exhibited longer shelf life and germination and remained intact even after 1 year of storage. The technology has wide applicability and can be extended to vegetable seeds imparting the appropriate crop specific bioagent.

vi. Crop-specific micronutrient formulations

Majority of soils in the spice growing areas are encountering fertility issues due to acidity, nutrient imbalances and deficiencies of secondary and micronutrients that becomes yield limiting. Besides crop specific, soil pH based micronutrient mixtures for foliar application in black pepper, cardamom, ginger, and turmeric crops which guarantees 10 to 25% increase in yield and quality have also been developed. The technology comes at very low cost and hence is very farmer friendly. The micronutrient technologies have been licensed to several entrepreneurs for large scale production and commercialization. Similar micronutrients mixture is possible for these crops.

vii. Organic farming Technologies:

Nutrient management plans for spices have been standardized for organic farming systems and organic packages have been developed for black pepper, ginger and turmeric integrating composts, oil cakes, biofertilizers/ PGPRs and biocontrol agents. Soil solarization coupled with $CaCl_2$ and PGPR (*Bacillus lichiniformis*) application showed good control of bacterial wilt of ginger even in sick field conditions. Bacillich, a *Bacillus lichiniformis*, based formulation for the control of bacterial wilt of ginger is a major breakthrough in IDM of ginger. Similarly, integrated management involving application of site-specific nutrient management, PGPRs and micronutrient application helped in sustaining the yield of virus affected black pepper plantations.

An entomopathogenic fungus, *Lecanicillium psalliotae*, effective in controlling the cardamom thrips was potentially identified and evaluated for agro-climatic conditions in Kerala and Karnataka. The technology is ideal for adoption in organic farming. A new species of group I multiple nucleopolyhedrovirus (NPV) infecting *Spilarctia obliqua*, a polyphagous pest of ginger, turmeric and other crops was also identified as potential bio-agent.

Alternate systems of growing:

Spices and herbs are highly amenable for different types of cropping systems. Also suitable for protected cultivation, vertical faming, hydroponics, crop rotation, ratoon, multi-cut cropping etc..,. These crops can be grown as an intercrop in tree crops or other perennial /annual crops to augment the systems productivity and farmers income.

Post harvest and Marketing:

Ultimately the farmers income is a major concern, unless farming is profitable, farmers will lose the interest and it is essential to take care the interest of primary producer by developing value chain models and buy-back arrangement and value addition etc..,. On-farm processing and value addition has to be imparted to the farmers for better quality products. Group farming is also possible in this group of crops for steady supply of sufficient quantities, so that traders can visit and buy the materials. The research on alternate use of under-utilized spices has to go a long way to strengthen sustainable production of these crops.

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44. Processing and value addition of a few underutilized fruits in India

Ram Krishna Pal
Chairman, Scientific Panel of Fruits &Vegetables, FSSAI, Min of Health & FW
Former Director, ICAR-NRCP, Solapur, Maharashtra
Former Professor & Head, Division of PHT, ICAR-IARI, New Delhi-110012
e-mail: rkpaug58@gmail.com

Introduction

India and other trop#ical countries are lucky to have access to a variety of naturally grown fruits and vegetables. Citrus fruits, guava, mango, apple, and banana are just a handful of the many widely available fruits. Fruit lovers and the general public should be aware that more fruits are occasionally referred to as "underutilized fruits" that are incredibly nutrient-dense in terms of their vitamin C, carotenoids, and antioxidants. A few years back and before the onset of Covid-19 pandemic, these fruits were inexpensive and widely available across the country.

Compared to exotic fruits like kiwis and avocados, some have distinct flavours and are simple to grow in arid climates. The underutilized fruit plants are also inherently resistant to disease and have evolved to thrive in hot, arid climates that are quite like equatorial climates. They are primarily found in the arid states of Gujarat, Madhya Pradesh, and Rajasthan in India. Arid natural or semi-arid areas are home to some of them.

Most underutilized fruits are rarely grown on farms, and information about their fruits and nutritional worth is sparse and dispersed. Moreover, since wild fruits contain many undesirable ingredients like tannins and glycosides, many individuals do not prefer to eat them. As a result, fewer of these fruits are consumed. Native fruits are small, juicy, and have a great number of seeds. These fruits are quite perishable and difficult to preserve in their fresh state. The majority of wild fruits are difficult to handle and eat. Many of them are frequently only sold in local markets and are little known throughout the rest of the nation.

Significance and processing underutilized fruits:

There is a huge untapped potential for their utilization and marketing both in India and abroad. With the latest awareness of nutraceutical and antioxidant properties in these commodities, there is an upward trend of consumption of these fruits and choice of therapy and nutrition through natural resources. These tropical and sub-tropical fruits namely bael and jamun are abundantly available in the eastern region of India and are known for their therapeutic and nutritive values particularly hypoglycemic factors in jamun juice and seed; curative factor of stomach ailments in bael. These fruits have been used in the traditional system of medicine; however, there is a great difficulty in the consumption of these fruits in fresh form.

Aonla (*Emblica officinalis*)

Aonla/Amalaki/Amla tree is climate resilient, a prolific bearer, and an ideal choice for arid areas of the country. One of the key messages of the concluding session of the International Year of Fruits and Vegetables by the UN-FAO held in Feb 2022 was to adopt diversity in dietary patterns with various fruits for daily consumption. The recently concluded G20 summit on Global Food Regulators Summit 2023, it was learnt about the great potential of Aonla for its anti-ageing factors in the experimental model using drosophila primarily due to its antioxidant properties. To harness the goodness of multiple health benefits, combating malnutrition, prevention of non-communicable diseases, including the strengthening of the immune system, it was advised to include Aonla in the diet regularly because of their numerous nurticeutical benefits. It is highly nutritive and one of the richest sources of ascorbic acid. It contains over 500 mg of ascorbic acid per 100g of pulp. The gallic acid present in aonla fruit has antioxidant properties. This fruit is extensively used in the preparation of Ayurvedic and Unani medicines. This fruit has gained wide popularity due to its nutritive and miraculous medicinal properties. It treats conditions like sleeplessness, scurvy, and constipation and is also used as a cooling agent to lessen the effects of sunburn.   In diabetic patients, it lowers blood sugar.

Aonla is also a common ingredient in hair tonics. The growth and colour of hair are both enriched. Hair loss and early greying are prevented by it. The fruit is difficult to eat as fresh or table fruit, as it is very astringent and highly acidic. Hence, processing plays a key role in making this wonder fruit popular among consumers. It is utilized to manufacture several ayurvedic tonics, including triphala and chayvanprash. But aonla fruits are processed into various food items, including preserves, jams, jellies, candies, toffee, pickles, sauces, squash, juice, RTS beverages, cider, shreds, dry powder, etc. Thus, the fruit finds a place in the food, pharmaceutical and cosmetic industries.

Moreover, due to very short period of availability, suitable technology for their processing is essential. Methods have been standardized at IARI, New Delhi, in the Division of Post Harvest Technology for extraction of pulp or juice from these fruits. Processes were optimized for production of several value added products viz., nectar, squash, syrup etc.

Antioxidant Rich Functional Food from Aonla

Attention has been focused on the preparation of different value-added products from aonla. Aonla preserve is an extremely popular traditional product, which is also known as *amla murabba* in India. Aonla preserve has the beneficial effect of purifying blood. This also helps in reducing the cholesterol levels in blood and in improving eyesight.

Nowadays, fruit candies are becoming increasingly popular because of high acceptability, minimum volume, higher nutritional value and longer storage life. These have the additional advantage of being the least thirst-provoking and ready-to-eat snacks. To prepare aonla candy, mature fruits are washed, pricked and dipped in 2 per cent salt solution for 24 hours. Then, fruits are washed and dipped in 2% alum solution for 24 hours. The fruits are thoroughly washed and blanched in boiling water for 5 minutes and steeped in 50° Brix syrup solution for 24 hours. The next day, steeping is done in 60° Brix for 24 hours. Again, steeping is done in 70° Brix for 72 hours. Excess syrup is drained. The fruits are dried to 15% moisture content and coated with powdered sugar/pectin. Packaging is done in LDPE pouches (400 gauge).

Aonla candy, developed in the Division of Post Harvest Technology, IARIi, New Delhi, has been proven by researchers that it is a nutritious, antioxidant-rich and a healthy product. A special type of aonla candy to enhance consumer appeal has been prepared by researchers too. This one is known as coloured Aonla candy that is antioxidant-rich and has natural food colour, distinctly different from normal aonla candy. Other aonla products are jam, sauce, biscuit and aonla drink etc.

Recently Aonla value chain was established for total utilization of harvested fruit by tribal women enterprises viz. M/S Jagriti International and Agrani International under the technological guidance and supervision of ICAR-CISH regional station at Malda, W.B. Several high-value products with viz. aonla juice, aonla powder and translucent aonla candies with both food safety and quality assurance were prepared and marketed through various marketing chains. An export license from APEDA has been granted to M/s Agrani International for export of various products

Bael (*Aegle marmelos*)

The bael, commonly called the stone apple or bengal quince, originated in India and Pakistan and has since spread throughout South-East Asia. It is one of the earliest domesticated fruits in India; it is significant in mythology because its leaves are used to worship Lord Shiva. The fruit is used for ayurvedic treatment for diarrhoea, eye dryness, and the common cold. Additionally, it strengthens the stomach and supports its functions while aiding in preventing scurvy.

The fruits are rich in nutrients such as calcium, phosphorus, iron, riboflavin, vitamin C, and beta-carotene. It contains 31.8% carbohydrates, 1.8% protein, 0.3% fat, 1.7% minerals, and 2.1% fibre. Additionally, it includes antioxidants with great therapeutic effects, such as marmelosin and psoralen. Due to its hard shell, mucilaginous, and very fibrous pulp and numerous tiny embedded seeds, bael fruit is not widely consumed as table fruit and is considered a difficult-to-eat fruit. Nevertheless, it has long been employed for making preserves from fully ripened green fruits. This is the only fruit that can yield 1 kg finished pulp from one Kg fruit due to its high content of water-soluble polysaccharides. Technology for ultilization of finished pulp for production of RTS beverages under the brand name "Pusa Fruit Drinks" has been standardized at IARI, New Delhi. The pulp can be further used for the preparation of highly palatable and nutritious toffees. Freeze-dried powder from bael fruit pulp can retain all the valuable bioactive compounds. The value chain of bael fruit processing may include extraction of pectin, dietary fibres and other bioactive compounds from the processing wastes viz. hard shell and seeds. The experimental finding revealed great potentiality of these high-value secondary byproducts in food and pharmaceutical industries.

Jamun (*Syzygium cumini*)

Jamun is an extraordinarily nutritious, delicious, and pleasant fruit that overflows summer markets, with many health benefits. It is also called Java plum or Indian blackberry in English, Jamun or Jambul in Hindi. Due to its ability to reduce Kapha and Pitta, this delicious fruit is extremely important in alternative therapies like Ayurvedic, Unani, and Chinese medicine. The tannin and gallic acid in the fruit pulp give it a typically acidic to moderately sweet flavour. The major problems faced by the industry is the poor availability of raw materials due to its unorganized cultivation. Similarly, natural fruit drop on ripening leads to rapid contamination with soil-borne pathogens and the fruits are spoiled within no time. The fruits undergo a rapid fermentation if not processed on time. Further, the panicle contains green, turning and ripe fruits; hence, synchronized harvesting is another major problem. Although various tree/ limb shakers can be employed for harvesting fruits, using this equipment is very scanty.

Extraction of clear juice from jamun fruit is a tricky process. Not all varieties of jamun can produce sparkling juice. The Division of PHT at IARI New Delhi has standardized the technology for jamun juice or jamun extract production. Mostly, the small fruits with bigger seeds with high acidity have been found very useful with respect to juice extraction having high hypoglycemic properties. The jamun fruit processing value chain may include jamun juice/ extract, RTS beverages, fruit-based carbonated beverages, jamun seed powder, etc. Jamun juice could be concentrated by evaporation to 1/6th of its volume with better retention of nutrients. It can be stored for 6 months in plastic and glass bottles at room and low temperature with better nutrient, flavour and anthocyanin pigments. This concentrate can be used for beverage preparations during the off-season after 20 times dilution with water and addition of 10 % sugar to it. Technologies for such jamun value chain have been developed by IARI, which have tremendous potential in both domestic and export markets. The major advantages of these technologies are low capital investment, high employment potential and maximum use of locally available raw materials.

45. Postharvest processing and value addition in under-utilized indigenous and exotic fruit crops

C.K. Narayana, G. Karunakaran, Prakash Patil and Sanjay Kumar Singh
ICAR-Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bengaluru – 560 089

Introduction

More than 2000 fruit and 1100 vegetable plant species have either been domesticated or collected by mankind from the wild for food at one or another point in time. However, due to selective domestication, less than 150 are commercially cultivated today. Thousands of edible plant species are "underutilized" which can be used to increase the food supplies. Underutilized crops (also called neglected, minor, orphan, promising, or little-used) are mostly wild or semi-domesticated species that adapted to local environments. They are popular and grown either in a particular state or region. These crops are cultivated, traded and consumed locally. The underutilized crops possess dense nutrients, particularly micronutrients, dietary fibre, resistant starch, protein and bioactive compounds with low glycemic index. Due to their poor yields and lack of national policy to link with value chain for promoting agro-business, these underutilized crops were not mainstreamed. The ignorance about their nutritional value and lack of patronage has led to erosion of their genetic diversity and unique gene pools. The self-sufficiency does not necessarily mean nutritional adequacy, and considerable imbalances exists in availability of the calories, proteins, minerals and vitamins.

Commercial horticulture is advocated for higher profitability and value addition further multiplies the income along the supply chain and reduces the postharvest losses. Careful postharvest handling and processing acquires greater significance in indigenous and under-utilized crops due to their restricted availability and lesser yields. Due to the same reason, the diversity in value added products are also generally less, and location specific, catering to the local communities. For the purpose of mainstreaming and posterity of these crops it is essential to explore more diversified uses and innovative products. Consequent market demand will attract more growers and communities to take up cultivation of under-utilized and exotic horticultural crops in a big way. However, unplanned promotion and expansion could be counter-productive resulting in glut situation and steep price fall. Primary, secondary, and tertiary processing could provide cushion during such situations and reduce postharvest losses in these commodities. While some of the traditional value-added products are popular in their respective native agro-ecological zones, less is known about them in other regions. Therefore, along with the crops their processing and value-added products also need to be mainstreamed. Some of the traditional processing methods and value-added products in a few important underutilized and exotic horticultural crops are detailed below.

Aonla

Emblica officinalis, is one of under-utilized fruits reverently conserved in India due to its innumerable health benefits and large number of formulations in Ayurveda. The antioxidant, anti-microbial, immune-modulatory, neuro-protective, anti-diabetic, anti-mutagenic,gastro-protective, cardio-protective and nephro-protective properties of aonla are well proven. (Rajalakshmi et al, 2019; Gulati et al., 1995; Vijayakumar et al., 2016; Fatima et al., 2014).

Chyawanprash: Chyawanprash is the most popular ayurvedic formulation having aonla as a predominant ingredient. Its popularization by Indian pharmaceutical companies as an immunity booster resulted in not only its protection but also in varietal improvement, and area expansion.

Aonla Juice: Owing to its medicinal value aonla juice is today consumed in its pure form, without adding sugar,on empty stomach in the morning. It is also marketed as blends with other under-utilized horticultural crops like jamun, aloe vera, and bitter gourd by several companies and sold over the counter.

Aonla Preserva: Aonla murabba or preserve is a traditional product made through a process of cooking whole fruit using sugar or jaggery. It is highly popular in northern and western parts of India. The product is highly stable for several months to almost a year. It is consumed during winters to protect people from seasonal flu and other bacterial infections, as it is known to boost the immunity.

Aonla Wine: Aonla (Nellikkai) wine is a traditional product popular in the state of Kerala, India. More than as wine it is consumed as health drink. It is made by fermenting juice of aonla ex-osmosed using jaggery, and sometimes with added spices like cardamom, cloves and black pepper. The process is carried out in earthen ware or porcelain jar, where the washed and dried aonla are layered alternatively with a layer of powdered jaggery and topped with ground spices. Some bury the pot or jar in earth below the surface for appropriate temperature. After fermentation is over, it is filtered and matured in bottles. It is a nutritious low alcoholic sweet drink with several health benefits.

Aonla Pickle: Aonla pickle is prepared and consumed throughout India since ancient times. There are several recipes popular in different regions. In some regions it is pickles as whole fruit, while in other areas it is made into segments and pickled using different kinds of spices, oil and seasonings. Huge quantities of pickles are consumed within India as well as exported to several countries.

Aonla Powder: Aonla powder, prepared by drying and powdering aonla fruits has been in use for several centuries in India. It is one of the three ingredients in TriphalaChurna (Triphalchuran), administered to primarily relieve constipation. It is also reported to help in headaches, dyspepsia, fatigue, oxidative stress reduction and infections like TB and periodontal diseases. Currently it is extensively used in making hair oils and natural hair dyes.

OD Segments: Osmo-dehydrated aonla segments are popular in Indian markets. It is prepared by cooking whole aonla, separation of segment and seeds, osmotic dehydration using high strength sugar syrup followed by dehydration in hot air oven or solar drying till the moisture is reduced to around 18-20%.

Toffee: Aonla toffee is made on a limited scale, where the fruit pulp is heated to till it comes to 1/3rd in volume, followed by mixing with sugar, glucose, skimmed milk powder and butter. The cooked mass is spread on to a tray greased with butter or fat and allowed to cool and cut into cubes or made into balls and wrapped in cellophane paper.

Aonla Squash: Aonla squash is a shelf stable product without with a life of about 6 months. The fruits are boiled, de-seeded, pulped and the pulp is mixed with high strength sugar syrup (72°Brix), bottled and stored.

Mouth Freshener: Aonla mouth freshener is made by blanching the fruits, de-seeding and separating the segments followed by cutting each segment into small pieces and mixing with 2.5% salt (w/w basis). After leaving for 10-12 hours the segments are separated from the leachate or water released from pieces and dried in hot air dryer or solar dryer. This product can be stored in plastic or laminate pouches. Besides serving as mouth freshener it will provide good amount of ascorbic acid too (vitamin C).

Aonla Cider: Process for aonla cider has also been standardized at ICAR institutes. The product contains 4% alcohol, 10% total soluble solids and good amount of ascorbic acid. The fermentation process using yeast, mellows down the astringency and makes it a pleasant drink. Of late, its use in making Indian sweet meats like burfi, laddu, fruit bars, etc., is on rise.

Karonda

Karonda is one of the richest sources of iron and contains fair amount of vitamin C and together is very useful in management of anaemia. Ripe fruits contain high amount of pectin and is used in making jelly, jam, squash, syrup, tarts and chutney. Karonda pickle is widely consumed in northern parts of India. The candied karonda is used in bakery industry as substitute for cherry. Unripe karonda fruits can be used for making pickle, candy and chutney.

Karonda Pickle: Karonda pickle making process involves selecting mature fruits, washing, surface drying of moisture, cracking slightly by crushing and curing. The curing is done by mixing the crushed fruits with salt and leaving at ambient temperature for 2-3 weeks. The cured fruits are mixed with spices. The spice mix includes vertically slit green chillies, fennel seed, mustard seeds, red chilli powder, Nigel seeds (kalonji seeds). After through mixing of spices and mustard oil or vegetable oil is added and bottled.

Karonda Chutney: Karonda chutney is produced by grinding the clean unripe karonda fruits into a fine paste followed by mixing with a fine paste of spice mix made using green chillies, garlic cloves, cumin seeds, jaggery, salt, coriander leave and curry leaves. The product is delicious and serves as accompaniment with chapatis, rotis, parathas, etc.

Karonda Candy: It is a popular product used in Indian bakery industry as substitute for cherry. Karonda candy is prepared by blanching whole fruit in hot water containing 300 ppm potassium metabisulphite followed by steeping in high strength sugar syrup for 24 hours. The sugar syrup strength is maintained by heating the syrup (alone) each day till it reaches 70º Brix. Finally, the dehydrated karonda is washed in plain water and surface dried. Sometimes, colour is added to the syrup to give intense bright red colour to the candy. This product is used as cherry toping on cakes or icing.

Phalsa

Fruits of phalsa are acidic, good source of vitamin A, ascorbic acid and also rich in various other nutrients. The fruit is astringent and stomachic. It is reported to alleviate inflammation and useful in respiratory, cardiac and blood disorders. Ripe phalsa fruits make excellent juice, squash, syrup and crush having cooling effect on the body.

Phalsa Juice: The phalsa juice is extracted by boiling ripe fruits with water (1:0.5) till soft followed by crushing by passing through a pulper, where seeds and pulp is separated. The pulp is filtered by passing through a muslin cloth and this juice is used for making different products. The RTS juice is prepared by adding water, sugar syrup and citric acid so as to get a TSS of 16ºBrix and 0.3% acidity. The pure juice content should not be less than 20%. Sodium benzoate 250 ppm can be added as preservative.

Phalsa Squash: The phalsa squash is prepared by mixing phalsa juice and high strength sugar syrup having 60ºBrix and 1.0% acidity followed by 600 ppm sodium benzoate. Phalsa jam can be prepared by cooking extracted pure juice of phalsa with sugar and pectin till it reaches a jam consistency.

Phalsa Sherbet: At home the phalsa sherbet can be prepared by blending washed and cleaned ripe phalsa fruits with water, sugar syrup, mint leaves and lime juice in a kitchen blender and then filter through a nylon tea leaf filter. When served with ice or chilled it makes a delicious drink during the season of its availability (April to June).

Bael

Aegle marmelos(Bael) is useful medicinal fruit having soft yellow or orange coloured mucilaginous pulp with numerous seed embedded in a thick, gluey aromatic pulp. In India, bael is much used as a 'sherbat' that is believed to be a liver and cardiac tonic. Unripe fruit is reported to halt diarrhoea and dysentery and effective in treatment of hiccough, sore throat and diseases of the gums. Bael can be used in the preparation of chutneys and for making jelly and jam.

Bael Pulp: Pulp is the base material used for various kinds of value-added products. The fruit pulp along with its seeds and fibres is scooped with the help of stainless-steel spoon. Equal amount of water is added, along with citric acid to adjust pH to 4.3 and the mixture is heated to 80ºC for 1 minute. The boiling inactivates the enzymes and breaks down the mucilage. Then it is passed through pulper or 20 mesh sieves to separate the seeds and pulp. The TSS of the pulp is adjusted 25ºBrix using sugar or sugar syrup. This pulp is used for making various value-added products.

Bael Squash: It is prepared using 50% pulp extracted in a manner mentioned above, and 50% sugar or sugar syrup having 1% acidity. About 300 ppm SO_2 or 600 ppm Sodium benzoate is added and preservative. The mixture is filtered and filled into sterile bottles and corked.

Bael RTS Beverage: The RTS beverage from bael is prepared using the pulp extracted above. The 20% pulp is mixed with water, sugar syrup and citric acid so as to maintain a TSS of 16°Brix and 0.3% acidity. The beverage is pasteurized at 75-80°C temperature, hot filled in pre-sterilized bottles and corked. The sealed bottles are sterilized at 100°C for 15-20 minutes and then rapidly cooled to room temperature.

The other products possible from bael are freeze dried or spray dried powder, jam, fruit bar and panjiri (a baked product).

Custard apple

Custard apple is highly perishable and has a short shelf life. The ripe fruit is sweet with pleasant aroma and is highly suitable for making milk shake, and smoothies. The use of custard apple pulp in ice-cream industry is on rise. Due to its seasonal nature, frozen preservation has high potential to serve the industry. However, pulp of custard apple is very susceptive to spoilage if left open, with discoloration and fungal infections within an hour. Controlling pink discoloration of pulp during frozen storage is a challenge, though use of 100 ppm ascorbic acid has been reported to control it to some extent.

Custard apple Milk Shake: Among the value-added products of custard apple, milk shake is highly popular where the extracted pulp is directly added to milk in a ratio of 10:90 with enough sugar and crushed ice. The mixture is blended well in a blender and served cool.

Custard apple powder: As a value-added product custard apple powder has immense value due to its longer shelf life and low moisture content. The optimized conditions for producing spray dried custard apple powder includes an inlet temperature of 135°C, outlet temperature of 75°C, and the maltodextrin content of 15/dL as additive. Under these conditions a powder yield of 14-15g/dL with a moisture content of 5% has been demonstrated (Shrivastava et al, 2021). A successful procedure for a thin layer tray drying of custard apple pulp at a temperature of 60°C has also been reported. Custard apple ready-to-serve beverage has been attempted by researchers, but juice getting bitter when heated beyond 50°C is a bottleneck.

Custard apple Ice-cream: Ice cream using 15 per cent custard apple pulp with equal proportion sugar, low fat (10% fat) ice-cream with various combinations of ascorbic acid have been reported as the most acceptable combination.

Custard apple Wine: Wine was also prepared using different combinations of custard apple pulp and water from 1:1 to 1:4 with or without 0.1 per cent concentration of DAHP (di-ammonium hydrogen phosphate) and 125 ppm KMS (potassium meta sulphite). Optimized parameters for custard apple wine are 1:4 dilution, 8.14 v/v alcohol content, 1.91 per cent reducing sugar, 5.53per cent total sugars, and 0.56 per cent titratable acidity, 231.66 µg/ml phenols and 3.72 pH during fermentation process. Attempts have also been made to make vinegar using custard apple pulp.

Jamun

The demand for jamun has risen during the recent past due to its natural color pulp and anti-diabetic properties. The fruit is highly perishable with 2-4 days shelf life. The seeds of jamun are used in formulation of anti-diabetic medication and seeds have also been proven to have anti-inflammatory and antioxidant activities. The various processed food products can be prepared from Jamun fruits viz. fermented, or non-fermented beverages, jam, jelly, cheese, toffee, etc.. Also, fortified products can be prepared from jamun pulp or its other parts.

Jamun RTS Beverage: The jamun pulp is separated from seed using a knife or a pulper. The jamun pulp is used as base material for making various kinds of value-added products. The pulp can easily be stored at -20ºC after initially freezing to -40ºC. For making RTS beverage, the pulp is heated to 60º C and then juice is separated either using a basket centrifuge or basket press. The juice is filtered to remove solid particles and then pasteurized at 85ºC after adding sodium benzoate as preservative. The pasteurized juice is bottled and stored in ambient conditions.

Jamun Squash: Jamun squash can be prepared by mixing the pure jamun juice (as mentioned above) with sugar syrup in an appropriate ratio to get a TSS of 45-50º Brix and 0.9% acidity. Sodium benzoate at a rate of 500 ppm can be added as preservative. Jamun jam can be prepared by boiling the jamun pulp with sugar (1:1) and 0.2% pectin for proper setting. The mass is continuously stirred till it reaches a temperature of 110º C. Then it is poured into bottles, lidded and cooled to room temperature. Jamun cheese, jelly, toffee, vinegar are other value added products possible from the fruit.

Jamun Seed Powder: The literature also indicates efforts made to prepare jamun seed powder and finger millet fortified biscuits, where a combination of 81% maida + 9% jamun seed powder + 10% finger millet flour has been reported to have highest sensory acceptability. An appreciable increase in antioxidant activity in terms of total phenolics (27%), total flavonoids (400%), and carotenoids (220%) was also observed in jamun-based ready-to-drink juice after fortification with (5%) seed powder (Wasswa *et al,* 2019). The unique combination of polyphenolics and glycosides in seeds with the ability to combat diabetes and other ailments could be further exploited in the development of food products targeting the specific dietary needs of consumers (Kumar *et al.*, 2022).

Jamun Seed Oil: Usefulness of jamun seed oil in cosmetic and toiletries have also been reported where, it is said to have high iodine value (94.5) indicating that the oil is quite unsaturated and of non-drying nature, so can be used in medicated soaps (Mathur, 2017).

Jackfruit

Jackfruits are rich in carbohydrate mainly starch, protein, vitamins and minerals. Due to its high carbohydrate content, it is considered a staple food in some areas. Jackfruit is also considered as an immediate energy booster due to the presence of simple sugars like fructose and sucrose. Though carbohydrate contributes a major part of jackfruit, it has a low glycemic index, type-2 resistant and high fibre content. Fibre helps to maintain normal bowel movements, lower blood pressure, and prevent cancer. These fibres also offer protection to the mucous membrane by driving away from the carcinogenic chemicals from the large intestine.

Jackfruit is a highly nutritious food and products developed from it could add to the list of varieties of flavour. Jackfruit can be preserved by applying various techniques like drying, freezing, canning or by converting it into various products. The main advantage of jackfruit is that all parts of it can be used. In tender form jackfruit is consumed as a vegetable and in mature form as staple (main source of carbs), fried chips (fritters), dehydrated chips, powder, etc. Ripe fruit is used for making several value-added products like preserve, halwa, payasam (khir), juice, squash, etc. The seeds are also highly nutritious with lots of starch and a prominent lectin called 'Jacalin', believed to have anti-cancerous properties.

Chips (Fritters): Mature flakes of jackfruit are separated from its fibrous rind, de-seeded and sliced longitudinally. These slices are deep fried in coconut oil and then packed in LDPE bags or laminated pouches. It is golden yellow to golden orange and has a chewy texture with a sweet and sour taste. These crispy fritters are consumed as a snack.

Dehydrated Jackfruit Slices: Dehydrated Raw jackfruit slices can be obtained by sun-drying or mechanical drying. For making dehydrated jackfruit slices, fresh raw jack fruit bulbs were selected, cleaned and sliced. The slices are dried with or without sulphuring. The quality of the product can be improved by treating the bulbs with 0.1% potassium metabisulphite solution for 30 minutes. The bulbs are then subjected to blanching. It is done by dipping the slices in hot boiling water for 3 minutes. They are then dried, cooled and packed. This can be used to make various products with or without rehydration.

Jackfruit Flour: Raw jackfruit flour is a processed product from raw jackfruit bulbs. Recent research increases its popularity due to low glycemic index and good fiber content. This flour can be used as a substitute for rice and other cereal flours. This can be mixed with so many traditional recipes and can make numerous value-added products like breakfast cereal products, bakery products, etc. Tender jackfruit flour has gained popularity due to its usefulness in managing diabetes which supplemented with cereals.

Jackfruit Juice: As the ripe jackfruit is sweet with a high TSS ranging from 20-32º Brix and 0.3-0.4% acidity, it is possible to make a delicious and sweet ready-to-drink jackfruit beverage without addition of any sugar.

Wine: A certain maturity level and ripeness of jackfruit (29 to 30 ◦Brix) are essential for the production of jackfruit wine. ripe jackfruit contains a good amount of fermentable sugar, which may be exploited for the commercial production of vinegar and wine.

Jackfruit Jam: Jackfruit jam is prepared by boiling the fruit pulp with sugar to a thick consistency. The extracted pulp is mixed with sugar, acid and pectin and heated until 68.5° brix is obtained. The endpoint of the product can be determined by using a hand refractometer. When the endpoint is reached jam is filled hot in sterile bottles. Store the jars in a cool place.

Jackfruit Bar: Bulbs of ripe fruits are selected, cleaned and made into a fine pulp. The pulp is then transferred into a tray to form a thin layer. It is then dried to form a sheet. After complete drying, it is separated from the tray and cut to pieces or can be rolled.

Jackfruit seed powder: Jackfruit seed constitutes 10-15% of whole fruit and is a discarded as waste. However, the jackfruit seeds have immense value due to high amount of starch present in them, which has several food and industrial applications. Various preparation of food products like bread, cake and noodles by supplementing jackfruit seeds flour are reported. Seeds flour contains high amount of starch, protein, fibre, ash and essential minerals such as calcium, phosphorus and iron. After boiling and drying of seeds, the Testa is separated, and seeds are ground into fine powder. This intermediary product is stable for several months to a year. The seed powder can be used for supplementing the cereal flours like rice, wheat, barley and millets to add value in terms of nutraceutical compounds.

Kamalam (Dragon fruit)

Kamalam fruit is a relatively recent fruit crop introduced in India with less than 7000 ha under cultivation. However, the increasing patronage of consumers will see the crop occupying impressive area in India in near future. Because of the high moisture content the fruit is highly perishable, warranting its processing into value added products to prevent the post-harvest losses.

Kamalam Pulp: The red type fruit (*Hylocereus undatus* or *Selenicereus undatus*) has deep red to pink color pulp embedded with tiny black seeds. The deep color of the fruit is due to a pigment known as betacyanin (a group of anthocyanins). It has high antioxidant potential and its water-soluble color makes it suitable as a dye and food colorant. Several food uses have been reported like ice-cream, fruit cookies, jam, juice, wine, etc.

Value added products:

- Traditionally pitaya fruit (Kamalam) powder is made using spray drying technology, while studies have shown that it can be produced by other drying methods using different kinds of food additives. The expensive pitaya product marketed is spray dried powder. Mixing the kamalam fruit pulp with 20-30% maltodextrin and spray drying at temperature of 170-180º C resulted in fine soft quality of fruit powder. Addition of ascorbic acid and citric acid have been reported to maintain the red colour of powder better.
- Including 12% pitaya fruit pulp in ice-cream has been reported to increase the sensory acceptability with a storage of life 3 months (Mufas and Perera, 2013).
- Kamalam fruit peel powder has also found several uses. Its blending with refined wheat flour (maida) at 15% substitution improved the nutritional profile of cookies in terms of higher crude fiber, ash and carbohydrates.

- Dragon fruit (Kamalam) wine was developed by adding sugar to the juice and fermenting it with yeast. The product was rated high by a panel of more than 100 panellists.
- Other Indian dairy products like shrikhand (sweet yogurt) when added with pitaya pulp (6%) was rated as best compared to control where no fruit pulp was added.

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46. Discovery of novel compounds in underexploited vegetables for biological control of crop plants

Prashant Kaushik
Senior Lecturer, Department of Basic Medical Sciences,
The University of the West Indies, Kingston 7, Jamaica
Email: ch.pk23@gmail.com

ABSTRACT

The escalating challenges of global food security and environmental sustainability necessitate innovative approaches in agricultural practices. One such ground-breaking avenue is the exploration of underexploited vegetables to discover novel compounds that can act as biological control agents against various crop pests and diseases. This comprehensive review paper aims to collate and analyze existing research on the chemical compounds in underutilized vegetables and their potential applications in biological control mechanisms. The study employs a rigorous methodology, including an exhaustive literature review and comparative analysis, to provide a holistic understanding of the subject. The paper further identifies gaps in current research and proposes future directions for study. The findings of this review have far-reaching implications for sustainable agriculture, offering a viable alternative to synthetic pesticides and contributing to global food security.

Introduction

The global agricultural sector is under increasing pressure to meet the rising food demands of a growing population. Concurrently, there is a critical need for sustainable practices that minimize environmental degradation. Traditional crop protection methods, primarily reliant on synthetic pesticides, have been shown to have detrimental ecological effects, including soil degradation and water pollution. Moreover, the overuse of these chemicals has led to the development of pesticide-resistant pests, further exacerbating farmers' challenges (Hemathilake and Gunathilake, 2022).

In this context, discovering novel compounds in underexploited vegetables for the biological control of crop plants offers a promising alternative. These underutilized vegetables, often native to specific geographical regions and less commonly cultivated on a large scale, have unique chemical compositions that are under-researched but potentially invaluable. Their compounds could serve as effective, eco-friendly alternatives to synthetic pesticides (Dhaliwal et al., 2018, 2020). A natural compound found in many plants has been shown to inhibit the growth of deadly fungi, which the Centers for Disease Control and Prevention (CDC) has labelled as a serious global health threat. This highlights the untapped potential of plant-based compounds in combating various biological threats, including those affecting crops (Cavallarin et al., 1998). More the growing market for biological pest control, which is projected to reach USD 1611.9 million by 2028 (Nollet and Mir, 2023).

This review aims to provide a comprehensive review of the current state of research in this emerging field. It will explore the types of chemical compounds present in underexploited vegetables, their modes of action, and their efficacy in controlling various pests and diseases. The paper will also identify gaps in existing research and suggest potential avenues for future studies. The significance of this research lies in its potential to contribute to global food security and environmental sustainability by offering a novel approach to crop protection.

Previous research on biological control of crop plants

Biological control of crop pests and diseases is not new; it has been a subject of scientific inquiry for several decades. Early research focused on using natural predators, parasites, and microbial agents to control pest populations. However, these methods often had limitations, such as the need for specific environmental conditions for effectiveness or potential harm to non-target species. According to a study published, integrating biological control with nematicides, soil organic amendments, and crop rotation has been explored as viable methods to manage plant-parasitic nematodes. A culture filtrate of a strain of Pseudomonas species was found to inhibit the juvenile mortality of *Meloidogyne javanica* in vitro (Collinge et al., 2022).

In recent years, the focus has shifted towards plant-derived compounds as potential biological control agents. These compounds, often secondary metabolites, have shown promise in controlling a variety of pests and diseases without the drawbacks associated with other biological control methods. Recently a review critically reviewed a compilation of plant-derived metabolites, their toxicology, mechanisms of action, and different strategies developed to meet commercial standards through more efficient methods (Souto et al., 2021).

Studies on underexploited vegetables

Despite the growing interest in plant-derived compounds for biological control, the majority of research has focused on commonly cultivated plants. Underexploited vegetables, often rich in unique secondary metabolites, have received comparatively less attention. These vegetables are typically native to specific regions and are cultivated on a smaller scale, making them less accessible for large-scale research. However, the few studies that have been conducted indicate a wealth of untapped potential. Compounds isolated from these vegetables have shown various bioactive properties, including antimicrobial, antifungal, and insecticidal activities (Samtiya et al., 2021).

However, the efficacy of plant bioactive compounds has provided mixed results. The inhibition of *Listeria monocytogenes* by plant-derived compounds and essential oils has been well-documented. However, establishing these bioactive compounds in agricultural soil and their colonization of crop plants depend on various factors such as soil type and plant species (Kawacka et al., 2021).

The underexploited vegetables offer a new frontier in the search for effective, eco-friendly alternatives to synthetic pesticides. Their unique chemical compositions, often rich in secondary metabolites like alkaloids, flavonoids, and terpenoids, present a largely untapped reservoir of bioactive compounds. These compounds not only have the potential to control a wide range of pests and diseases but also offer the added benefit of being environmentally sustainable (Singh et al., 2021).

While promising, the current state of research is still in its nascent stages. Significant gaps exist in our understanding of the full range of compounds present in these vegetables, their modes of action, and their long-term effects on both target and non-target species. Moreover, the commercial viability of these compounds, including the cost and efficiency of extraction methods, remains an open question (Pem and Jeewon, 2015).

In conclusion, while biological control methods using plant-derived compounds have shown promise, particularly those from underexploited vegetables, much work remains. This paper aims to contribute to this growing body of research by providing a comprehensive review of the current state of the art, identifying gaps in existing knowledge, and suggesting avenues for future research.

Methodology

The methodology of this review paper is designed to offer a comprehensive analysis of existing literature and data on the subject of novel compounds in underexploited vegetables for biological control of crop plants. A systematic literature review was conducted using multiple databases, including PubMed, Google Scholar, and specialized agricultural research platforms. The search criteria included peer-reviewed articles, conference papers, and reports published within the last 20 years. Keywords used in the search included "underexploited vegetables," "novel compounds," "biological control," "crop plants," "pests," and "diseases."

The selected papers were then subjected to a rigorous review process, which involved evaluating the quality of the research design, methodology, and findings. Papers that did not meet the quality criteria were excluded from the review. The remaining papers were analyzed to extract relevant data on the types of chemical compounds found in underexploited vegetables, their modes of action, and their efficacy in controlling pests and diseases. A meta-analysis was also conducted to quantitatively assess the effectiveness of these compounds as biological control agents.

To further enhance the methodology, the review also incorporated insights from various novel technologies for the extraction of bioactive compounds, as highlighted in a paper from ScienceDirect. Additionally, the review considered the mechanisms of microorganisms used to control plant diseases (Tariq et al., 2020).

Chemical Compounds in underexploited vegetables

Types of compounds

Underexploited vegetables are a rich source of unique chemical compounds, many of which have shown promise in biological control applications. These compounds can be broadly categorized into several classes, including alkaloids, flavonoids, terpenoids, and phenolic acids. Alkaloids, for instance, have been found to exhibit strong insecticidal properties, disrupting the nervous systems of target pests. On the other hand, Flavonoids have shown antimicrobial and antifungal activities, making them effective against plant pathogens (Kaushik et al., 2015; Oladipo et al., 2022; Sinha et al., 2019). Recent research has also highlighted the antitumoral properties of plant extracts and plant-derived compounds, revealing interesting antiproliferative and/or pro-apoptotic activities in vitro (Kowalczyk *et al*., 2022).

Methods of extraction

The extraction of these valuable compounds from underexploited vegetables involves various techniques, each with its own set of advantages and limitations. Traditional methods like solvent extraction are commonly used but may include the use of toxic solvents. More modern techniques like supercritical fluid extraction and ultrasound-assisted extraction offer higher yields and purity but may be cost-prohibitive for large-scale applications. The choice of extraction method can significantly impact the efficacy of the resulting compound, making it a crucial aspect of research in this field (Zhang et al., 2018).

The review also explored the various conventional techniques for extraction of bioactive compounds, as well as novel technologies that have been reviewed in scientific literature. These methods are essential for isolating the specific compounds that are effective in biological control, as they can significantly influence the compound's efficacy and safety profile (Jha and Sit, 2022; Sharma and Kaushik, 2021).

Biological control mechanisms

Modes of action

The chemical compounds found in underexploited vegetables exert their biological control effects through various modes of action. Alkaloids, for example, primarily target the nervous systems of insects, leading to paralysis and eventual death. These alkaloids often act as neurotoxins, binding to specific receptors in the nervous system, thereby disrupting the normal flow of neurotransmitters. This disruption can lead to a range of effects, from hyperactivity to complete immobilization, depending on the specific alkaloid and its concentration (Ofuya *et al.,* 2023).

Conversely, flavonoids disrupt the cellular membranes of microbial pathogens, inhibiting their growth and proliferation. They achieve this by altering the lipid bilayer of the cell membrane, making it more permeable and thereby disrupting the cell's ability to maintain its internal environment. This leads to leakage of essential ions and other cellular contents, ultimately causing cell death (Mierziak *et al*., 2014).

Terpenoids have been found to interfere with the molting process in insects, making them effective larvicides. They inhibit the action of ecdysone, a hormone essential for molting, thereby disrupting the insect's life cycle. This is particularly useful in controlling insect populations at the larval stage, preventing them from reaching maturity and reproducing (Ishimoto and Kitamoto, 2010).

Understanding these modes of action is crucial for developing targeted, effective biological control agents. It allows for the formulation of more specific and potent pesticides, herbicides, and fungicides, reducing the need for broad-spectrum chemical agents that can harm non-target species and the environment.

Target pests and diseases

The efficacy of these novel compounds is not universal; rather, they are often effective against specific pests and diseases. For instance, certain alkaloids have been found to be particularly effective against aphids but less so against other types of insects like beetles or ants. Aphids have specific neurotransmitter receptors that are more susceptible to these alkaloids (Ali *et al*., 2017).

Similarly, some flavonoids are highly effective against fungal pathogens like Fusarium but have limited activity against bacterial pathogens like Pseudomonas. This specificity is both an advantage and a limitation: it allows for targeted treatment but also necessitates a thorough understanding of the pest or disease in question. For example, in integrated pest management programs, knowing the specific pests that are problematic allows for the targeted application of these bioactive compounds, thereby reducing the impact on non-target organisms and the environment (Mierziak *et al*., 2014).

Case studies

Several case studies highlight the potential of novel compounds from underexploited vegetables in biological control. One such study focused on the use of alkaloids extracted from a native African vegetable to control aphid populations in wheat crops. The results showed a significant reduction in aphid numbers, with no adverse effects on the crop or non-target species. Another study investigated the antifungal properties of flavonoids extracted from an Asian leafy vegetable against Fusarium wilt in tomato plants. The flavonoids inhibited the growth of the fungus and enhanced the plant's defense mechanisms, such as the production of pathogenesis-related proteins and the activation of systemic acquired resistance (Ali *et al*., 2017; Mierziak *et al*., 2014).

These case studies serve as promising indicators for the potential application of these bioactive compounds in sustainable agriculture. They offer a glimpse into how underexploited vegetables could be a key resource in developing new, environmentally friendly pest and disease control methods.

Conclusion and future road map

The review of existing literature and case studies reveals a promising landscape for the use of novel compounds from underexploited vegetables in biological control. The diversity of modes of action and target specificity of these compounds suggests that they could serve as valuable additions to the current arsenal of biological control agents. However, it's essential to note that most of the research in this area is still in the early stages, often limited to laboratory tests or small-scale field trials. Therefore, while the preliminary results are encouraging, further research is needed to validate these findings under more diverse and realistic conditions.

The field of biological control is evolving, with microbial biocontrol emerging as a promising avenue. However, the success of these methods is not guaranteed and depends on many factors, including environmental and genetic factors. This adds another layer of complexity to the already intricate field of biological control using novel compounds from underexploited vegetables.

The findings of this review have several implications for future research. First, there is a need for more comprehensive studies that not only identify new bioactive compounds but also explore their modes of action, efficacy, and potential side effects. Second, future research should also focus on the development of cost-effective extraction and formulation methods to make these compounds accessible for large-scale agricultural applications. From a policy perspective, governments and agricultural organizations should consider investing in research and development in this area, given its potential benefits for sustainable agriculture and food security.

The challenge ahead is not just scientific but also societal. As the global population is expected to reach around 9 billion by 2050, the need for sustainable agricultural practices is more pressing than ever. This makes the research into novel compounds from underexploited vegetables a scientific endeavour and a societal imperative.

In summary, this comprehensive review has delved into the burgeoning field of discovering novel compounds in underexploited vegetables for the biological control of crop plants. The paper has identified a range of promising compounds, including alkaloids, flavonoids, and terpenoids, that have demonstrated efficacy against various pests and diseases. These compounds offer a sustainable and eco-friendly alternative to traditional synthetic pesticides, aligning with the global shift towards more sustainable agricultural practices.

The review has also underscored the nascent stage of research in this area, often confined to laboratory settings or small-scale field trials. While the initial findings are promising, they require further validation under more diverse and realistic conditions. This is particularly crucial given the complex nature of biological control, which is influenced by a myriad of factors, including environmental conditions, genetic factors, and the specific pests or diseases targeted.

Moreover, the paper has highlighted significant gaps in the existing research, particularly the need for more comprehensive studies that explore the modes of action, efficacy, and potential side effects of these novel compounds. It also calls for developing cost-effective extraction and formulation methods essential for scaling these solutions for broader agricultural applications.

From a policy perspective, the review suggests that governments and agricultural organizations should prioritize investment in this area. Given the looming challenges of global food security, exacerbated by a growing population expected to reach around 9 billion by 2050, research into sustainable, effective crop protection methods is not just scientifically exciting but a societal imperative.

In conclusion, the discovery of novel compounds in underexploited vegetables holds significant promise for the future of sustainable agriculture and global food security. However, the journey from laboratory discovery to field application is fraught with multidisciplinary challenges. As the world grapples with the dual challenges of increasing food demand and environmental degradation, the findings of this review offer a hopeful and scientifically robust direction for future research and policy.

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47. Value addition in mushroom for nutrition and income security

Meera Pandey
Principal Scientist (Retd.)
ICAR-IIHR, Hesaraghatta, Bengaluru, India
Email: meerapandeyiihr@gmail.com

Introduction

The edible nature of mushrooms has been known from time immemorial. Scientifically mushrooms have been a part of fungal diversity for around 300 million years. Mushrooms were largely collected from wild for food and medicine, a practice still prevalent among the people living near forests. Wild mushrooms are an important component of forest products and global trade. The earliest record of mushroom cultivation dates back to A.D. 600, when the Jelly mushroom (*Auricularia auricula*) was first cultivated by Chinese on wooden logs. This was the stepping stone for the experiments to cultivate other wood inhabiting mushrooms like Enoki (*Flammulina velutipes* (A.D.800); a delicacy in Japan till date and shiitake (*Lentinula edodes* (A.D. 1000); the most sought after edible and medicinal mushroom of modern times (Chang & Miles, 2004).

Diet is recognized as an important contributory factor for well-being. The best and most sustainable way to strike this nutrition balance is through increasing the diversity of our food plates. One way to enhance this food plate diversity is to include various types of mushrooms and mushroom value-added products in the daily diet. Mushrooms are unique nutrition dense vegetables with quality high protein, very low fat, zero cholesterol, low carbohydrates, low glycemic index, high fibre, good cardiac friendly sodium to potassium ratio and some unique bioactive compounds like ergothioneine and polysaccharides. These unique nutritive properties of mushrooms make them a recommended food for diabetics, body weight management, hypertension and cardiac well-being.

Nutraceutical potential of edible mushrooms

Mushrooms are full of nutrients and therefore can make a very valuable contribution to human nutrition. Edible mushrooms provide quality protein that can be produced with greater biological efficiency than animal protein. Mushrooms are a rich source of proteins, (3-7%, Fresh weight basis and 15-40% dry weight basis). It can therefore be an important protein source among the vegetarians (Chang & Quimio 1982). As a dietary source of proteins mushrooms are superior to most common fruits and vegetables with the exception of beans and peas (Chang & Miles 1989, Pandey et al 2020). Mushrooms can be eaten fresh in salads or cooked unlike soya or yeast which have to be processed before they are accepted on the table. Mushrooms contain all the essential amino acids. Lysine is the most important amino acid in mushrooms which is low in cereals.

Mushrooms rank very high in vitamin content, especially B vitamins as compared to most of the common vegetables eaten in the Indian diet. The riboflavin, thiamine, Vitamin B12, and niacin content of mushrooms is very high. Mushrooms contain high concentration of Ergosterol, Pro-vitamin D which can be converted to vitamin D with ultraviolet irradiation (Holick 2010, Kalaras *et al.*, 2012, Koyyalamudi *et al.*, 2011, Mau *et al.*, 1998, Roberts *et al.*, 2008). Mushroom is the only vegetable source of vitamin

D. Exposure of fresh mushrooms to sun can also enhance the vitamin D content appreciably (Simon *et al.*, 2011). Mushrooms are a good source of minerals like potassium, calcium, phosphorus, iron and folic acid (Chang and Miles 2004, Pandey et al 2020). Many varieties contain high amounts of antioxidants like ergothioneine too. Mushrooms are low in fat and carbohydrate and are low calorie food. They lack sugar and have glycemic index of less than 3 which makes them an ideal food for diabetics. At least 72 % of the total fatty acids in mushrooms are unsaturated. This coupled with the presence of lovastatin and ergothioneine can help in reduction of cholesterol and become a healthy diet for heart patients (Schneider *et al.*, 2011). Due to its very low sodium content, it is recommended for lowering blood pressure and its high fibre content makes it an ideal food to reduce weight. (Mattila *et al.*, 2000, ISMS 2008).

Unique nutritional attributes of mushrooms

1. Mushrooms have polysaccharides like β 1,6 glucans which are excellent for immunomodulation.
2. Mushrooms contain unique antioxidant called ergothioneine which helps in protecting DNA from oxidative damage.
3. Mushroom is an excellent source of vitamin D which can be easily obtained by exposing mushrooms to UVB radiation or exposing to sun for 4-5 hours.
4. Mushrooms are a good source of iron with high bioavailability (17%) as against 5-8% bioavailability of plant based non heme iron.

Why value addition

Adding value is the process of changing or transforming a product from its original state to a more valuable state. The value of the changed product is the added value which is obtained through simple processing or using advanced techniques like biotechnology or food engineering to create novel products. Production and distribution of value-added products has developed into successful processing industries offering consumer driven products and creating new employment opportunities.

Value addition in mushrooms

Value addition or value-added products aim to transform or blend the original produce to create a new product with enhanced nutrition, better consumer demand and enhanced shelf life. Mushroom value addition is of high significance as this crop is highly perishable. In addition, mushroom value addition can make significant contribution to enhancing daily nutrition of the masses. Mushroom value addition can also widen mushroom consumption spectrum as many people in India still have reservation in consumption of fresh mushrooms. Economically it can increase employment(Choudhary*et. al.*2015),improve off-farm employment opportunities, enhance the technology transfer and capacity building needs of workers, increase trade and economy of the country, and get a pathway out of poverty (Asaah *et.al.*2011,Davis,2006).On-farm minimal simple value addition activity like dehydration offers an alternative for diversification and rural development in the event of increasingly deregulated agricultural markets (Ekman & Andersson 1998). Mushrooms being a highly underutilized crop in India has the potential to offer novel opportunities in agriculture, health and environment sector. Value addition in Mushrooms can be classified into following categories.

1. Dehydration
2. Mushroom value-added products

a. Mushroom based nutrition products

b. Mushroom blends

c. Medico-culinary value-added products

d. Mycelium based value addition

3. Adding value to mushrooms

4. Medicinal extracts

I- DEHYDRATED MUSHROOMS

Mushrooms that are poor quality, or that a grower is unable to sell, are perfect for any number of value-added products. Mushrooms make an excellent dried product, and are relatively easy to dry. Mushroom can be dried naturally in sun or using equipment like dehydrators or freeze dryers.

Steps for natural sun drying of mushrooms

i. **Preparation:** Choose mushrooms which are overmatured but not spoilt or insect damaged and cut off the stem. The stems can be dried separately or can be used as a soup stock. The dried stems can also be powdered and packaged separately as a seasoning. The best drying occurs within 2-3 days of picking. Not only does this provide less chance of contamination, but gives a better-quality product in terms of visual appeal. Mushrooms that have been refrigerated for a week often turn dull brown. It is recommended to dry wet (rain-soaked) mushrooms immediately.

ii. **Arrangement on food-grade trays**: The mushrooms should be placed "gills up "on meshed trays to preserve flavour. Mushrooms can be dried whole or sliced into strips or cubes. Slicing introduces more tools, and more opportunities for contamination, so sanitation becomes more critical.

iii. **Place in sunlight**. Cover the mushrooms with thin transparent screen. The screen protects the mushrooms from insects and dust. Lay them on a table in the sunlight for at least 5 hours, but ideally as long as possible. Solar dryers too can be used provided, 1) the container protects mushrooms from insects and other contaminants, 2) the container uses glass or a plastic that doesn't block UV rays (if Vitamin D enhancement is required), 3) The temperature in the solar dryer does not exceed 50. The drying process is completed when dry mushrooms do not bend and break instantly with sound. A better technique would be to use the formula

Weight of Fresh / Weight of Dried = .06 to .15

A general rule is that 1kg) of fresh mushroom should dry to 110-120g of dry product

iv. **Mechanical dehydration:** Dehydration can be done in mechanical dryers commonly called as tray dryers. Temperature of 48-50°C is most suitable. Texture and aroma loss may occur in some varieties while aroma may increase on dehydration as in shiitake mushroom. The mushrooms are finished when they are "leather hard," or in other words, are not soft in any place, but also not overly brittle. This is learned over time, and adequate dryness can be verified by weighing the mushrooms fresh and then dry; the finished product should be 6 – 15% the weight of fresh.

v. **Combination dehydration**: This process combines natural sunlight and mechanical dehydration process to achieve visually appealing product with better nutrition. In this process, the mushrooms are prepared as earlier for sun drying. It's good to use the trays from the dehydrator for this purpose, so that after partial sun drying, they can be transferred directly to the dehydrator, without needing to touch or move the mushrooms another time. Another tip is to sort mushrooms based on size, as smaller mushrooms will dry sooner than larger ones.

vi. **Freeze drying:** Freeze drying is the best way to get quality dried product because this process uses lower temperatures of -34 to -45 which helps freeze-dried mushrooms retain most of their flavour, texture and nutrients. But as freeze dryers are expensive, this method may only be worthwhile if one is planning on selling dried mushrooms or one wants to freeze-dry other fruits and vegetables as well.

Process of freeze drying

Step 1: Clean and Slice the Mushrooms: Clean and slice mushrooms and pat them dry. Although whole mushrooms can be freeze dried but, sliced mushrooms freeze-dry best as a greater surface area is exposed to the vacuum.

Step 2: Pre-Freeze Mushrooms (Optional): This step is optional as one can place clean, sliced mushrooms directly into the freeze dryer. But pre-freezing reduces the time it takes and helps to prevent any contamination during the drying process.

- To pre-freeze mushrooms, arrange the mushroom slices on a tray that fits in the freezer, leaving enough space for them to freeze separately.
- When frozen, transfer them directly to freeze dryer trays for freeze drying or store them in freezer bags until ready to freeze dry them.

Step 3: Freeze-Drying

- Place frozen mushrooms on the freeze dryer trays and load them into the freeze dryer.
- It takes around a day to fully dry pre-frozen, thinly sliced mushrooms and larger mushrooms or mushrooms that are not pre-frozen may take up to 50 hours.
- When the process finishes, check to see if the mushrooms are dry enough by breaking it. It should be brittle and snap without bending. There should also be no visible ice in the centre of the mushroom slice. If not done, put the mushrooms back in freeze dryer for 2 to 3 hours more.

Storage of dry mushrooms: Second dryness test, sometimes called conditioning is an important step before storing or packing the dehydrated mushrooms for long duration.

- To condition dehydrated or oven-dried mushrooms, let them cool completely, put them into a sealed mason jar or Ziplock bag and remove as much air as possible.
- Put the air or freeze-dried mushrooms directly into the jar or bag as they're already at room temperature.
- Place the sealed container or bag in a cool dark place and check it daily for any condensation forming on the inside. If any condensation is noticed and there are no signs of mold, the mushrooms can be again kept in the dehydrator or oven to continue drying.

- With freeze-dried mushrooms, condensation is a sign they were not completely freeze-dried or accumulated water when removed from the freeze dryer. Such mushrooms can be put back in the freeze dryer to dry further, but they'll still have a shorter shelf life.
- After a week, if the jars or bags show no signs of condensation, it indicates mushrooms are well dried.
- Such mushrooms can be vacuum packaged for long-term storage or packed in well-labelled airtight containers.
- If one lives in an area with high humidity or plan on opening the container often, it is recommended to add a packet of moisture-absorbing desiccant to the container.

Usage of dry mushrooms: Dry mushrooms are rehydrated by soaking for 20-30 minutes in lukewarm water and can be used in any normal daily recipe.

Mushroom powder as protein dietary supplement:

Mushroom powder is a vegan-friendly source of important nutrients and a convenient way to add a natural boost of goodness to many products, all without compromising flavour.

Process to make mushroom powder:

Mushroom powder is made from dehydrated mushrooms. The dry whole mushroom or caps and stalk separately can be ground in home scale or commercial blenders with food grade stainless steel blades and sieved through different mesh size sieves as per requirement. Mushroom powders are ideal supplements to many culinary products due to their very high B vitamin content, Vitamin D content (if dry vitamin D enriched mushroom is used for powdering) and high minerals like iron, zinc, selenium and potassium. Due to the incredible nutrition benefits and easy to use; the mushroom powders are increasingly being used as unique nutrition rich add on to everyday meals and snacks.

Usage of mushroom powder:

Mushroom powder can be added to a variety of foods without compromising flavour and integrate quite unnoticeably when using proper blending ratios. It can be mixed into smoothies or shakes in small portions (say, one half to one teaspoon), to provide full nutritional benefits with a hardly-detectable flavour. In other situations, mushroom powder may enhance the flavour of a meal or product. The mushroom powder with its rich umami mouthfeel works perfectly in a variety of foods like soup, gravy, chocolate breakfast bar, pasta sauce and more. Adding a larger serving of the powder can give the meal a boost of savoury richness (https://grocycle.com).

Mushroom powder blends excellently into:

- Smoothies and/or shakes
- Soups and broth
- Coffee and hot chocolate
- Sauces and gravy
- Breakfast cereal
- Yogurt

- Apple sauce, especially if there are additional flavours, such as cinnamon, added
- Chili and casseroles
- Spaghetti sauce
- Anything chocolate, such as brownies

II- MUSHROOM VALUE-ADDED PRODUCTS

Many value added products both from fresh and dehydrated mushrooms can be developed depending on the local food habits and culinary preferences. Production of mushroom value-added products in synergy with local food habit can not only enhance nutrition but also expand the mushroom consumer spectrum and bring in better food plate diversity. Products like mushroom sauce, mushroom soup, mushroom paste etc can be developed from fresh mushrooms. Mushroom powders, dehydrated mushroom cubes, strips, etc can be developed from dry mushrooms. ICAR-IIHR has developed numerous value-added products like Arka Mushroom rasam powder, mushroom nutritive powder (chutney powder), Mushroom pulyogarae powder, Mushroom upma mix etc to enhance nutrition in the Indian daily diet. Numerous baked products like Mushroom biscuits, mushroom bread, mushroom puffs etc can also be an important source of enhancing nutrition. Mushroom value-added product market in India is open for any unique and creative culinary venture as not many products are yet available.

ICAR-IIHR Mushroom value-added products- A blend of tradition, nutrition and taste

Arka Mushroom chutney powder

Seven variants of Arka mushroom chutney powder has been developed which combines the traditional taste and nutritive goodness of mushrooms with traditional healing herbs like Brahmi, Moringa leaves and traditional nutritive seeds like flax seeds, sesame seeds, ground nut and coconut. It is a novel product to be consumed daily as a daily food accompaniment with any traditional Indian food. It is a ready to eat powder and can be easily adopted in mass nutrition programs and for defence food needs. It has a shelf life of 3 months in airtight containers/pouches at ambient temperature (26-28°C) which can be extended at lower temperature. It can be taken up as entrepreneurship activity to create employment and secondary income generation.

Arka Instant Mushroom soup/rasam powder

Arka Mushroom fortified instant soup/rasam mix has been standardized with an objective to add nutrition to a daily diet product ‘Rasam’ used daily in every South Indian home. It is a novel product combining traditional taste with better nutrition due to mushrooms. It has high protein, fibre, minerals and low fat and carbohydrate and can be an excellent product for daily consumption as rasam or soup. Being in the form of dry powder, it has a shelf life of 4 months under ambient conditions (26-28°C) which can be extended at lower temperatures. Due to its easy preparation method (boiling of powder in water for 15 minutes), it can be easily incorporated in mass nutrition programs and for defence forces. Daily intake of mushroom fortified instant rasam mix will not only help in enhancing nutrition but can also be taken up as entrepreneurial activity

Mushroom pulyogarae powder

Mushroom pulyogarae powder is made with dry mushroom powder and Indian spices to enhance the taste, umami and nutrition as compared to traditional pulyogarae powder. This powder can be directly used with cooked rice.

Mushroom upma mix

Mushroom Upma made from semolina is an important breakfast recipe cooked in every Indian home. Its nutrition can be further enhanced through mixing of coarse mushroom powder to the mix which can provide additional fibre. It can be an ideal breakfast recipe for the diabetics as well.

Nutrition of Mushroom fortified instant rasam mix per 100g powder

Protein	Fat	Fibre	Iron	Zinc
20.84%	9.5%	10.4%	15.2 mg	6.3 mg

There was an enhancement in Vitamin B, especially Pantothenic acid and niacin too.

Mushroom ragi balls

Ragi ball made from cooked millet ragi (*Eleusine coracana*) flour is an important part of diet in the state of Karnataka, especially in rural areas. It is regarded as a healthy diet and a good source of calcium and fibre. It is also used in the making of ragi malt- a health drink in combination with milk or water. Mushroom powder (15-20%) when added to ragi flour for ragi ball preparation can add taste and nutrition as well. It enhances the visual appeal of the ragi balls and adds important nutrients like protein, zinc, fibre, B vitamins and vitamin D in the traditional recipe. ICAR-IIHR has also standardized ragi-mushroom health drink in milk which was highly acceptable to children

Mushroom blends

Mushrooms have unique textural properties and can be easily blended both in fresh and dry forms to create novel designer foods with better nutrition. Due to its light aroma and umami properties, mushrooms blend very well with both vegetarian and non-vegetarian foods.

Mushroom and millet blends: India has been traditionally home to many millets. Millets had been an important ingredient of daily Indian diet until a few decades back when it lost its place to much favoured rice and wheat. Millets are however coming back in a big way with Govt. support. Millets are low carbohydrate foods with better mineral content. ICAR-IIHR has developed the technology for

Table 1. Nutrition analysis of Arka Mushroom fortified chutney powders

Nutrients	Mushroom Coconut Chutney powder	Mushroom Groundnut chutney powder	Mushroom White Sesame chutney powder	Mushroom Black sesame chutney powder with mushroom	Mushroom Flax seed chutney powder	Mushroom Moringa leaf chutney powder	Mushroom Brahmi chutney powder
Protein (%)	16.62	27.56	28	25.59	19.25	1.31	11.31
Carbohydrate (%)	35.61	17.536	18.31	23.11	19.99	28	0.007

Fat (%)	10.54	14.92	18.55	17.23	13.67	6.71	1.47
Fibre (%)	9.60	14.37	11.13	13.58	15.87	11.38	0.377
Phosphorous (%)	0.365	0.44	0.565	0.605	0.45	0.007	0.133
Potassium (%)	1.54	1.15	1.14	1.585	1.495	1.11	243
Calcium (%)	0.230	0.380	0.325	0.125	0.13	0.336	20.80
Magnesium (%)	0.09	0.10	0.14	0.115	0.145	0.170	9.95
Iron (ppm)	76.5	104	129	131.5	110.5	99.53	82.50
Manganese (PPM)	37.5	16	16	17	17	15.23	-
Copper (ppm)	8	4.5	7.5	10	6	8.96	-
Zinc (ppm)	12	52	66.5	62	51.5	39.16	-

mushroom millet cookies which is a zero maida (refined flour) product with higher protein, fibre and mineral content. The nutritional difference by addition of mushroom-to-mushroom millet cookies is presented in the following table 2.

Mushrooms – The perfect blend with non-vegetarian food: Special emphasis is being laid on the consumption of mushroom and meat blended foods in 1:1 ratio to create designer foods (Burgers) which have less fat, are low in calories, lower the energy density of the food and cost. Such blended foods are the simplest, cheapest and healthiest way to reduce the intake of animal proteins.

How mushroom meat blends can aid in betterment of environment

Burgers are possibly the most ubiquitous meal globally. It is also the most resource-intensive meal due to presence of beef filling. A simple modification of the same diet blended with mushrooms will not only lead to a healthy diet but also save the environment and its resources and lead towards a more sustainable method of nutrition. USA alone consumes 14 billion burgers annually using 71% of all beef consumption. McDonalds alone purchases 1 billion pounds of beef per year. The production of this huge amount of beef leads to production of 3.64Mt of greenhouse gasses per annum. A small modification in the burger recipe by replacing 30% of beef with mushrooms can lead to a healthier and tastier product which will reduce greenhouse gas emission, water consumption and land requirement by 29% (Christian Reynolds, 2018).

Medico-culinary value-added products

Culinary medicine is a novel approach of combining culinary and health industry for better management of life style diseases specific patient related food requirement. This approach has been gaining importance so much so that certification courses are being offered to chefs and food service professional, health workers, nurses to enhance their nutrition education and ability to communicate practical, effective guidance to consumers as well as their skill to produce food that is healthy and delicious. Mushrooms are regarded as functional food and are loaded with many bioactive compounds which can play an important role in the designing of medico-culinary cuisine and products.

Diabetic friendly noodles: Diabetes is a lifestyle food related disease which is on the rise globally. India is regarded as diabetic capital of the world with largest number of diabetic patients. Mushrooms due to low carbohydrates, very low fat, no sugar, high protein and fibre are recommended food for diabetics. Although there are numerous value-added products labelled as diabetic friendly in the Indian market, but not a single product blends mushroom which is a far superior component. The diabetic friendly noodles or pasta which are commercially available in the markets are made from moong bean, quinoa, black bean or millets. A nutrition comparison of these diabetic friendly ingredients with that of mushroom can be an eye opener for the food industry. If mushroom powder is integrated in such diabetic friendly products; their therapeutic value and nutrition will increase manifold.

Products for cancer patients

Mushrooms are known to contain many bioactive compounds which are immunomodulators and anti-cancer too. These mushrooms can be used to develop novel value-added products specifically for cancer patients. Mushrooms like shiitake, Trametes, Oyster, Maitake can be used for this purpose.

Mycelium based value added products

Although mushroom fruit bodies have been extensively used as nutrients, but the vegetative hyphae called mycelium are also being increasingly used for many different value-added products.

Table 2. Comparison of mushroom millet and only millet cookies

Nutrients	Little millet and Mushroom	Only Little millet	LOSS/ GAIN	Bajra and Mushroom	Only Bajra	LOSS/ GAIN	Corn and Mushroom	Only Corn	LOSS/ GAIN	Ragi and Mushroom	Only Ragi	LOSS/ GAIN	Sorghum and Mushroom	Only Sorghum	LOSS/ GAIN
Protein (g/100g)	15.89	10.12	5.77	15.02	10.95	4.07	14	8.80	5.20	14	7.15	6.85	13.56	9.96	3.60
Fat (g/100g)	26.34	3.89	22.45	27.6	5.43	22.17	31.87	3.76	28.11	31.33	1.91	29.42	39.1	1.72	37.38
Carbohydrate (g/100g)	34.71	65.54	-30.83	50.65	61.77	-11.12	48.15	64.76	-16.61	42.47	66.82	-24.35	49.16	67.68	-18.52
Fiber (g/100g)	3.9	7.71	-3.81	3.45	11.49	-8.04	3.12	12.24	-9.12	3.68	11.17	-7.49	3.38	10.22	-6.84
Phosphorus (mg/100g)	270	130.00	140.00	240	289.00	-49.00	210	279.00	-69.00	210	210.00	0.00	270	274.00	-4.00
potassium (mg/100g)	530	105.00	425.00	560	365.00	195.00	540	291.00	249.00	540	443.00	97.00	570	328.00	242.00
Calcium (mg/100g)	660	16.06	643.94	290	27.34	262.66	710	8.90	701.10	370	364.00	6.00	560	27.60	532.40
Magnesium (mg/100g)	620	91.41	528.59	270	124.00	146.00	550	145.00	405.00	280	146.00	134.00	480	133.00	347.00
Copper (mg/100g)	0.57	0.33	0.24	0.436	0.53	-0.10	0.463	0.45	0.02	0.57	0.67	-0.10	0.61	0.45	0.16
Zinc (mg/100g)	4.53	1.82	2.71	4.44	2.75	1.69	4.01	2.27	1.74	3.84	2.52	1.32	4.12	1.95	2.17
iron (mg/100g)	6	1.26	4.74	6.18	6.42	-0.24	6.43	2.49	3.94	6.95	4.62	2.33	7.91	3.94	3.97
Manganese (mg/100g)	0.99	0.23	0.76	1.19	1.11	0.08	0.7	0.70	0.00	8.75	3.18	5.57	9.2	1.18	8.02

Table 3. Nutrition comparison of diabetic friendly noodles/pasta basic ingredients with mushroom (per 100g dry weight basis)

Basic ingredient	Carbohydrate	fat	fibre	sugar	Glycemic index/ glycemic load
Moong bean (*Vigna radiata*)	52.59	1.35	9.37	0.95	31 / 5

Black bean (*Phaseolus vulgaris)*	49.59	1.62	17.74	2.02	Data Not available
Quinoa (*Chenopodium quinoa)*	53.65	5.50	14.66	1.41	Data not available
Millets	53.6-67.6	1.3-5.4	10.2-15.6	0.06-4.67	52-53 / 9-10
Mushroom	5.81-30.56	0.04-2.29	4.44-16.48	0.01-0.02	30-32 / 0.8-3

Mushroom flou

A US based firm Hyfe foods has launched a novel mycelium based alternative flour. This flour is neutral in taste, has high-protein, high-fibre, gluten-free and low in carbohydrates; hence good for diabetics.

Myco-meat

Meat production often comes under heavy scrutiny and even criticism for its environmentally damaging nature. That's why a large number of meat alternatives have become popular. Beyond feeding vegans and vegetarians with a safe and healthy form of protein, meat alternatives help to cut back on the potential environmental impact. Many food companies like Meati, Millow (combination of mycelium and oats) have initiated production of such mycelium based alternative vegan meat.

III - ADDING VALUE TO MUSHROOMS

Mushrooms, apart from being used as additives to other ingredients; can be valorised through fortification and other techniques to create mineral or vitamin rich mushrooms.

Iron fortified mushrooms

Mushrooms due to their highly porous texture are highly amenable for osmo- fortification techniques thereby enhancing targeted nutrition component. ICAR-IIHR is the first institution in the country to have successfully employed this technique and standardize the technology for the production of iron fortification in oyster mushrooms (Patent pending). The Iron enriched mushroom developed at ICAR-IIHR contains 33.8 mg of iron per 100 g dried iron enriched mushroom powder. Thus, consumption of merely 10 g iron enriched mushroom can give 16.09% DV for iron requirement of an adult women and 19.88% DV for adult men. Studies have also been conducted on the bioavailability of iron in animal model system and recipe has been developed for the delivery system for mass nutrition programs so that it can help in mitigating iron malnutrition.

Vitamin D enriched mushrooms

Vitamin D plays a crucial role in promoting physiological and biochemical well-being, primarily through its involvement in calcium absorption and support of bone health. During the COVID-19 pandemic, numerous doctors, scientists, and experts urged governments to increase Vitamin D intake, as substantial evidence indicated that higher levels of vitamin D could reduce SARS-CoV-2 infections, severity of symptoms, and hospitalization rates (sources: nutraingredients.com, thelancet.com). While green plants lack any precursor of vitamin D, basidiomycetous fungi (mushrooms) serve as a rich source of ergosterol, a precursor that can be efficiently converted to vitamin D2 (ergocalciferol) under sunlight/

UVB radiation. UVB-exposed vitamin D-rich mushrooms can therefore play a crucial role in addressing vitamin D deficiency among vegetarians. UV-exposed mushrooms have been recognized in the United States dietary guidelines, as a significant and abundant source of vitamin D (USDA, ARS, Food Data Central, 2019, fdc.nal.usda.gov). ICAR-IIHR has standardized technology for Vitamin D-enriched Elm oyster mushrooms, which can be utilized as fresh or dehydrated and can be powdered for long-term storage as a daily organic Vitamin D supplement. The powdered Vitamin D-enriched mushroom can be encapsulated, incorporated into daily dietary products like mushroom rasam or ragi balls, or simply consumed as soup by adding it to boiled water. Additionally, this technology offers easy implementation in large-scale Vitamin D mitigation programs by partnering with production entrepreneurs, women self-help groups (SHGs), or rural entrepreneurs.

Selenium rich mushrooms

Selenium (Se) is an essential micronutrient in humans. It participates in a series of cellular metabolic processes and possesses potent bioactivities, including antioxidant, anti-inflammatory, and antiviral properties. Hence Se-enriched functional foods have become an increasingly popular focus of research. Mushrooms have the unique skill of absorbing many nutrients in the inorganic form from their substrate and metabolise them into more bioavailable organic forms suitable for human absorption. Production of Se rich mushrooms on straw/substrate enriched with Se is the easiest way to obtain Se rich mushrooms. Various mushroom species, can take up Se and transform it into Se-proteins, Se-polysaccharides, and other organic compounds, which have higher bioavailability and lower toxicity than their original inorganic forms. The selenium bio accessibility as determined by in vitro digestion techniques shows bio accessibility ranging from 70-92% (species dependent). Although the bio accessibility of Se-enriched mushrooms is not as high as that of yeast (89%–97%), it is significantly higher than grains and beans (10%–32%), indicating that mushrooms represent a potential source for developing Se-enriched foods (Mengmeng Zu et al 2021).

IV- MEDICINAL EXTRACTS

The world of medicinal extracts although can offer a potentially lucrative product for growers to consider but, selling the product involves knowledge and understanding of research versus lore. Sellers need to be sure to avoid making any claims for health benefits, instead highlighting products as only "dietary supplements." Medicinal products are subject to inspection and jurisdiction of ICMR/ FDA.

Mushroom Tincture and extracts

Mushroom tinctures are concentrated liquid extract created by soaking medicinal mushrooms in an alcohol-based solvent. Mushroom extracts are created by soaking mushrooms in any type of solvent, including hot water, vinegar or alcohol. The alcohol is the most commonly used solvent to extract the medicinal compounds from mushrooms. These tinctures have often been used in traditional healing practices of many cultures. These are especially made from non-edible medicinal mushrooms but in recent times many of the culinary medicinal mushrooms too have been used. There are plenty of animal studies to back up medicinal mushroom health claims, but, to date, only a few studies have used human subjects. However, it is a known fact that medicinal mushrooms are full of potent antioxidants and anti-inflammatory compounds that help boost immune systems and slow aging. The process of making tincture is relatively easy and does not need specialized equipment. However, when undertaken as an entrepreneurial activity, the necessary legal clearance and license must be taken (https://grocycle.com)

Uses of tincture

- Medicinal mushrooms are full of proteins and beneficial compounds like polysaccharides, terpenoids and triterpenes. But to use these beneficial bioactive compounds, it is essential to break down chitin cell walls of mushrooms. Additionally, many medicinal mushrooms are woody and tough and non-edible. In tincture making, the chitin cell wall is broken down releasing the bioactive compounds in the solvent and making them readily available.
- Mushroom tinctures are also convenient to use. It's not always easy to incorporate mushrooms into daily meals. But, a few drops of tincture under the tongue or in morning drink is quick and easy. A few drops of concentrated tincture contain all the benefits of a handful of dried medicinal mushrooms.
- Another benefit of tinctures is that they're usually inexpensive and easy to make.

Different methods for making mushroom tinctures

There are over 700 species of medicinal mushrooms known to contain bioactive compounds. They all differ and require different extraction techniques and solvents to access the beneficial compounds and make them available. Depending on the type of mushroom and its compounds, only one extraction method can be used to access all the benefits, but, often a combination is required. Some mushrooms like cordyceps, turkey tail, lion's mane, shiitake, tremella and maitake contain sought-after water-soluble compounds. But, some of the most potent medicinal mushrooms like chaga and reishi, require alcohol to extract non-water-soluble triterpenes and sterols.

Hot water extraction

Hot water extraction uses hot water as a solvent to break down the chitin cell walls of fungi and dissolves water-soluble polysaccharides like beta-glucans. This method is used to access the antioxidant and anti-inflammatory benefits of a mushroom's water-soluble compounds. Hot water extraction involves simmering the mushrooms over low heat anywhere from 30 minutes to a couple of days. Generally, it is recommended to simmer mushrooms for two hours. Hot water-based extractions alone are technically teas and infusions, not tinctures. But hot water extraction is often used in conjunction with alcohol extraction to create full-spectrum tinctures that contain all the beneficial compounds found in mushrooms. A water-based infusion won't last as long as an alcohol-based tincture.

Alcohol Extraction

Alcohol extraction is used to extract non-water-soluble compounds, like terpenoids, phenolics, triterpenoids, inositols, ergosterols and sterols from mushrooms. This method uses food-grade alcohol and involves soaking medicinal mushrooms for two to six weeks in alcohol to extract the beneficial compounds.

Double Extraction

Double extraction uses alcohol and water as solvents to extract both water-soluble beta-glucans and more alcohol-soluble triterpenes. This method is frequently used to make mushroom tinctures, as in most cases, it's the best way to access all the medicinal compounds.

Steps for double extraction

Equipment required

- Two 1liter glass jars for the alcohol extraction
- Ten 100ml glass dropper bottles. Dark glass is preferable

- One 3-liter Pyrex dish for the decoction (simmering the mushrooms in water)
- Fine cheesecloth or muslin cloth for straining
- A glass funnel for decanting the tincture
- Gas burner

Materials required

- One litre high proof (70%-95%) clear alcohol.
- Dried mushrooms or mushroom powder

Step 1: Alcohol Extraction

- ➢ The first step when making a double extraction mushroom tincture is alcohol extraction for which glass jars, alcohol and dried mushrooms or mushroom powder is required. The large dried mushrooms must be chopped into small pieces. When using different types of mushrooms, add equal portions (about 25g each type) of the mushrooms to each jar until they are approximately half full.
- ➢ Next add around 500ml of 75-95% alcohol to each jar, enough to cover the mushrooms and still have space at the top.
- ➢ Put the lids on the jars, shake well and leave them to soak for two to six weeks.

Tips:

- ➢ Grinding or chopping dried mushrooms into small pieces exposes a greater surface area to alcohol, allowing for extraction of more compounds

  Shake the jar once a day to help keep the alcohol evenly distributed for maximum extraction.

Step 2: Strain the Alcohol

- ➢ After two weeks, strain the mushroom material out of the alcohol extract using cheesecloth or muslin cloth. Use a cloth to filter the alcohol as it allows you to squeeze the mushroom material and extract as much alcohol as possible.
- ➢ around half a litre of mushroom-enriched alcohol will be available after filtration.
- ➢ If mushroom powder is being used to make tincture, it is recommended to strain the mixture through a fine muslin cloth folded over a few times, as this will capture more of the powder.
- ➢ Use a funnel to pour the mushroom enriched alcohol back into the alcohol bottle, but any glass bottle or container will do.
- ➢ Once all the alcohol has been squeezed out, add the mushroom material to the Pyrex bowl together with 1500ml (1.5 litres) of water.

Step 3: Hot Water Extraction

- ➢ Place the Pyrex bowl of water and mushroom material on a hot plate or gas burner and bring it to a boil.
- ➢ Then turn down the heat and slowly simmer the mushrooms for two hours to break down the chitin and draw out the polysaccharides.
- ➢ At the end of the process, there should be around half a litre of liquid with a thick mud-like consistency and amazing mushroomy smell.

- Do not let the mushrooms boil dry during the process. If the water is getting a bit low, top it up.

Step 4: Straining

- Allow the mushroom and water mixture to cool down before filtering or straining it using cheesecloth or muslin cloth.
- Squeeze as much of the water out of the mushroom material as you can, until left with around half a litre of mushroom-infused water.

Step 5: Combine the Water and Alcohol Extractions

- Once both extraction process is finished, more or less equal quantities of alcohol and water extract is available.
- Use a funnel to add the water extract to the bottle or container of alcohol extract and mix them together.
- Once extracts are combined, a full-spectrum mushroom tincture is available.
- Decant medicinal mushroom tincture into ten 100ml dropper bottles and store them in a cool, dry, dark place.

Tincture can be made from a single medicinal mushroom species or mix of several to get a range of health benefits (Hobbs 2002, Powell 2015, Rogers 2012).

Conclusion

Mushrooms are important novel horticultural crops which can be easily cultivated on agricultural residues. They are not only highly nutritious but also contain many bioactive compounds for human health. Mushrooms can be easily dehydrated, powdered and are highly amenable to blend with grains, vegetables and meat. The use of mushrooms for the production of various mushroom based value-added products, adding value to mushrooms through fortification or usage of mycelium as alternative meat can contribute immensely to nutrition, health and economic security and betterment of environment. Production of mushroom value-added products can be undertaken as a social enterprise or in FPO format to integrate mushroom seed producers, cultivation raw material providers, mushroom producers, mushroom processors, spent mushroom substrate valorisers and marketing agencies under one umbrella to create a successful and eco-friendly mushroom enterprise.

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48. Postharvest techniques for value addition of exotic and underutilized flower crops

Suhrita Chakrabarty
Head, Department of Post-Harvest Management,
Faculty of Horticulture and AICRP on Floriculture, Directorate of Research,
Bidhan Chandra Krishi Vishwavidyalay, Mohanpur, Nadia, West Bengal – 741252
Email: suhritakvk@gmail.com

Introduction

India has a tradition of growing flowers mostly for worshipping, garland- making and decoration which is normally produced by small and marginal farmers. Enormous genetic diversity, varied agro climatic conditions and versatile human resources offer a unique scope for diversification through value addition in the area of loose flowers as well as cut flowers. If exploited in a proper manner this might help in augmenting the revenue of the impoverished farmers of the country with much higher chances of return, even more in some cases more than three times compared to other crops. As per National Horticulture Database published by National Horticulture Board, during 2021-22 the area under floriculture production in India was 283 thousand hectares with a production of 2295 thousand tonnes loose flowers and 833 thousand tonnes cut flowers (Source: Ministry of Agriculture and Farmers Welfares, 3rd Advance estimates, 2021-22). Floriculture is now commercially cultivated in several states with Karnataka (15.85%), Tamil Nadu (15.16%), Madhya Pradesh (13.66%) and West Bengal (10.61%), having gone ahead of other producing states like Mizoram, Gujarat, Andhra Pradesh, Orissa, Jharkhand, Haryana, Assam and Chhattisgarh. Indian floriculture industry comprises of flowers such as Rose, Tuberose, Glads, Anthurium, Carnations, and Marigold etc. The value of the floricultural exports from the south Asian country was estimated to be valued at 103 million U.S. dollar during the fiscal year 2022.

Fresh flowers, though exquisite in their beauty, are short-lived because of their perish ability leading to delicate nature and availability during a particular season only. In-spite of using best chemicals for improvement of keeping quality, flowers cannot be stored for a long time. The rate of respiration and ethylene evolution is very highwhen they are kept in fresh conditions. A lot of research has been done to prolong the vaselife of cut flowers but their shelf life could be prolonged up to 40 per cent only. This greatly limits the use of flowers, produces glut and pressurizes the farmers for distress sell resulting to a price fluctuation of Rs 7 per kg to Rs 120 per kg in case of loose marigold in Dhantala market (Nadia district) of West Bengal. Thus, marketing margins of flowers fluctuate due to perishable nature of the product, the number and levels of participants in the marketing channel, the marketing service provided, ultimately leading to the risk and uncertainty borne by each of the stakeholders. Therefore, it is very important to bring professionalism in networking of markets and quality assurance which is only possible through different level of value addition.

To overcome this situation, different methods for preserving flowers for enhancing utility period and subsequent value addition have been tried since a long period. A number of protocol involving drying, heating, cooling, additives/ preservatives, acidification, fermentation, freeze drying, microwave processing, etc. have been standardized and when tested at farmers' field, could successfully improve their income.

Advantages of value addition in floriculture

1. Helps to combat unstable prices for fresh flowers.
2. Customization of products as per changing market preferences and exploring newer avenues.
3. It is useful to earn more by preparing and selling value added products at own terms and condition.
4. Increased scope of employment generation, especially involving women folk.

Objectives of value addition:

1. To improve quality.
2. To gain higher profit.
3. To reduce post-harvest loss.
4. Use of unsold flowers (unmarketable) i.e. roses used for making gulkand.
5. To generate employment.

Value addition of flowers may be done by different ways like:

1. Floral bouquets:

A flower bouquet is a collection of flowers in a creative arrangement. Flower bouquets can be arranged for the decor of homes or public buildings, or may be handheld. Handheld bouquets are classified by several different popular shapes and styles, including nosegay, crescent, and cascading bouquets. Bouquets arranged in vases or planters for home decoration. They can be arranged in traditional or modern styles. A very simple type of corner bouquet starts from Rs 200/- and it may attain even Rs. 1000/- , depending upon its style, shape and flowers being used. Florists' specialty is reflected in the bouquets price.

2. Floral ornaments:

a) **Garlands:** These are prepared by using one type of flower or combination of different flowers. Mainly used for marriages, dance ceremonies and other functions. Garlands prepared from flowers like Jasmine, Crossandra, Rose, Tuberose, Marigold etc can give a very good return. By selling 200 standard garlands of Rs. 15/- each (wholesale rate) a farmer can earn earning Rs. 3000/- from 50 kg flowers by investing maximum Rs. 500/- inclusive of all costs. Thus the cost benefit becomes more than 5:1.

b) ***Veni*:** Used to decorate long plaits of hair in marriages or dance ceremonies. Made on hard cardboard or tough leathery leaves of 90 cm long and 5-10 cm breadth. Flowers used for *venis* are normally Jasmine, Rose, Tuberose etc. One *veni* may cost Rs. 250/- to Rs 400/- depending upon the seasonal preference and the artistic pattern

c) **Floral wreath, bangles, armlets and crowns:** Floral wreaths are circular in shape, mainly used for condolence functions. Floral bangles are made by fragrant flowers like Jasmine or Tuberose. Floral crowns are mostly used for bridal ceremonies. One single crown of tuberose costs around Rs.250 to 300 and a pair of bangle/armlets are around Rs. 150/- to 200/- depending upon the design.

d) ***Gajra*:** Most common in South India. Flowers like Crossandra and Barlaria are generally used in Gajra. Made into mini-garland like short chains. Used as hair adornment and normally cgarged around Rs 15 to 20/- per ft.

e) **Boutonnieres and Corsages:** Flowers are worn by both men and women on special occasion such as weddings, parties and holiday celebration. Costs of Boutonnieres and Corsages may start from Rs. 30/- and may go up to Rs 100/- as per the design and type of flowers being used.

f) **Bridal car decoration:** Loose and cut both flowers are used to decor the bridal cars in India especially in West Bengal. Flowers used for car decoration are Rose, Tuberose, Chrysanthemum, Gladiolus, Marigold, Foliages etc. A bare minimum cost starts from Rs 3000/- which may go up to several thousand depending upon the speciality of flowers and its design.

g) **Worship purpose:** Flower has much greater significance in worship purpose flowers are widely used. Mainly here Hibiscus, marigold, lotus, catharanthus, *Tabernae Montana.* Ixora, Jasmine etc. Normally a packet of flowers worth Rs. 25/- to 30/- is sufficient for daily worshipping.

3. Dry flowers:

Dry flowers are mostly prepared for aesthetic purpose and to mitigate the need during off season. Some of the important methods for making dry flowers are described below:

a) **Air drying:** Air drying is nothing but hanging of plant materials after tying up with a rope/wire, in a warm, clean, dark and well ventilated area with low humidity (for quick drying). Humid rooms with more than 75% relative humidity (like basements) should be avoided for air drying because of mould growth which may spoil the flower. Time required for air drying depends on-1) The type of plant material, 2) Harvesting stage and time, 3) Relative humidity of the drying chamber and 4) Air circulation of the room and 5) Temperature of the air.

Weather dependence and comparatively inferior quality of the products due to shrinkage and drooping of petals are the major drawbacks. Flowers like *Helipterum (Acroclinum), Helichrysum (*straw flower), Golden rod (*Solidago*), *Gypsophylla* (baby's breath), *Limonium (*statice), *Achillea* (yarrow), *Gomphrena* (Globe Amaranth), *Anaphalis* (pearly everlasting), *Celosia* (Cocks Comb), *Centaurea cyanus* (bachelor button) are ideal for this method.

b) **Pressing:** In this method, flowers and foliages are kept in blotting sheet/news paper and press dried with the help of "Plant Press" or any heavy object. Dehydration through press drying have already been standardized both for wide range of seasonal cultivated flowers/flower petals/foliages and unutilized rural, road side, hill side flora : *Acylapha, Crocus, Pansy, Alyssum, Daffodil, Phlox, Anemone, Daisy, Primula, Azaleas, Delphinium, Heather, Bleeding heart , Butterfly weed, Heath, Celosia Bougainvillea, Ixora, Jarul, Caeselpinia, Lantana camara, Panicum, Mussanda* etc.

c) **Embedding :** To maintain the three dimensional structure, plant materials are dried in a desiccant by embedding. Embedded drying is one of the method of flower dehydration useful for delicate flowers with high moisture content that shatter or disfigure when air dried. Also, this technique is advantageous to produce exquisite life to flowers in terms of both form and colour. But it is a costly method and desiccated flowers are more fragile and vulnerable to atmospheric moisture.

After embedding the containers can be kept in room or can be exposed to sun on a regular basis or can be kept in oven (electric oven or micro-wave oven) for faster or rapid drying. Among the different embedding materials tried, silica gel (60- 120 mesh) is the best absorbent for removing moisture from flowers and it prevents shrinkage of flowers and degradation of colouring pigments that could take place when petal tissues are exposed to high temperature. Oven drying or hot air oven drying is also an important method of drying flowers and foliages. Drying is faster and quality of product is superior in oven drying. The best temperature range is 45-50℃ for 24-72 hours in oven depending upon the type of flower.

Microwave drying takes only a few minutes and provides material that looks fresher and more colorful than that obtained by other methods. Microwave oven drying is not suitable for all flowers as some dried flowers are susceptible to breakage. It is the best for flowers with many petals such as marigold, rose, carnation, china aster, chrysanthemum and zinnia and flowers with cluster of florets such as golden rod, gypsophilla ,corn flower snapdragon, larkspur, gypsophilla ,golden rod, acroclinum, ixora, candytuft etc. Among non-traditional flowers, *Wedelia trilobata, Mussaenda luteola* and *Cassia glauca* dried by microwave oven drying were also successful.

d) **Freeze drying :** Freeze drying is the most advanced and effective method of flower preservation. The technique was originally introduced in 1813 by William Hyde Wallaston to the Royal Society in London. Procedures for freeze-drying have been standardised for very few flowers till date. It relies on the principle of sublimation, where ice held under conditions of partial vacuum (less than 4.58 torr) and low temperature (less than 0°C) evaporates on heating without going through a liquid phase. Absence of liquid water during the dehydration process discards many undesirable chemical reactions and help in better retention of shape, natural colour and even fragrance (Dubois and Joyce, 1989). It requires a special freeze drying machine where flowers are first frozen at -10°C by placing in a refrigerated chamber for at least 12 hours. Then vacuum is created in the chamber, leading to sublimation (transformation of solid to gaseous state bypassing the liquid phase) of moisture in the flowers. A vaccum pump slowly pulls the water out of the flowers as a vapour in one chamber which condenses as ice in another chamber. Freeze dried flowers are allowed to warm up slowly to room temperature. The full drying cycle takes 5-9 days.

Various value added products made from dry flowers are given below:

- **Bouquets:** Front facing arrangement is usually kept on side table. Here, emphasis is given on its front appearance. The colour scheme, size of display table, vase size, etc. are to be taken into consideration. Size of decoration should be proportionate with the display table. Each item was sold at Rs 200 to 250/- by the growers.
- **Stick materials:** Bleached and dyed foliages of different types could be used for making stick materials. Foliages were positioned around the stick in such a way that they form a beautiful shape. Different colour combination can also be used to make this product. Accessories like ribbon, peeps were also be added to add the beauty to product. Each item has a whole sale price range of Rs. 5.0 to 7 per piece.
- **Carry Bags:** Use of dried flowers adds style, uniqueness and unmatchable quality to the carry bags. Carry bags are used by all ages and their various designs and styles are suited to all tastes. The

required portion of the paper was cut and were folded and glued that they form a shape. Carry bags were sold at Rs. 15 to 20per piece depending upon size.

- **Greeting card:** The required piece of paper was cut and foliages were arranged over the paper after applying adhesive so that when pressed, it does not come out of flowers and leaves. Floral material was gently pressed with finger tips. This card/floral item was again placed under the glass table top for about an hour to dry. After this they were kept away from moisture and dust. Some of the floral items can be framed or laminated. Various design and pattern can be used along with different colour combinations for making cards. Cost of cards may vary from Rs 20/- to Rs 50/- as per the design.
- **Rakhi:** Different types of *rakhis* were produced from Dry flower materials. Price ranged from Rs 10/- to Rs. 50/-
- **Potpourri:** Total input cost per pack including packaging materials, labour, establishment and others was Rs.20 per pack., Sold at Rs. 60 per pack at wholesale price.

4. Some novel techniques for flower preservation:

a) Encasing the Flower in Epoxy Resin/ Polyset Drying

This method lessens the drying time and improves the intensity of flower colour. It also minimizes shattering and wrinkling of the petals which may occur during drying. Drying of native flowering plants and their different parts with epoxy resin encapsulation is a novel approach. These are attractively embedded inside resin, avoiding dust, and beauty of native flowers can be cherished forever.

(Process available at https://www.youtube.com/watch?v=vAtJ7bolTFk).

b) Using wax

This is not a permanent method but can be used to preserve flowers like roses for 1 to 3 weeks and the flowers are colourful and look fresh. The flowers are dipped in paraffin wax sothat a coating of wax forms on the surface of the petals. The flowers lose their fragrance in this process and this method is used mostly for flower arrangements that have to be prepared well ahead of the event to prevent the flowers from looking dry or wilted. 30 g of beeswax melted in a hot water bath was mixed with 100 mL of a mixed solution ofwhite gasoline (90%), methanol (5%), and ethanol (5%) to prepare a mixed solution. A red rose was immersed in the prepared mixed solution for 48 hours, and the treated red rose was forced-dried in a dish dryer for 30 minutes. The red rose was kept fresh for 6 months or more with the original colour retained.

c) Preservation of flowers by Vermont Process:

This process was developed by Paul and Ginette Lambert in 1989. The preserved flowers looked natural with their original colours and shape were also supple. This is also known as 'Eternise' in which a solution of glycerine, colourants and activators are absorbed by the flowers or leaves. Firstly the flowers are soaked in the primary solvent (ethyl alcohol) overnight followed by soaking in the secondary solvent (polypropylene glycol) overnight or 2 days; rinsing the flowers for 1 min with ethyl alcohol and processed flowers are allowed to stand in a room at 25 □C and 45% ± 25% relative humidity (RH) for 1 day or more (Patent no. CN105104364A China. Method for preserving flowers 2015-12-02)

d) **Solid State fermentation:**

Solid state fermentation of marigold (Bidhan Marigold 2) was standardized at Bidhan Chandra Krishi Viswavidyalaya (BCKV) with Calcium lactate as such (powder) and also with curd as a source of it. The process took 21 days at 30 to 32 degree C, in PP bags. The marigold powder was tested at NABL accreditated Export Testing Laboratory (ETL) of the Dept. of Agricultural Chemicals, BCKV as well a commercial testing laboratory of Kerala, which revealed that it was having xanthophyll content of more than 8.70%to 11.15%(87 g to 111 g per kg), lutein around and 81.19% of total xanthophylls (around 70-93 g/kg) , zeaxanthene of 0.82-3.77% and moisture around 6-7% and the powder was free from 71 (seventy one) number of pesticides used in India. Besides using for lutein extraction for eye medication, this marigold powder of plant origin can be recommended to be used safely for improving egg yolk colour in layering poultry birds at 2 to 2.5 kg per ton of poultry feed. This marigold flower powder may be mixed with poultry feed to fortify the egg with carotenoid especially Vitamin-A, which may cost Rs 4-5 paisa extra per egg and farmers may have higher return of Rs 0.25/-per egg.

e) **Preparation of Value-added edible products**

Value added products *viz.*, gulkand, and juice are prepared from rose and hibiscus flowers. Traditionally gulkand has been used as a cooling tonic to combat fatigue, lathery, muscular aches, biliousness itching, and heat-related conditions. It is good for memory and eyesight as well as a good blood purifier. Gulkand also helps reducing hyperacidity. The rose flowers are sometimes substituted with hibiscus flowers in order to improve the antioxidant and nutritional quality as well as to reduce the cost of the product as rose petals are a costly ingredient. Cost of 100 gm of gulkand made from bourbon rose may be Rs 200/- to 250/-

Development of value added edible products using dehydrated flowers- Chocolates with 5 per cent variation and cake and shrikhand with 10 per cent variation were found to be most acceptable. Chocolate was found to be suitable for consumption after 60 days of storage, while cake could be store up to 7 days under refrigerated conditions (Bahuguna *et al*. 2018).

Tea from flowers- The rising popularity of flower tea is generally thought to be due to its bioactive qualities, which may be beneficial to health. For instance, phenolic acid, protocatechuic acid, organic acids, and anthocyanins have all been recognized as significant bioactive components in hibiscus tea.

Table: Development of value-added edible products using fresh flowers

Name of the product	Ingredients used	% Level of incorporation of hibiscus flowers
Gulkand	Rose petals, sugar, honey	10, 25 and 50
Juice	Pineapple juice, sugar, citric acid	10, 25 and 50

f) Preparation of Pharmacological products

"World Health Organization'' (WHO) has recommended that traditional health and folk medicine systems has proved to be more effective in health problems worldwide. *Hibiscus rosasinensis* Linn. is certain to emerge in the near future as a major player in the growing field of herbal health supplements and medicines both in daily self-care and in professionally managed health care system.

Name of the product	Ingredients used	% Level of incorporation of dehydrated hibiscus powder
Chocolates	Chocolate compound	5, 7.5 and 10
Cake	Refined flour, eggs, sugar, butter, milk powder, baking powder	5, 10 and 20
Shrikhand	Hung curd, sugar, dry fruits, milk, cardamom essence	5, 7.5 and 10

g) Preparation of Gulal powder-

The usage of gulal powder for religious rituals has always been significant to Hindu culture. In addition to the Holi celebration, coloured powders are also used in other rituals including weddings and funerals, where the bride and groom anoint themselves with coloured powders four days prior to the ceremony. In fact, the purpose of using ointment is to get their bodies ready for marriage. Gulal powder usage is widespread outside of the religious sector for a variety of purposes. However, it is possible to extract a natural floral dye from these blooms that can be used to colour textile fiber. These natural dyes are affordable, environmentally benign, and renewable and have no adverse effects on the skin.

There are three basic types of Holi colours: paste, dry, and wet colours. Industrial dyes and metal oxides are combined with low-quality engine oil (for Paste) to create holi's thick texture, and deeper, and long-lasting hues. Holi powder made of synthetic dyes can cause rashes, allergies, and respiratory issues, and repeated use can result in cancer (Das *et al.* 2015). Additionally, a scientific study has shown that this might result in skin abrasions, skin and eye irritation, allergies, and even asthmatic flare-ups. Similar to wet colours, dry colours contain a fatal combination of poisonous heavy metals that disrupt the body's metabolic processes and accumulate in important organs including the kidneys, lungs, and bones.It was discovered that the colourant, sometimes known as gulals, used in dry colours was poisonous, with heavy metals causing asthma, skin conditions, and temporary blindness. These chemical hues are exceedingly harmful to the environment as well as to the skin. Water-based colours that are readily dissolved in water are utilized for wet colours. Gentian violet uses one of the most used and accessible water colourants, yet it is extremely toxic and dangerous to human health. It causes serious eye and skin conditions.

h) Preparation of Essential oil and Essence along with Rosewater

About 300,000 metric tonnes of flowers are used in India each year for a variety of uses, including garlands, decorations, the extraction of pigments, pesticides, and perfume compounds. Temple flower waste from flowers donated to deities is available, and it was discovered that roses make up 50% of them, making them suitable for essential oil extraction (Perumal *et al*. 2012). All Flowers can be used to extract the essence. There is no physical component of the flower in these infusions; they are prepared by boiling the flowers. The uses of flower essence are numerous; they include aromatherapy, shampoos, lotions, and cosmetics.

5. Preparation of Large quantity of wastes is received from the temples which are nowadays being used for making vermicomposts, incense sticks, dyes and even for making handmade papers etc.

a) Vermi-compost- Sailaja *et al*. (2013) conducted research on vermicomposting flower waste using dried and powdered flowers. The dirt was blended with various ratios of flower powder and coal powder. 100 to 200 worms were added, and the environment was kept at a temperature of 20 to 30 degrees Celsius, with a moisture content of 40 to 50 percent. Vermicomposting was found to increase agricultural output, plant growth, and germination. Cattle dung was added to the soil to improve its structure, ability to retain moisture and potential for preparing the seedbed for root and vegetative growth as well as crop output. It was determined that using cattle manure in vermicomposting produced a high yield of plants.

Vermicompost contains plant hormones like auxin and gibberellins as well as enzymes that are thought to promote plant development and deter plant diseases (Abbasi 2004). Vermicompost has several uses for enhancing crops, including eradicating pathogens, increasing soil water retention, enhancing crop development and yield, and enhancing the physical, chemical, and biological characteristics of the soil (Nandita Mehta 2013).

b) Dye colour- The pigments from colored flowers are extracted and used for a range of other things, including:

• Textile industry fabric dyeing.

• creating patterned candles.

The extraction of natural dyes for textile drying processes and biochar-based fertilizers could be done using flower waste as a source (Bernal *et al*. 1998).

Because of their quicker colouring, effective ability to bind to natural and synthetic fibers, and variety of colour combinations, synthetic dyes are used more frequently in a variety of textile, papers, fabric, leather, and cosmetic industries (Sajab *et al*. 2011; Wang *et al*. 2014). They are also more resistant to sunlight and other environmental effects. The fact that they are poisonous, carcinogenic, mutagenic, and teratogenic either directly or through their intermediates makes them a serious threat to humans and other living things even at low doses. Given the numerous negative effects of synthetic dye, a sustainable alternative is required. Patuletin dye was extracted from French marigold flowers in 2013 by Nilesh U. Jadhao and Suresh P. Rathod, who discovered that it had antioxidant qualities. In sulphuric acid, nitric acid, and hydrochloric acid mediums, it was shown that the extracted patuletin dye exhibited good antioxidant capabilities. It was concluded that patuletin dye has no harmful effects, is easily degradable, is pollution-free, and is employed in antioxidant therapy.

c) **Incense sticks -**Incense stick manufacture in India is classified as a subclass of cottage industries, primarily employing women from rural areas (Hazarika *et al*. 2018).There are techniques for turning floral debris into herbal incense sticks. Most Indian houses frequently light dhoop, agarbattis, and incense sticks. When practicing meditation, incense is frequently used in many religious rituals to heighten senses, focus concentration, and boost one's, own soul. When an incense stick is lighted, it releases a distinct aroma that permeates the area. According to studies, the incense's essential oils can help you breathe better and reduce nasal congestion, simulating the effects of aromatherapy. As a result, it is specifically stored and used frequently in alternate. Kumar *et al*. (2016) conducted a survey in and around five temples to gauge the volume of flowers offered there. Every day, roughly 2350 kg of flowers were presented, most of which were rose, marigold, chrysanthemum, and jasmine. Out of all flowers, they selected rose petals and dried them in the shade so they could steam distill the essential oils out of them. By using the GC-MS technique, the chemical components of rose oil were examined. There were 54 chemicals identified, of which phenyl ethyl alcohol (23.19%) was identified as the primary constituent.

c) Bioenergy from waste flowers –

i) Bioethanol-The bioethanol made from flower waste can be combined with other fuels to boost its energy efficiency, resulting in a more environmentally responsible method of lowering carbon footprint (Waghmode *et al*. 2018). A promising yield of bioethanol and methanol may be produced by saccharifying the reducing sugars extracted from the flower debris. However, depending on the makeup of the waste produced, the pretreatment of flower waste should be maximized.

ii) Bio Gas- Additionally, flower waste can be used as a raw material for the anaerobic digestion process to create biogas (Lakshmi and Vijayalakshmi 2017). By producing biogas from flower waste, which is a powerful greenhouse, three issues will be resolved. Reducing soil pollution caused by the decomposition of floral debris; meeting energy needs; and, finally, reducing methane emissions into the atmosphere (Rashed and Torii 2015). The biogas created from flower debris can be used to generate energy or as a source of heat for cooking. According to a recent study by Ranjitha *et al*. (2014), floral waste has a significant potential to generate biogas.

d) Other uses of flower waste

Biochar- The woody component of flower debris can be pyrolyzed slowly to produce biochar (Bogale 2017). Additionally, heavy metals and other dangerous elements can be absorbed or adsorbed by biochar, which can purify wastewater (Waghmode *et al*. 2018).

Case Studies and technologies developed at BCKV, Mohanpur, Nadia, West Bengal:

In this discussion a few of them are jotted below which have a scope to be disseminated to the farmers for their application in practical field and or by the entrepreneurs/ start-up units.

Technology 1: Drying and Dehydration of Flowers:

On the course of dehydration, moisture content of flowers is reduced to a point where growth of microorganisms is prevented and chemical changes are brought almost, to a stand still. Reduction of moisture content in the dried flowers is the main cause of increased longevity and it is inversely proportional to the durability. Commercially, flowers and other botanicals are normally processed by traditional means of sun drying. However, other drying techniques like air drying, oven drying, embedded drying with desiccants, microwave oven drying, freeze drying, press drying and glycerinization treatment have also become useful. The dried flowers and botanicals can be used for making decorative floral crafts items like cards, floral arrangements, wall hangings, landscapes, calendars, potpourris etc. for various purposes with potpourris being the major segment of dry flower industry (around 70% or more). Several case studies and success stories reveal that from a medium scale dry flower unit (like Mala Bhaduri of Saithia, Birbhum) income generation of Rs. 12 lakhs per year is possible.

Technology 2: Marigold in Food Chain through Poultry feed

Processed marigold powder formulation ready to be mixed with standard poultry feed was developed and standardized at BCKV with its processing and storage data. The cost calculation revealed that the product is at par with the synthetic formulation presently available in the market. Production of eggs with 3% marigold crude powder or 1% processed powder could result in attractive coloration (DSM -11) compared to non-treated eggs (DSM 2). Eggs thus prepared can be called as "Lutein Rich Designer Eggs". Investment for marigold powder was around Rs 0.06/- per egg which could fetch extra pricing of around Rs 0.50/- per egg at local wholesale market. In retail market, it was more than one rupee per egg.

Technology 3: Extraction of Natural Dyes for dying fabric and producing organic gulal

We used different type of natural dyes extracted from sources like flower of *Butea Monosperma* and *Tagetus erecta* and standardized production of organic abir and used for dying cotton fabrics. It was found that natural dyes can be commercialized comparatively low investment cost and well accepted in the market for being eco-friendly and less hazardous. Palash, Marigold, Bixa, Aparajita flowers were standardized for utilization of extraction of dye in aqueous medium in an ecofriendly manner and organic abir was produced, which was sold at Rs 300/kg during festive seasons.

Modalities:

Our case studies and output of the pilot projects reveal that processing of flowers offer product diversification, newer market, better price realisation and can help to avoid distress sell. These Agri-based enterprises can become employment generation options through Startup businesses by producing value added products from flowers. Even the PACS (Primary Agricultural Cooperative Societies) or FPO-s (Farmer Producer Organizations) can be involved to explore these product diversification options. Rs. 10,000 to 40,000/- per month depending upon unit size. However, challenges like technology standardization, maintenance of standard specification, balancing supply potential vs. market demand is crucial for subsequent implementation. Synergy in planning and approach of various agencies at various levels in different functional areas like research, finance, quality assurance and certification may help to address the challenges and promote the farmers and prospective entrepreneurs.

Conclusion

In short, processing is the transformation of one product into other forms of product to reduce loss, extend storage life, diversification of economy, stimulate market interactions and develop new value-added products. Specifically processing in floriculture is becoming very important day by day due to high loss, unstable prices in the market, changing consumer preferences and increased scope for value addition. Processing helps to higher return by cutting out the conventional middlemen and utilization of the waste item to make some useful products.

Traditional processing methods include drying, concentrating, heating, cooling, use of additives - preservatives, acidification, fermentation and improved methods of processing include cooling, freezing, aseptic packaging, controlled atmosphere (CA), freeze-drying, modified atmosphere (MA) and vacuum packaging etc. However, the challenges and constrains to be faced under different aspects through value addition are:

- Technology of product development, processing, pigment extraction and other protocols are complicated enough. Thus simplification of existing technology and trickling the skill to grass root level is a huge challenge. In each step of processing there is tremendous need to standardize the techniques for better cost effectiveness and ease to handle the system. While innovating and standardization of different techniques the factors affecting rate of moisture loss during drying and estimation of pathological infestation and other degradation in storage are major changes of this project.
- Logistical and infrastructure challenges - Poor rural transport infrastructure tends to increase transaction costs in output markets and squeeze producer margins. However, these are not uncertain events but are known challenges, which none- the-less requires attention.
- Cost effectiveness and commercialization of technology: Scientists are more engrossed in

standardization of technology. But time has come when we need to focus on the scaling up and piloting of our technology for proper validation by the stake holders. In this aspect the existing Agricultural Research System should put more focus and small and medium scale projects for technology validation should come up in more numbers.

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49. Postharvest techniques for value addition in exotic and underutilized horticultural crops (spices)

M. Madhava Naidu
Chief Scientist & Head (Ret.), Plantation Products, Spices & Flavour Technology,
CSIR-CFTRI, Mysore-570020, Karnataka, India
Email: madhavanaidu45@gmail.com

The present day's agriculture is relying less than 100 plant species to provide food and nutrition to more than 90 percent of the population. There are more than 12,500 edible plant species in the world. Out of these, about 7,000 species have been used to a significant extent by humans at some point in time. A large number of edible species remain neglected. In the present situation, the agricultural production must look for the sustainable use of the available diversity in the exotic and neglected under-utilized crops. Underutilized crops have specific problems, intended to be better elucidated and addressed through in-depth deliberations involving researchers, intellectuals, regulatory authorities, policy makers, industry executives, farmers, NGOs, philanthropists and other stakeholders meeting on a common platform. This could bring out a clear roadmap to formulate an implementation strategy for various policies, programmes and capacity building at large. To analyse the status of underutilized and several exotic horticultural crops and plan for future, the World Health Organization (WHO) estimates that 65–80% of the population of the developing countries depends on medicinal/Horticultural plants for basic food/pharmaceutical care (WHO, 1998). Accordingly, the WHO has been stimulating studies involving medicinal/horticultural plants, with the aim of evaluating the potential benefits of using them. There is still a lack of knowledge of the clinical efficacy and safe use of many of these remedies. India has a great diversity of plants, which increases the chances of identification of substances with pharmacological activities. Numerous crude extracts and pure natural compounds from plants have been reported to have antioxidant and antimicrobial activities. Among the antioxidant compounds, flavonoids and phenolics which are largely distributed in nature, have been studied more comprehensively. Many countries across the globe have taken initiatives to support Horticulture Industry due to its significant contribution to their domestic economy, besides export. The challenges of overcoming malnutrition to majority of the global population are yet to be fulfilled, hence horticulture has major role to play.

1. Utilization of Palash (*Butea monosperma* L) an endangered forest produces as a potential nutraceutical

Butea monosperma Lam. Kuntze (Fabaceae), commonly known as palash, is a well-documented medicinal plant, which is used in Ayurvedic system of medicine for liver ailments. Found in greater parts of India, Burma and Srilanka, it is capable of growing in water logged situations, black cotton soils; saline, alkaline, swampy, badly drained soils and barren lands except in arid regions. Butrin and isobutrin are major principle compounds in the flowers and the plant has great potential in treating a number of ailments, as it is known to possess hepatoprotective, anti-inflammatory, anti-diabetic, anti-stress, anti-diarrheal, aphrodisiac, and antimicrobial properties. The leaves are astringent, tonic, diuretic and aphrodisiac. The bark is also reported to possess astringent, bitter, pungent, alterative, aphrodisiac and anthelmintic properties. The seed is anthelmintic and seeds are pounded with lemon juice and applied to the skin as rubefacient. Palash is grown in almost all states of India. However, major palash producing state is Chattisgarh. During 2020-2021 crop seasons, the highest area under palash cultivation was in Chattisgarh. The production was recorded in Chattisgarh, which produced 22050 Metric tons. Currently, 90% of this produce is being unutilized. About 10% of fresh flowers are collected and shade dried, and used for ayurvedic preparations by the tribal population. A huge quantity of palash flowers is available in India for value addition hence; the focus is to points towards the potential use of endangered medicinal palash plant components as antioxidants for food preservation and in health supplements as nutraceuticals. Conserves were prepared from Palash flower powder, using various solvents and solvent mixtures. The yields of extracts/conserve were maximum (47.6%) with methanol plus water (60:40) followed by 41.6% in ethyl alcohol plus water (60:40). Increasing the polarity of the solvent, yields of the conserves increased. However, polyphenol content in conserves decreased with increase in polarity of the solvent. The methanol extract showed highest antioxidant activity compared to ethanol and isopropanol extracts. At a concentration of 200 ppm, the methanol extract showed 76% and 92% of antioxidant activity by beta carotene-linoleate and DPPH methods in comparison to corresponding value of 95% for BHA. The total polyphenol content of methanol extract was found to be 39.7, as gallic acid equivalents. The antioxidant activity could be correlated to the polyphenolic compounds present in the extracts. Studies show that the isopropanol extracts particularly, has an inhibitory effect on the growth of at least two gram-negative bacteria. The extract was profiled by TLC and HPLC, wherein, butrin and isobutrin could be identified and separated. Further, these compounds were isolated by preparatory HPLC and characterized by MS and NMR analysis. A process for extraction of palash flowers and preparation of bioactive conserve from these flowers was standardized on a 15 kg level wherein 28.8% yield of the conserve as obtained.

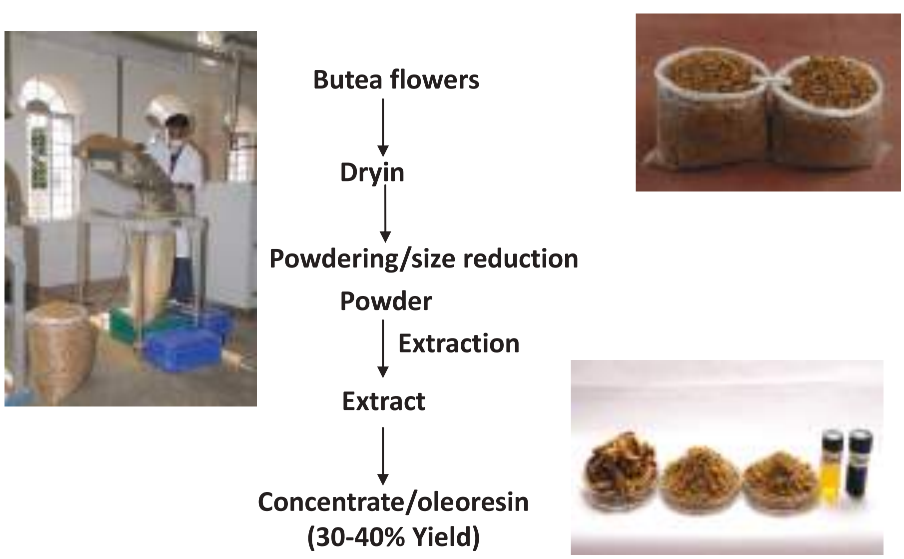


Figure 1. Preparation of *Butea monosperma* oleoresin

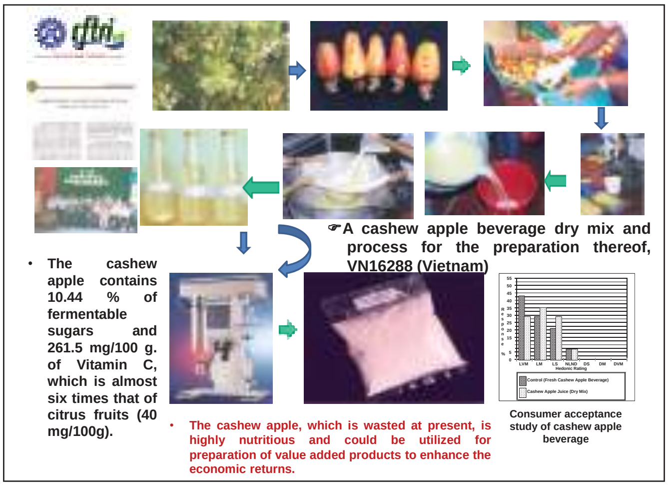
Utilization of bio-active conserve from palash flowers in the form of a beverage was envisaged. Accordingly, a beverage dry mix formulation incorporating palash flower extract/conserve was developed. Sensory results indicated that palash conserve at 300 ppm concentration was rated as “like very much” by 80% of the panel; “like moderately” by 20% of the panel. The present study points towards the potential use of methanolic extract components as antioxidants for food preservation and in health supplements as nutraceuticals.

Nutraceuticals from Cashew apple

The cashew is native of tropical America, including Brazil and the West Indies (Ramsammy 1996). Cashew is introduced into India by Portuguese travelers during 16 th century. Currently it is grown in an area of 7.12 lakh ha with a production of 4.99 lakh tons of raw cashew nuts. During 2021-2022, India earned a foreign exchange of 450 Million US$ by exporting 0.98 lakh tons of cashew kernels. For every ton of cashew nut, 8-10 tons of cashew apples are produced.

Cashew apple, the fruit of the cashew tree (*Anacardium occidentale* L) is a false fruit and is only a swollen fleshy peduncle while the fruit proper is the kidney-shaped nut attached to it. The plant prefers deep, fertile, sandy soils but will grow well on moist soils except pure clays or soils that are otherwise impermeable, poorly drained or subject to periodic flooding. It grows well under a wide range of tropical and subtropical climates but is sensitive to low temperatures and freezing. The cashew apple is pear-shaped and it looks like an over ripened apple. Its color varies between different shades of red and yellow. There is a wide variation in weight and size of the apple and also in size of the fruits. The cashew apple has a fibrous flesh and is full of juice. When tender, the fruit is acidic and highly astringent, but when fully ripe it is sweet and slightly astringent. It possesses an exotic flavour with pleasing aroma. The average weight of the fruit is about 30 to 100 g depending upon variety.

The cashew apple is highly nutritious and rich in vitamin 'C', and fiber that could help in prevention of hemorrhoids, varicose veins, hiatal hernias, and diverticulosis. Cashew fruit, according to Nadkarni's Materia Medica, is useful as an anaesthetic in leprosy and psomiasis and as ablister in warts, corns and ulcers. The cashew apple contains 10.44 % of fermentable sugars and 261.5 mg/100 g. of Vitamin C, which is almost six times that of citrus fruits (40 mg/100g). Thus, the fruit and the wine both have very good antiscorbutic properties. The liquor is also valued as a diuretic and has a healthy effect on the kidneys and advanced cases of cholera as well (S.N.Mahendru,). Various products can be made from cashew apples, such as fruit paste, candied fruit, canned fruit, jam and jelly, chutney, pickles, fruit juice, wine spirit and vinegar (Jain & Girdharilal 1962, Ohler, 1979, Lynannaz 1994). Literature is scant with regard to the pigments and also the nature of fiber in the fruits. The major problem in cashew apple utilization for product development is the presence of tannins which is responsible for the astringency, seasonal availability and short shelf life. However, tannins could be removed by precipitating with gelatin.



Research work conducted at National Research Centre for Cashew (NRCS, Puttur), Central Food Technological Research Institute (CFTRI, Mysore), Kerala Agricultural University (Madakkathara), and University of Agricultural Sciences (UAS, Bangalore) has resulted in developing protocols for preparation of a number of products from cashew apple. Preparation of some cashew apple products was developed on a cottage scale by Jain and Girdhari Lal (1963). Studies on some quality aspects and storage studies on cashew apple juice was studied by Gopi kumar and Aravindaksham 1962. The cashew production and processing technology were reviewed by R.C.Mandal (1992). Vaidehi *et al* (2000), reported cashew apple fruit and nut based recipes with nutritive value. Recently, CFTRI has developed a process for preparation of a novel flavoured candy & flavoured beverage dry mix (patent). NRCS, UAS, and KAS are mainly working in the area of cashew nut processing, varietal development through crop improvement programmes, and field evaluation studies.

1. New starches from underutilized plants for food applications

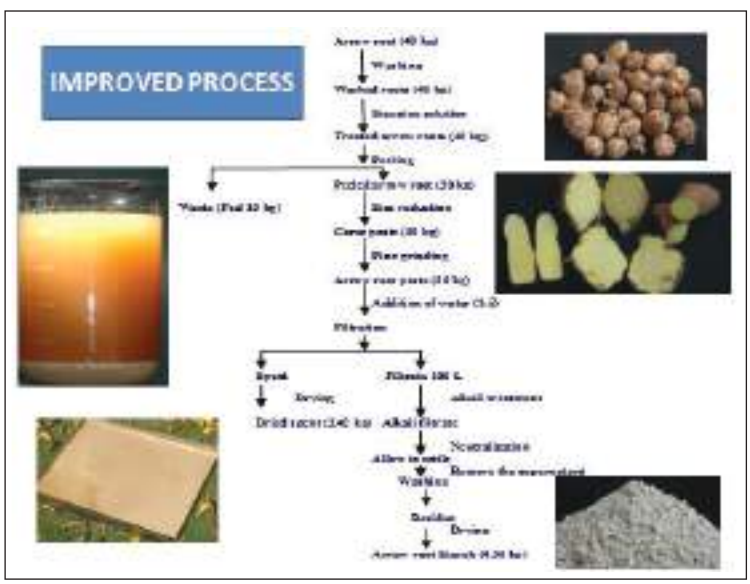
A. Curcuma angustifolia, (Zingiberaceae)

Starch is a major source of energy, and is available abundantly in plants. Starches from fruit and roots/ tubers and seeds/grains have been studied extensively for their application in processed foods. Food industry needs have become more complex with processing of more elaborate dishes; this is forcing the starch sector to search for new products to meet new consumer and processor market demands. Introducing new starch sources with industrially interesting processing features has been attracting the attention of industrialists as it could influence the world market. Such new crop sources including *Zenzuber zerumbet, Curcuma angustifolia,* (Zingiberaceae), *Marantha arundinacea*, (Maranthaceae) *etc.*, which are native to Asia and they are stem less herb with long fleshy fibrous roots, terminating in oblong tubers. Rhizomes are dried and powdered, and starch is isolated. The present review is focused on various methodologies available for the isolation, characterization of starch from selected unutilized agricultural crops. In addition, various physico-chemical and bioactive properties of their main constituents and methods applied for their authentification for quality assurance have also been reviewed.

Curcuma angustifolia (Zingiberaceae) is native to Central India, distributed in the west Bihar, north Bengal extending to Maharastra and South India. It is stem less herb with long fleshy fibrous roots termininating in oblong small tubers. It grows very well in most deciduous forest. Rhizomes are dried and powdered, and the starch obtained forms the chief source of Indian arrowroot. The rhizomes are used in inflammation, bone fracture, intestinal diseases, etc. by the tribals of Madhya Pradesh and Chattisgarh states of India. *C. angustifolia* rhizome is contains *ar*-curcumine (27.8%), ß-pinene (17.9%), α-terpineol (13.4%), camphor (12.1%), zingiberol (9.5%) and borneol (7.0%) as major constituents of *C. angustifolia* of Indian origin. Untreated Tikhur flour has bitter taste and unfit for consumption Traditional preparation of starch from the curcuma tuber is cumbersome and time consuming. Debittered Tikhur floor is used in food preparations such as Halwa, Burfi & Sharbat. To the best of our knowledge there are no scientific reports on debittering and technological aspects of C. *angustifolia* rhizome. Hence, the objective of the present study is to develop a method for debittering and preparation of powder from tikhur rhizomes and to check the suitability of the powder in product preparation.

Curcuma angustifolia L rhizomes were obtained from Chhattisgarh State Minor Forest Produce Co-Operative Federation Ltd., Raipur. They were washed, air-died and stored in cold room at 4°C. Rhizomes

(200 g), which contained ~ 60% moisture, were taken in each experiment. Peels (50 g) were removed by de-skinning of the rhizomes. The de-skinned rhizome were sliced and made into a paste using a laboratory grinder. Water (1 l) was added to paste and passed through a muslin cloth. The fibrous residue (6 g) was discarded. The filtrate in each trial was subjected to pretreatments with different reagents viz., hydrochloric acid (0.1, 0.2, 0.5%), acetic acid (1.0, 2.0, 4.0%), salt (2.0, 4.0, 6.0, 8.0%), acidified methanol (0.1%), gelatin (0.1, 0.5, 1.0%), sodium bicarbonate (1.0, 5.0%), magnesium carbonate (1.0%), potassium carbonate (1.0%), calcium carbonate (1.0%), calcium oxide (1.0%), potassium metabisulphite (2.0%) and sodium hydroxide (0.05, 0.1, 0.25, 0.5%). The treated mixture in each case was centrifuged at 5000 rpm for 30 minutes supernatant discarded and residue was re-dissolved in water. This was neutralized to pH 7 and centrifuged. The resulting flour sediment was washed with water to afford a clean white product. The concentrations of 0.25% gelatin, NaOH (0.1%) and $K_2S_2O_5$ (2.0%) were found to be optimum for the removal of bitterness from curcuma angustifolia with little effect on physico-chemical characteristics of flour. The product, obtained after sun drying, was subjected to sensory studies for its color and taste attributes and also, the prepared flour was evaluated for its chemical composition, mineral profile, and functional properties. The product deteriorative characteristics were studied and functional and economical package was designed to get shelf life of more than a year for the product. The study, thus, provides a simple solution for effectively removing the bitterness of Curcuma angustifolia L. rhizomes and obtaining quality shelf-stable flour. The new process obviates tedious and time consuming process steps of the traditional process. Further, sensory studies on the flour from the present process showed it to be comparable to the control sample from the traditional process.



In conclusion, Potassium meta-bisulphite (2%), gelatin (at optimum concentration of 0.5%) and Sodium hydroxide (at optimum concentration 0.1%) were found to be effective in removal of bitterness from *Curcuma angustifolia* with little effect on physico-chemical characteristics of tikhur flour. These permitted additives, by being water-soluble, are however removed from the product in the process. The study, thus, provides a simple solution for effectively removing the bitterness of *Curcuma angustifolia L.* rhizomes and obtaining a quality flour product. This flour product had small, medium and big size granules with amylose content of 21-27% and gelatinization temperatures in the range of 64.12–72.99°C. The isolated flour showed excellent swelling power and solubility, lower pasting temperature, higher viscosity peak, higher viscosity breakdown and lower setback; higher paste clarity and freeze–thaw stability. Sensory studies on the flour product from the present process showed it to be comparable to the control sample from the traditional process. The product characteristics indicate potential application of *Curcuma angustifolia* L flour in food products.

A. Zingiber zerumbet **Ginger**

In the Southeast Asian countries the *Zingiberaceae* family are generally used as spices, flavouring agents, the source of certain dyes and medicines, because of their exclusive flavour and new sources of active compounds (Habsah *et al.,* 2000) as well as due to their medicinal properties (Burkill, 1966). Infectious diseases are the leading cause of death worldwide. The emergence of multidrug resistant pathogens threatened the clinical efficacy of many existing antibiotics. This situation fuels the on-going research to discover antimicrobial agents from natural origins (Eldeen *et al.,* 2010).

The rhizome of *Z. zerumbet* has been used to treat various ailments in Asian and Arabic traditional medicine since ancient times (Jaganath *et al.,* 2000; Altman & Marcussen, 2001; Nalawade, 2003 and Tushar *et al.,* 2010). Some of the RZZ traditional usages as botanical medicine include the treatment of inflammation, headaches, fever, ulcers, toothache, indigestion, constipation, colds, diarrhoea, severe sprains, and to relieve pain, cure for swelling, sores and loss of appetite, nausea and even menstrual discomfort as well as antispasmodic, anti-rheumatic, diuretic agents and has a rich source of compounds of phyto-medicinal interest. The juices of the boiled rhizomes are used as a medicine for worm infestation in children. (Wutthithamavet, 1997; White, 2007; Bhuiyan *et al.,* 2009; Sulaiman *et al.,* 2010 and Zakaria *et al.,* 2010). *Z. zerumbet* is also used as a herbal medicine for the treatment of rheumatological conditions and muscular discomfort (Langner *et al.,* 1998 and Chang *et al.,* 2012). The Malays used the fresh rhizomes as a cure for edema, stomach ache, sores, and loss of appetite while the juice of the boiled rhizomes is used to treat worm infestation in children (Burkill, 1966; Somchit, 2003; Ruslay *et al.,* 2007 and Sulaiman *et al.,* 2010). In Thailand, the fresh rhizomes are also used as antiflatulent agent. Meanwhile, the Chinese macerated the rhizomes in alcohol and use it as a tonic, depurative, or stimulant while the Taiwanese used the plant as an anti-inflammatory adjuvant for stomach ache, sprain, and fever. In India, the rhizome powder is mixed with ripe *Morinda citrifolia* (Indian mulberry, noni) for the treatment of severe pain, the cooked and softened rhizome is used to treat toothache, cough, asthma, worms, leprosy, and other skin diseases, and the ground and strained rhizome is mixed with water and consumed to treat stomach ache (Zakaria *et al.,* 2010). The Hawaiians apply the compressed RZZ to sore spots, bruises, and cuts and also used it to treat headaches, toothache, ringworm/other skin disease, achy joints/sprains and stomach-ache. In addition, they also used ashes from burnt *Z. zerumbet* leaves, which are then combined with a mixture of ashes of *Schizostachyum glaucifolium,* nut sap of *Aleurites moluccana*, and tuber sap of *Z. zerumbet,* as a remedy for cuts and bruised skin while the RZZ was mashed with salt and rubbed on the head to treat headaches (Abbott, 1992 & Chun, 1994). Moreover, the plant's pine cones are used as an ornamental in gardening, and the milky juice obtained from the pine cones is famously used as a shampoo in Hawaii (Wagner *et al.,* 1990; Chien *et al.,* 2008 and Yob *et al.,* 2011).

Shampoo ginger (*Zingiber zerumbet* L.) has been studied by using headspace solid-phase microextraction (HS-SPME) combined with gas chromatography (GC). The effects of extraction with different fibers like polydimethylsiloxane (PDMS, 7 µm), polyacrylate (PA, 85 µm); at varioustime, temperatures on the HS-SPME was investigated by using response surface methodology coupled with full factorial experimental design. SPME-GC-Mass Spectroscopyanalysis was also performed to identify the components extracted from the volatile fraction. Zerumbone was a major compound in *Z. zerumbet* L samples and area percentage ± relative standard deviationobtained by HS-SPME was 56.3±4.7%, 47.5±27.2%with PA-85 µm, PDMS-7 µmfibers respectively. Results indicated that HS-SPME-GC method proved to be a single and straightforward tool for the determination of fingerprinting characteristic of the volatile composition of*Z. zerumbet*and thus, the simplicity of SPME makes it a convenient tool for qualitative comparison of different species of ginger aiming at the marker compound such as zerumbone. *The study, thus, provides a simple solution for effectively removing the bitterness of Curcuma angustifolia L. and Zenzuber zerumbet rhizomes and obtaining quality shelf-stable flour.* The new process obviates tedious and time consuming process steps of the traditional process. Further, sensory studies on the flour from the present process showed it to be comparable to the control sample from the traditional process.

50. Biological control options for insect pest management in exotic and underutilised fruits and palms in India

Chandish R. Ballal[1], V. Sridhar[2], A. T. Rani[3] and N. Anusha[4]
[1]Former Director, ICAR-NBAIR, Bangalore, [2]Principal Scientist, [4]PhD student,
ICAR- Indian Institute of Horticultural Research, Bengaluru 560089, India
[3]Scientist, CHES, Chethalli
Email: ballalchandish@gmail.com

Introduction

Exotic stands for anything "originating or characteristic of a distant foreign country". As Indian palettes open up to global cuisines, the domestic demand for exotic fruits and vegetables has grown considerably. India's annual import of exotic fruits is estimated to be 4,00,000 tons annually and it is valued at roughly Rs 40 billion. The exotic fruit market is estimated to be worth Rs.3000 crores. Exotic produce is priced higher and is sold at 50% higher rate than local fruits. In fact, the demand for exotic fruits in India had grown to such an extent than in 2021, the Indian Government decided to promote 10 commercially viable exotic fruit crops in India. This directive was the result of a collaboration with the Food and Agriculture Organisation (FAO).

Major exotic fruit crops gaining popularity in the recent past include avocado, blueberry, dragon fruit, figs, kiwi, mangosteen, persimmon, passion fruits, rambutans and strawberries. Underutilized fruits are those which have market value but not widely grown in the field and rarely found in the market. Similarly, India has several palms which are native as well as exotic and are being grown as both crops and ornamentals. Important pests on some of these crops and the feasible biological control options for their management either singly or as a part of IPM module are discussed in this paper.

The following is a general list of pests infesting exotic and underutilized fruits and palms based on information available from India and other countries. A clear crop-wise documentation on the identified major pests infesting these crops in different parts of our country is still not available.

Insect-pests of avocado

Avocado, *Persea americana* (Mill.) is a potential exotic and high value fruit crop. In India it is commonly known as Butter fruit. In recent years, there is an increased demand for avocado and the crop is gaining popularity as a cash crop because of its various nutritional properties and industrial requirements. There has been simultaneous increase in the number and severity of insect and mite pests recorded on this crop, thus detrimentally affecting quality avocado production in India. Major pests recorded on Avocado are mites, mealy bugs, scales, leaf roller, leaf miner and twig borer and shot hole borer. The damage caused by some of the important pests are given below (A. T. Rani, unpublished information).

Avocado trunk borer *Synanthedon* spp. or *Pyropteron* spp. (Order: Lepidoptera, Family: Sesiidae): The larvae burrow into the stem near ground level. The presence of the borers is indicated by brownish gummy frass, which exudes from the bark around the infested part.

Avocado shot hole borers *Xyleborus* spp. *Xylosandrus crassiusculus* (Order: Coleoptera, Family:

Curculionidae): Holes in the bark made by adult beetles give the appearance of a shot-gun blast, leaving "shot holes". The bark of infested twigs, branches and trunks is perforated with many small round holes. The frass is ejected from the entrance hole in the form of cylinders.

Avocado stem borer *Zeuzera* spp. (Order: Lepidoptera, Family: Cossidae): The larva bores into the stem near ground level, makes irregular tunnels and it can be identified by the presence of big pellets of larval excreta or frass deposited at the base of tree. These increase in size as infestation progresses.

Fruit fly, *Bactrocera dorsalis, B. caryeae* (Order: Diptera, Family: Tephritidae): The fruit flies lay eggs under the rind of ripening fruits. The eggs hatch out within few days and the maggots start feeding inside fruits. The affected fruits can be easily distinguished by the presence of a rotten, round necrotic patch at the oviposition site. Affected fruits fall off. The maggot pupates in the soil and emerges as adult flies after 7-10 days.

Shoot and inflorescence webber (Order: Lepidoptera, Family: Tortricidae): During vegetative stage the terminal leaves are clumped together by silken webbing and larvae feed within the web. During flowering, larvae web the inflorescence and feed within web.

Leaf miner (Order: Lepidoptera, Family: Gracillariidae): During vegetative growth period the larvae feed on the epidermis producing irregular mines. Several mined portions merge and appear as whitish blistered patches on the leaf surface.

Spiralling whitefly, *Aleurodicus* spp. (Order: Hemiptera, Family: Aleyrodidae): Nymphs and adults occur in large numbers on the underside of the leaves and suck the plant sap from leaves. Honey dew secretion leads to development of sooty mold fungus, thus affecting photosynthetic activity of the plant.

Mealybugs, *Pseudococcus* spp., *Planocccus citrii* (Order: Hemiptera, Family: Pseudococcidae): The nymphs and adults are found in clusters and suck the plant sap from the tender plant parts and excrete honeydew, which leads to the growth of black sooty mold on leaves, twigs and on fruits.

Tea mosquito bug, *Helopeltis* spp. (Order: Hemiptera, Family: Miridae): Nymphs and adults make punctures and suck the sap from tender parts and flower buds. Brownish black necrotic patches can be seen on the affected portion due to injection of toxin, leading to flower dropping.

Insect pests of Passion fruit, *Passiflora edulis* (Passifloraceae)

Pest	Symptoms of damage
Bark borer, *Indarbela tetraonis* & *Batocera rufomaculata*	Infestation by the pest is localized to bark and phloem region leading to death of the plant
Aphids, *Myzus persicae* and *Aphis gossypii*	Cause malformation in foliage, and are very important as disease vectors, transmit viral disease that causes hardening of fruits.
Mealy bug, *Planococcus citri*	If a severe infestation occurs, loss of vigour, leaf drop, and fruit malformation may occur. If unchecked, an infestation may cause death of the plant.
Trunk borer	Yellowing of affected branch or tree is the primary symptom which leads to drying of entire branch or tree
Fruit fly, *Carpomyia vasuviana*	Eggs laid under the skin of the fruit and larvae make their way into the fruit, eventually causing rot and making it unfit for market

(Source: Jeyarani and Kowsika, 2019)

Insect pests of Rambutan (*Nephelium lappaceum* L.)

Pest	Symptoms of damage
Fruit borer (*Conogethes punctiferalis*)	Larvae bore into immature and mature fruits, feeding on the seeds, rendering them empty and unmarketable. Oozing out of the excreta and frass at the mouth of the bore hole affects the marketability of even the uninfested fruits of the same bunch.
Fruit webber (*Eublemma anguilifera*)	Larvae spin webs, shelter under the webs and feed on fruits. Pupation takes place in cocoons near the base of the fruit or in nearby branches. The infested fruits dry up.
Mealy bug (*Planococcus citri*)	Both nymphs and adults suck sap from the flowers and fruits. Sooty mold observed on the infested part due to secretion of honey dew.
Leaf folder (*Thalassodes quadraria*)	The larvae fold the new vegetative flush and feed from the inner portion

(Source: Jayarani and Kowsika, 2019)

Insect pests of Mangosteen, *Garcinia mangostana*

The most serious pests are *Hyposidra talaca* (Walker) (Lepidoptera: Geometridae), a highly polyphagous insect. *Hyposidra talaca* is a typical looper, causing defoliation in tropical lowlands and highlands. The citrus leafminer, *Phyllocnistis citrella* (Lepidoptera: Phyllocnistidae), mines leaves causing leaf deformation and often leading to early fall. *Sictoptera cucullioides* Guenée (Lepidoptera: Noctuidae) is reported to feed voraciously on young flushes (Pena, 2008).

Insect pests of Fig

Pests of national significance are stem borer, *Batocera rufomaculata* (De Geer) (Coleoptera: Cerambicidae); fruit fly: *Bactrocera* spp. (Diptera: Tephritidae); fig midge: *Anjeerodiplosis peshawarensis* Mani (Diptera: Cecidomyiidae), mealybug: *Drosicha stibbingi* Green (Hemiptera: Coccidae), and *Planoococcus lilacinus* Cokerell. (Hemiptea: Pseudococcidae). Major insect and mite pests recorded in Punjab were fig leaf roller, *Phycodes minor* Moore and *P. radiata* Ochsenheimer, fig borer or red spotted long horned beetle, *B. rufomaculata*, hairy caterpillars, *Euproctis lunata* Walker and *Spilaractia obliqua* (Walker), fruit flies, *Bactrocera dorsalis* and *B. zonata*, cottony cushion scale, *Icerya* sp., aphid, *Aphis gossypii* Glover and two-spotted spider mite, *Tetranychus urticae* Koch. Among unidentified insects, whitefly, fruit weevils and thrips were observed. The seasonal occurrence of the pests was also recorded (Singh and Kaur, 2017).

Insect pests of strawberry

Some of the major arthropod pests that affect strawberry production include two-spotted spider mites, *Tetranychus urticae* Koch, thrips, *Frankliniella* and *Scirtothrips* spp., armyworms, root-boring pests, and many different hemipterans that cause injury to the strawberry leaf and fruit including the tarnished plant bug, *Lygus hesperus*, and the seed bug *Neopamera bilobata* Say. (Liburd and Elena, 2019).

Insect pests of Blueberry

The insect pest complex found in blueberries consists generally of blueberry maggot fly, cranberry fruitworm, cherry fruitworm, aphids and leafhoppers (virus vectors), various leafrollers, blueberry blossom weevil, blueberry tip borer, blueberry stem borer, dogwood borer, plum curculio, scale insects, Japanese beetles, yellow jackets, and sometimes gypsy moth (Concklin, 2012).

Insect pests of dragon fruit (Kamalam), *Selenicereus* spp.

Pest	Symptoms of damage
Ferrisia dasylirii (Cockerell)	They insert a stylet into the plant to draw the sap: as they feed and colonize plants, they extrude honey, a sugary substance conducive to the growth of sooty mold
Franklieniella occidentalis (Pergande), *Scirtothrips dorsalis* (Hood), *Thrips palmi* (Karny)	Thrips scar the fruits as they feed, cause deformation when ovipositing and leave fecal deposits that turn reddish brown to black
Leaf footed bugs, *Leptoglossus phyllopus* (Linneeus),	Feeding produces unsightly punctures that result in poor quality fruits and may allow bacteria and fungi to infect the fruit. They can also damage the stems and arms of the plants. This damage is represented as deep puncture wounds.
Aphis craccivora (Koch) *Aphis gossypii* (Glover)	Sucking the sap from the leaves, flowers and fruits
Mealybugs, *Ferrisia virgata* Cockerell	Sucks the sap and in severe infestation causes drying of the plant
Fruitfly, A*nastrepha* sp.	The maggot damages the fruit by feeding on its pulp, contaminating it with bacteria and fungi and causing premature fruit drop

(Source: Duncan et al., 2021)

Pests of underutilised fruit crops: Underutilized fruits are those which have market value but not widely grown in the field and rarely found in the market. Common pests on some of the underutilised fruit crops are listed below

Ber *Zyzyphus jujuba* (Ramnaceae)

Pest	Symptoms of damage
Ber fruit borer, *Meridarches scyrodes*	The reddish larvae bore into the fruit and feed on the pulp and faecal mass get accumulated within
Ber seed weevils, *Amblyrrhinus poricollis* and *Myllocerus sp*	Feed on leaves and inflorescence, fruits are cut open, the developing seed is completely eaten away by the pest. In the hollowed area, each of these fruits can hold a grub, a pupa or an adult
Ber fruit flies, *Bactrocera zonata*, *Bactrocera dorsalis* and *Carpomyia vesuviana*	Larval stage feed on the pulp and make galleries in it. The excreta of the larvae accumulate in the galleries, which may result in rotting of the fruit. Infested fruits become deformed and their growth gets arrested. A large number of such fruits drop off from the trees

Bark Eating Caterpillar, *Indarbela quadrinotata, I. watsoni and I. tetraonis*	Heavy infestation by this pest stunts the trees and adversely affects fruit yield.
Hairy Caterpillars, *Dasychira mendosa, Euproctis fraternal*	Hairy caterpillars feed on the young leaves and fruits. The older caterpillars spread in all directions and devour leaves and fruits and sometimes even tender shoots. They start eating new foliage as it grows after pruning and this is continued by the overlapping generations

(Source: Jeyarani and Kowsika, 2019)

Carambola, *Averrhoa carambola*

Major pests include, Carambola fruit fly, *Bactrocera carambolae,* Fruit piercing moths, *Gonodonta spp*. and *Eudocima spp*. (Lepidoptera: Noctuidae); Armored scale, *Morganella longispina* (Morgan) (Hemiptera: Diaspididae); Stink bug, *Nezara viridula;* False spider mite, *Brevivalpus phoenicis* (Geijskes) (Acarina: Tenuipalpidae), causes bronzing of the fruit (Pena, 2008).

Jamun

Root grub	*Holotricha serrata* Fabricius
Leaf webber	*Dudua sp.*
Helmet caterpillar	*Carea angulate* Fabricius
Bark eating caterpillar	*Inderbela tetraonis* Moore
Twig & Fruit borer	*Conogethus punctiferalis* Guenee
Fruit fly	*Bactrocera dorsalis* Hendel, *Zeugodacus cucurbitae* Concqullet

(Source: Jeyarani and Kowsika, 2019; Mani, 2022)

Annona

Pest	**Symptoms of damage**
Annona seed borer, *Bephratelloides cubensis*	The probes in young fruits look like dark pinpricks surrounded by a round whitish patch and in older fruits the whitish patch does not appear, and the probe marks are permanent and often ooze sap.
Fruit borers, *Heterographis bengalella*	Caterpillar makes irregular tunnels and damages the mesocarp by feeding the internal content of the fruits
Fruit fly, *Bactrocera zonata;* *Bactrocera tryoni*	Maggots bore into the semi ripened fruits and feed on the pulp. Affected fruits become shrivelled, deformed, rot and drop.
Annona Scales *Parasaissetia nigra, Saissetia coffeae, S. oleae and Philephedra tuberculosa*	Direct damage is caused by insertion of stylets during feeding by the nymphs, which causes premature leaf drop and drying of twigs. Sooty mold develops on honeydew excreted by these scale insects and incase of severe infestations shoots or branches die and the entire plant can get killed too.
Pink mealybug, *Maconellicoccus hirsutus*	The mealy bugs suck sap from twigs, leaves and flowers. Infested fruits have uneven shapes, poor quality and are susceptible to secondary infections by pathogens

(Source: Jeyarani and Kowsika, 2019)

Jack fruit, *Artocarpus heterophyllus*

Pest	Symptoms of damage
Flies *Anastrepha* spp.	Adults cause oviposition injury in green fruits, leading to disfigurations of the fruit surface. The maggots damage the fruit by feeding on its pulp, contaminating it with bacteria and fungi and causing premature fruit drop
Jackfruit borer *Diaphania caesalis*	Attacks the tender shoots, male and female spikes and fruits of all development stages. At flowering stage the larva bores into spike and feeds on internal tissues. Early infestation results in deformation of fruits and sometimes dropping off the immature fruits. The larvae bore into the mature fruit and cause damage to the edible part. Later infested fruits frequently get rotten due to entrance of rainwater in to the fruits. In nursery, caterpillars damage the tip of jackfruit sapling causing retardation of growth of the saplings and initiation of lateral branches
Fruit fly, *Bactrocera umbrosa*	Eggs laid under the skin of the fruit and larvae make their way into the fruit, eventually causing rot and making it unfit for market
Wood boring insects *Elaphidion mucronatum, Nyssodrysina haldemani, Leptostylopsis terraecolor*	Yellowing of affected branch or tree is the primary symptom which leads to drying of entire branch or tree
Jackfruit trunk borer *Batocera rufomaculata*	Bores into the tender shoots and buds (Ahmed et al., 2013)
Bud weevil/leaf eating weevil *Ochyromera artocarpi M., Onychocnemis careyae*	The small whitish grubs bore into tender flower buds and fruits, and induce premature drop. The greyish brown adult weevils nibble and feed on the leaves (APAARI, 2012)
Bark eating caterpillar *Indarbela tetraonis*	Bores into the trunk or branches, eats the bark of the tree in the immediate vicinity of the hole. Small trees are easily ring-barked by this pest and die. even large trees are disturbed by the interrupted sap flow; they may fail to flush and drying of the branches occurs. Large dark-brown webby masses, comprising chewed wooden particles and faecal matter, are conspicuously seen plastered loosely on tree trunks or main branches (Rajkumar et al., 2018)

(Source: Rajkumar et al., 2018; Jeyarani and Kowsika, 2019)

Rajkumar et al. (2018) have also listed about 38 species of insect pests which attack jackfruit. Besides the above-listed ones, the additional major pests include mealy bugs *Drosicha mangiferae, Nipaecoccus viridis, Planococcus lilacinus*, spittle bugs, *Cosmoscarta relata*, *Clovia lineaticollis*, trunk borer *Aprioma germari* and fruitfly *Bactrocera rufomaculata.*

Exotic and under-utilised palms

The important exotic palms belonging to family Arecaceae are Date Palm (*Phoenyx dactylifera* L.), and Oil palm (*Elaeis guinensis*) (family Arecaceaea) and the under-utilised ones are the Toddy palm/ Sago/ Fish tail palm (*Caryota urens* L.) and Palmyra palm (*Borassus flabellifer* L.)

Major pests of Palms

Date white scales, *Parlatoria blanchardii*. red palm weevil, *Rhynchophorus ferrugineus*, rhinoceros beetle, *Oryctes rhinoceros* Red scale, *Phoenicococcus marlatti*, Caroub moth, *Ectomyelois ceratoniae*; Termites, *Microtermes diversus*; Mites *Oligonychus afrasiaticus, Mackiella phoenicis, Tenuipalpus eriophyides* and whiteflies.

Biological control options for insect pests infesting exotic and under-utilized fruits

Avocado

It is reported that indigenous natural enemies are extremely important in the control of avocado pests in California (McMurty, 1992). Hence, minimal use of foliar pesticides is recommended for conservation of the natural enemies. The two lepidopteran pests, *Sabulodes aegrotata* (Guenée) and *Amorbia cuneana* Walsingham, have guilds of natural enemies, which usually seem to be effective in maintaining them below damaging levels. However, augmentative releases of *Trichogramma platneri* Nagarkatti have also been shown to be effective in suppressing populations of these pests and they are used by some growers for supplemental control.

Avocado brown mite *Oligonychus punicae* (Hirst) was observed to be kept under check by the indigenous coccinellid beetle *Stethorus picipes* Casey. Exotic Phytoseiid mites were introduced, however they did not establish. This failure to establish was considered to be either due to competition with the native phytoseiid *Euseius hibisci* (Chant) or due to the fact that avocado is not a suitable host plant for its establishment.

The Latania scale, *Hemiberlesia lataniae* (Signoret) was never considered a problem as several groups of natural enemies including the twice-stabbed lady beetle *Chilocorus stigma* Say, the wasp *Aphytis proclia* (Walker), and the mite *Hemiscarcoptes cooremani* Thomas could regulate the population of this scale insect.

The six-spotted spider mite *Eotetranychus sexmaculatus* (Riley) population was maintained at low levels by the phytoseiid mites *Euseius hibisci* (Chant) and *Amblyseius (Typhlodromalus) limonicus* Carman and McGregor. Also, *Typhlodromus rickeri* Chant, a species introduced from citrus in India in 1961 for biological control of citrus mites, became established on avocado and was associated mainly with six-spotted mite in Santa Barbara County and could be recorded even several miles away from the release sites.

The establishment of *Thripobius semiluteus* on greenhouse thrips probably was considered a partial success. Detailed studies in two orchards indicated that thrips population declines occurred when the estimated percent parasitization increased to about 60%. Further spread of *T. semiluteus* was facilitated by initiation of its commercial production and release beginning in 1990.

For the management of the long-tailed mealybug *Pseudococcus longispinus* (Targioni Tozzetti) in 1941, two encyrtid parasitic wasps *Anarhopus sydneyensis* Timberlake from Australia and *Hungariella peregrina* Compere from Brazil and Argentina, were released in San Diego County. Both species became established and they affected biological control within 2 years. This was considered a complete success on avocado.

Releases of six different species of phytoseiid mites (*Galendromus annectens, G. helveolus, G. pilosus, G. occidentalis, Neoseiulus californicus,* and *Typhlodromus rickeri*) at a rate of 2000 per tree were evaluated for their ability to control *Oligonychus perseae* on avocados in California. Early release made when 75% of sampled leaves were infested with one or more adult *O. perseae*, resulted in recovery of five out of six phytoseiid species released. Besides, densities of *G. helveolus* and *N. californicus* increased following the release and peaked 8 and 10 weeks post release, respectively (Hoddle et al., 1999).

Passion fruit

In Western Samoa, the aphelinid parasitoids *Encarsia berlesei* (Howard) and *E. diaspidicola* (Silvestri) were released against the diaspidid *Pseudaulacaspis pentagona* (Targioni-Tozzetti) on passion fruit vines. At one of the release sites, where vines survived, an endemic coccinellid predator, *Sticholotis quadrisignata* Weise, kept populations below 3000 females per vine until the parasitoids became established. Biological control of *P. pentagona* was achieved at both the release sites eight months after the parasitoids were introduced. (Liebregts et al. 1989).

In Queensland, *Aonidiella aurantii* (Mask.) infesting passion fruit was parasitised by *Comperiella bifasciata* How and *Aphytis chrysomphali* (Merc.), while *Cryptolaemus montrouzieri* Muls. and *Chrysopa* sp. were important predators of *Planococcus citri* (Risso) (Murray, 1976).

In India for the bark borer management, the affected branches are cleared of the frass and faeces and the dead branches are removed and burnt. Predators recorded on aphids include *Scymnus*, *Chrysoperla*, *Aphidoletes*, *Syrphus* and other coccinellids and parasitoids *Lysiphlebus testaceipes*, *Aphidius colemani* and *Diaeretiella rapae* and on mealybugs, predators recorded include *Cryptolaemus montrouzieri*, *Harmonia octomaculata*, and chrysopids and parasitoids *Coccophagus* sp., *Anagyrus coccidivorus*, *A. pseudococci*, *Leptomastidea abnormis* and *Leptomatrix dactylopii*. For trunk borer, no biocontrol option has been studied, proper field sanitation and plugging of holes with fumigating chemicals at early stage is recommended. (Jayarani and Kowsika 2019). For management of fruit flies, wrapping of fruits with empty cement bags or jute sacks is recommended (Jayarani and Kowsika 2019), while NIPHM recommends use of parasitoid *Opius fletcheri.*

Rambutan and mangosteen

A listing of the pests and some natural enemies recorded on rambutan, durian and mangosteen in North Queensland has been done by Astridge (2001). In Hawaii, to manage the mangosteen caterpillar *Stictoptera cuculioides* Guenee, the recommendation to growers was to monitor new flushes as they emerge, for evidence of feeding damage and then to utilise *Bacillus thuringiensis* or Azadirachtin, which could provide effective control (Nagao et al., 2004). In southern Mexico, ant *Azteca velox* (Forel) was found associated with mealybug *F. virgata* on rambutan (Hernández-Arenas et al., 2011). A study showed that in a *Citrus* sp. orchard system, where abundance of *Coccus viridis* decreased in the presence of *A. velox*, with a corresponding reduction in damage (Eubanks and Styrsky, 2006). It was expected that a similar relationship could happen with the mealybug in rambutan, when *A. velox* was present.

Several natural enemies have been recorded on *Conogethes punctiferalis* infesting cardamom and castor. For management of *C. punctiferalis* on rambutan or jamun, efforts could be made to evaluate biocontrol agents *viz.* macrobials such as *Trichogramma* spp. and *Chelonus blackburni* and microbials such as entomopathogenic fungus, entomopathogenic nematode, bacteria and viruses (Ballal et al., 2018).

Dragon fruit

In South Florida, the pests and natural enemies on dragon fruit has been listed by Carrillo et al. (2020) and Duncan et al. (2021). Some natural enemies, such as ladybugs, lacewing larvae, predatory mites, and the minute pirate bug were known to predate on thrips. Some tachinid flies were reported to attack adults of the leaf footed bugs and few eupelmid and scelionid wasps attacked the egg stage. Parasitoids

Lysiphlebus testaceipes (Cresson) and *Aphelinus* sp. and predators viz. lady bird beetles and lacewings were important naturally occurring biocontrol agents of aphids, keeping their populations at low levels. *Cryptolaemus montrouzieri*, which was commercially available was released against the mealybug *Ferrisia dasyliri*. A low salt maldison protein hydrolysate bait spray which is less harmful to beneficial insects was reported to manage the fruit fly (Zucchi, 2000).

Strawberry

Augmentative biological control has emerged as an effective tool to manage several strawberry pests such as thrips, mites, plant bugs, weevils, spotted wing drosophila, aphids, whiteflies, and various lepidopteran pests, especially through the use of predatory mites, entomofungal pathogens and entomopathogenic nematodes. However, conservation biological control tactics are yet to be utilized for strawberry pest management widely. The lack of adoption of conservation biological control can be attributed to the limited field research and cost-benefit analysis available (Lahiri et al., 2022).

Annona

An IPM module is recommended by DPPQ&S for managing the insect pests of Annona, which include collection and destruction of mealy bug infested leaves, twigs and fruits, ploughing of orchard in November, release of *Cryptolaemous montrouzieri* beetles and parasitoids like *Anagyrus dactylopii* and *Aenasius advena* to tackle mealy bugs; collection of fallen infested fruits and destroying them; summer ploughing to expose the pupae; immersion of fruits in hot water (45 to 47°C) for 60 minutes to kill eggs and maggots; setting up of 10 methyl eugenol traps per acre; field release of natural enemies *Opius compensates* and *Spalangia Philippines* to tackle *Bactrocera dorsalis*; control ants and dust which can give the scale a competitive advantage; spraying dormant oil in late winter before spring; spraying of horticultural oil, if needed, year round; adopting bagging of fruits and use of braconid parasitoids (*Apanteles* spp.) to parasitize lepidopteran larvae (Source: DPPQS**)**. The challenge, however, would be the availability of the biocontrol components included in the module.

Jackfruit

A low salt maldison protein hydrolysate bait spray which is less harmful to beneficial insects is recommended to manage the fruit fly, thus conserving the beneficials too (Zucchi, 2000).

Management of mealybugs

Mealybugs (*Planococcus* spp.) are reported on avocado, passion fruit, rambutan, fig and Annona. The coccinellid predator *Cryptolaemus montrouzieri* was introduced from Australia into India for the control of soft green scale *Coccus viridis.* Though it could not establish on soft green scale, it was reported as a common predator of many species of mealybugs and to some extent on scale insects in Karnataka. This exotic coccinellid can now be successfully mass produced and field released. This predator is a voracious feeder and an ideal biocontrol agent which can be produced by commercial insectaries. In fruit and plantation crops, viz., coffee, citrus, guava, citrus, grapes, mango, pomegranate, custard apple, sapota, ber, brinjal, crotons, etc, this predator has performed extremely well as a biocontrol agent. The added advantage was that it did not seriously impair the efficiency of local biocontrol agents. This coccinellid has established so extensively that it is not considered as an exotic predator any longer. This predator can be released against *Planococcus* spp. infesting the exotic and under-utilized fruit crops (Ballal, 2021).

Biological control options for insect pests infesting palms

Considerable amount of basic and applied research has been carried out by ICAR-CPCRI and ICAR-NBAIR on the biocontrol approaches to manage the major insect pests infesting the coconut palm and these have proved to be highly successful. These modules could be evaluated and adopted for management of the same pests when they infest the exotic and under-utilized palms.

Rhinoceros beetle: Two potential microbial agents *viz.*, green muscardine fungus (*Metarhizium anisoplzae*) and *Oryctes rhinoceros virus* (OrY) cause disease to the immature and adult stages of the beetle. Use of these microbial control agents is advantageous because they are relatively host specific, does not cause environmental pollution, safe to humans and are compatible with other control methods. The disease caused by the fungus is called green muscardine disease. *M. anisopliae var. major* is highly infective and widely used for the control of *O. rhinoceros*. The fungus gains entry into the body of the host through the cuticular region. The pathogen is highly virulent and produces epizootics in the grub population in the breeding ground. All stages of the host excepting the eggs are mycosed. Death and mummification occurs within 15-20 days after infection. A white mycelial mat appears externally, turning green few days later because of the production of spores. Field utilization of microbials has proved to be very successful.

Black headed caterpillar: Release of stage specific parasitoids has resulted in successful management of BHC. Field release of the three stage specific *Opisina arenosella* parasitoids *viz Goniozus nephantidis*, *Elasmus nephantidis* and *Brachymeria nosatoi* at fixed norms and intervals in a heavily infested coconut garden (2.8 ha) for a period of five years resulted in highly significant reduction in *Opisina* population. Follow up observations revealed that even after three years no build-up of the pest was noted in the released site (ICAR-CPCRI).

Red Palm weevil: An IPM module for management of RPW included Prophylactic delivery of filter paper sachets containing ten *Heterorhabditis indica*-infected *Galleria mellonella* cadavers in combination with botanical cake on the topmost three leaf axils (besides spot application of pesticides). Also, installation of pheromone traps @ 1 trap / ha through slow release delivery in community mode is an important step to be followed (Rajkumar et al., 2017). Studies conducted by Venugopal and Subaharan (2019) indicated that food baits (banana volatile compounds) with aggregation pheromone attracted a higher mean number of adult weevils Entomopathogenic fungi are generally considered as potential bioagents for management of RPW. Preliminary data generated in Taiwan indicated that four *Beauveria bassiana* isolates (JEF-484) and one *Isaria fumosorosea* isolate (JEF-014) proved promising (Yang et al., 2023).

Rugose spiraling whitefly: ICAR-CPCRI recommendation include: Application of 1% starch solution on leaflets to flake out the sooty molds. Installation of yellow sticky traps on the palm trunk as well as in interspaces to trap adult whiteflies. Encourage build up of parasitoids (*Encarsia* sp.) and re-introduce parasitized pupae to emerging zones of whitefly outbreak.In severe case, spray neem oil 0.5% and no insecticide is recommended. Through recommendations to farmers on a non-chemical pesticidal approach, in Karnataka the parasitoid *Encarsia guadeloupae* Viggiani was conserved and the pest population could be significantly reduced in most of the areas of infestation (Selvaraj *et al.* 2017). A fungal pathogen *Isaria fumosorosea* was also effective in managing RSW.

White grubs: Deep ploughing during pre and post monsoon periods exposes the grubs to predators. Setting up of light traps in the infested field helps to collect and destroy the beetles during peak period of emergence. *Metarhizium anisopliae* and entomopathogenic nematodes have been field tested and proved to be highly effective options for management of white grubs (Ballal, 2021).

Take home messages

- A structured study to be taken up to prepare a clear document on the pest species infesting the exotic and under-utilised fruits and palms with correct identification of the species recorded
- Search for the associated natural enemies (predators, parasitoids and microbials) of the major pests on the crop
- Evaluation of the proven bioagents (which have been successful against the same pest on other crops) on these exotic and under-utilised crops, initially in small plot trials and later in farmers' fields.
- Work out the cost economics of biocontrol strategies vs. other management strategies
- Standardisation of improved mass production technologies and transfer of technologies to private entrepreneurs to ensure availability of bioagents.

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51. Biotic stresses in palms

Vinayaka Hegde, Prathibha V.H., Daliyamol and A. Josephrajkumar
ICAR-Central Plantation Crops Research Institute, Kasaragod 671 124, Kerala
Email: hegdev64@gmail.com

Introduction

Palms are groups of woody monocotyledon plants belonging to the family *Arecaceae* and distributed throughout the tropical and subtropical regions of the world. There are about 2779 species of palms belonging to 200 genera all over the world and about 106 species of palms are distributed in India (Kulkarni and Mulani, 2004). Palms are widely regarded as being second only to the grasses in economic importance and form a vital component of forest and agricultural ecosystems, providing a wide range of economic products necessary for daily life. Palms could be classified into three groups namely cultivated, ornamental and wild.Millions of farmers in tropical and subtropical countries depend on cultivated palms for their livelihood. One of the important features of palms is that they are evergreen with leaves of various ages present continuously on their crown throughout the year. So they are considered hosts of many pests and diseases. Biotic stress is an adverse condition in which a palm cannot sustain its normal growth due to the interaction with deleterious weeds, insects and microorganisms namely fungi, bacteria, viruses, viroids, phytoplasma and nematodes. Biotic stresses are not only one of the major threats to the survival of palms globally, but also cause severe monetary losses. The major pests and diseases occurring on cultivated palms namely coconut, arecanut, oil palms and date palms have been documented over the years and production of these palms faces serious challenges due to many pests and diseases which may reduce productivity by as much as 30 %. Diseases like bud rot caused by *Phytophthora*, basal stem rot caused by *Ganoderma* and lethal yellows caused by Phytoplasma are common in most of these palms grown in tropical and subtropical regions (Hegde et al 2021). Similarly, insect pests like red palm weevils, defoliators and sap feeders. trunk borers, mites and nematodes are major inducers of biotic stress in these palms.

I. Diseases

A.1.Phytophthora diseases of palms

Diseases caused by *Phytophthora* are the major constraints in the cultivation of most of the palms causing huge losses annually. Several species of *Phytophthora* cause major diseases of palms throughout the world, with bud (heart) rot the most common and devastating disease. The *Phytophthora* infects the growing apical meristem of the palms and causes bud rot disease. Unlike other trees that have multiple apical meristems, each palm stem has only one apical meristem. Thus, when the bud (apical meristem) is damaged or diseased, the palm usually dies because growth ceases in the bud. Bud rot is a lethal disease that kills palms of any age. Every year hundreds of palms succumb to bud rot disease caused by *Phytophthora palmivora* or other species like *P.meadii* in the case of arecanut, *P. nicotiane* in *Washingtonia robusta* palm (El Meleigi et al., 2019). On coconut (*Cocos nucifera*) and other palms, an early symptom is the discolouration of the spear leaf (youngest unexpanded leaf). The initial visible symptoms appear as withering and drying of spear leaf which will come out by pulling the spindle. The basal portion of the spindle is completely rotten emitting a foul smell. Subsequently, younger leaves next to the spindle also fall away one by one leaving only the outer whorl of matured leaves in the crown. Ultimately, the palm succumbs to the disease with the death of the growing bud (Fig 1). The bud rot pathogen also causes water-soaked lesions on nuts, quite independent of bud rot, and results in nut shedding. Another species of *P.katsurae* is also known to cause bud rot in coconut in Hawai and premature nut drop is the earliest symptom of this devastating disease. Dropped nuts are of various sizes, but more often are large, nearly mature nuts with irregular brown to black areas beginning at the stem end of the nut. Similarly, arecanut fruit rot is caused by *Phytophthora meadii* and leads to severe shedding and rotting of immature nuts causing huge loss. The same oomycete species can also cause crown rot and bud rot thereby killing the arecanut palms (Fig.2). Recent epidemics of bud rots caused by *P.palmivora* have destroyed more than 70,000 ha of oil palms in Western and Central Oil palm growing regions of Columbia (Torres et.al 2016). Though epidemic of this extent is not yet noticed in Asian countries, sporadic occurrence of bud rot in oil palm is commonly seen. Though symptoms of bud rot or spear rot in oil palm (Fig. 3) looks like bud rot symptoms in other palms, there are differences of opinion among southeast Asian scientists that bud rot is a complex disease of unknown etiology. *Phytophthora palmivora* also attacks Mexican and California fan palms, *Washingtonia robusta* and *W. filifera* respectively, causing bud rot and destruction of young plants.

Though many species of *Phytophthora* are reported on palms, *P. palmivora* is the most commonly reported *Phytophthora* species on palms. with worldwide in distribution in tropical and warm temperate regions. This pathogen has been reported on palms from over 20 countries as well as from California, Florida, Hawaii, and Puerto Rico. The fungus has abroad host range and has been reported to attack over 25 palm species, but it is characterizedby host specificity among some isolates (Elliot et al., 2004). The *P. palmivora* induced bud rot is also reported in Canary Island date palm (*Phoenix canariensis)* from Italy (Pane et al., 2007).

Fig. 1. Bud rot of coconut caused by *Phytophthora palmivora*.
a) Whithering of spindle leaf, b) Deathof growing bud, c) Severe incidence of bud rot.

Fig 2. Bud rot and crown rot of arecanut caused by Phytophthora meadii

a) Seedlings with withering spindle,
b) Rotten portion of spindle coming out by gentle pulling,
c) Yellowing of crown region of the adult palm,
d) The crown rot affected palm showing intactbud but rotting and drying of other leaves
e) Drying of cron and death of the palm

Fig. 3. Symptoms of Bud Rot infections in Oil palm
a. Drying of spear leaves b) Rotting of spear c) Emergence of spear with gentle pull

The bud rot pathogen also causes water-soaked lesions on nuts, quite independent of bud rot, and results in nut shedding in coconut and arecanut. Arecanut fruit rot is caused by *Phytophthora meadii* and leads to severe shedding and rotting of immature nuts causing huge loss (Balanagouda et al., 2021).

I.2 Ganoderma diseases

The basidiomycete fungus *Ganoderma* causes basal stem rot (BSR) or Ganoderma wilt disease in arecanut, coconut, oil palm and many other ornamental palms and trees. In India, the disease on coconut was first reported in the Thanjavur district of Tamil Nadu in 1952, hence the disease is also popularly known as "Thanjavur wilt" Later the basal stem rot was also noticed on arecanut. Unlike *Phytophthora* diseases, the diseases caused by *Ganoderma* are more severe in the moisture-stress areas and get aggravated due to continuous drought and negligence in farming. The initial symptom of the disease is decay and death of the fine roots. The characteristic symptom of the disease is extensive rotting and discolouration of the root system. In severely diseased palms, more than 70 % root rotting is observed. The infection progresses from the bole region to the basal portion of the stem. The first visible above-ground symptom of the disease is the exudation of reddish-brown viscous fluid from the basal portions of the trunk of the affected palm (Fig. 4 and 5). As the disease progresses, bleeding patches extend up to three metres from the base of the palm. In advanced stages, the basal portion of the stem decays completely. Occasionally, some infected palms do not show bleeding symptoms. In some palms, the bark from the base of thestem peels off. Fruiting bodies of *Ganoderma lucidum* appear at the base of the trunk in some palms just above the soil level before wilting or after the death of the palm. Crown symptoms include wilting of leaflets and yellowing followed by drying and drooping of leaves in the outer whorls of leaves. The spindle leaf and surrounding two or three young leaves will remain erect and healthy. Ultimately, all the leaves droop and fall off leaving the decapitated stem. Heavy button shedding is also witnessed. The affected palms produce barren nuts. The decapitated stem shrivels and dries up. The time taken from the initial appearance of bleeding patches in the stem to the death of the palms is from 6 months to 54 months, the averagebeing 24 months. Trunk infestation with the scolytid beetle, *Xyleborus perforans* and the weevil, *Diocalandra stigaticollis* accelerates the death of the palm. Similar types of symptoms are noticed in basal stem rot affected arecanut also.

Ganoderma lucidum and *G. applanatum* are major species associated with the basal stem rot disease of coconut and arecanut. Recently other species namely *Ganoderma keralense* and *G. pseudoapplanatum* were also reported from infected coconut palms in Kerala. This fungus can infect a wide range of plants belonging to 19 families. For detecting *G.lucidum* inoculum in coconut plantations, subabul *(Leucaena leucocephala), Glyricidia maculata* or red gram or pigeon pea (*Cajanus cajan* (L.) Millsp.) can be used as indicatorplants since these plants show natural infection under field conditions at least six months earlier to visible symptom on coconut palms. The disease is generally observed in sandy or sandy loam soils in coastal areas on the east coast where coconut is grown under rainfed conditions and also in neglected plantations. Soil moisture stress during summer months, water stagnation during rainy seasons, presence of old infected stumps in the garden also aggravates the disease. Ganoderma wilt is a slow decline disease and can be managed by following good agricultural practices and integrated disease management approaches in the early stage of symptom expression itself. In the disease endemic area, regular application of 2 kg neem cake (5 kg in case of coconut) enriched with *Trichoderma harzianum* (1 kg *Trichoderma* + 100 kg neem cake) per palm per year is recommended. Soil drenching with 1% Bordeaux mixture (40 litres per palm) or 0. 2 % hexaconazole 5EC about 40 litres per palm thrice a year for one year or root feeding of hexaconazole 5EC (5 ml per 100 ml of water) at quarterly intervals till complete recovery of the palm (Greena et al., 2023;Elliot etal 2004).

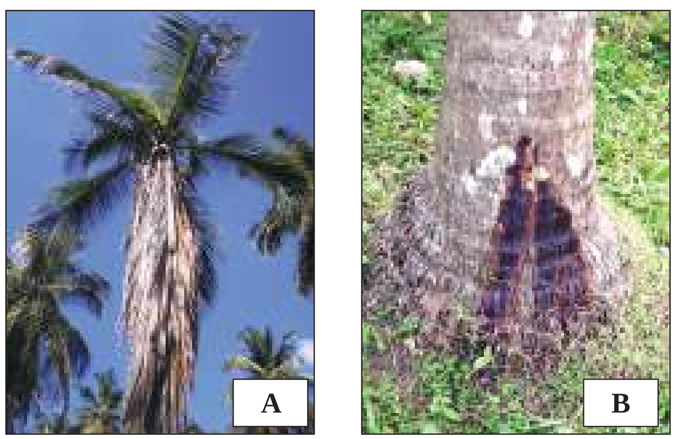

Fig. 4. Basal stem rot disease of coconut

a. Drying and drooping of leaves in the outer whorls of leaves;
b) Reddish brown bleeding patches at the basal portion of the stem

Fig. 5. Basal stem rot disease of Arecanut:

a) Drying and drooping of leaves
b). Bleeding patches on the basal portion pf the stem
c). Fruiting bodies of *Ganoderma* developed on thebasal portion

I.2 Phytoplasma diseases- a major threat to palms

Worldwide phytoplasma diseases pose great threat to the sustainability of the palm family members *viz*., coconut, arecanut, date palm, oil palm and ornamental palms causing setbacks in economic and livelihood security. So far, at least eight *Candidatus* Phytoplasma species belonging to different 16Sr groups have been reported to be associated with coconut. This includes *Ca*.P. asteris (lethal wilt disease in India; 16Sr IB), *Ca*.P.oryzae (Coconut root (wilt) disease in India, Welligama leaf wilt disease in Sri Lanka; 16Sr XIB), *Ca*.P.cynodontis (Coconut yellow decline in Malaysia; 16Sr XIV), *Ca*.P.malaysianum (Malayan yellow dwarf phytoplasma in Malaysia; 16Sr XXXIIB), *Ca*.P.palmicola (Cape St. Paul wilt in Ghana, Awka wilt in Nigeria; 16Sr XXIIB), *Ca*.P.cocostanzaniae (lethal yellowing in East Africa;16Sr IVC), *Ca*. P. noviguineense (Coconut bogia syndrome in Papua new Guinea) and *Ca*.P.palmae (Coconut lethal yellowing in Americas and Caribbean region; 16Sr IVA,B,E). Though there are several reports on insects transmitting coconut phytoplasmal diseases, except for LY in Florida and RWD in India, the vectors remain elusive. Susceptibility of date palms to phytoplasmal diseases *viz*., lethal yellowing, Al-wijam, White Tip Dieback (WTD) and Slow Decline (SD) or El Arkish' are emerging concerns in Arabian countries and North Africa. Oil palm is a potential host of diverse groups (16SrI, 16SrXI, 16Sr XIV and 16SrXXXII) of phytoplasma in many parts of the world. Yellow leaf disease caused by 16SrI, 16SrXI and16SrXIV group phytoplasmas is one of the major diseases limiting the productivity of arecanut in south India. Many ornamental palm species harbour a wide array of phytoplasma groups that could serve as an intermediary mode of transmission to cultivated palms. Large scale movement of ornamental palms through international trade warrants the need for strengthening the international quarantine networks and bio-security measures tocontain the spread of these phytopathogenic mollicutes. Despite rapid progress accomplishedin taxonomy using molecular approaches many palm phytoplasma isolates are yet to be characterized for the assignment of specific taxonomic status. Due to its confinement to phloem, non-uniform distribution and sub-minimal titres in palms, molecular detection is many a times intriguing. Palm-phytoplasmal interaction and transmission mechanism by auchenorrhynchan fauna are poorly understood (Hegde et al., 2022).

Root (wilt) disease and lethal wilt diseases of coconut and yellow leaf disease (YLD)of arecanut are the major phytoplasma diseases prevalent in India (Fig. 6) The association of phloem-bound mollicute phytoplasma with RWD and YLD has been established by electron microscopy, antibiotic therapy and transmission studies. The phytoplasma associated with RWD and YLD has been identified as '*Candidatus* phytoplasma oryzae' related strain belonging to the 16SrRNA group. The insects, lace bug (*Stephanitis typica*) and plant hopper (*Proutista moesta*) have been identified as the vectors transmitting the disease. In disease- endemic areas, thrust is given to integrated management to enhance palm health and farmers' income whereas, in disease emerging tracts, eradication of diseased palms forms the keystrategy. In the endemic area, removal of severely affected uneconomic adult palms (yielding less than 10 nuts) and diseased juvenile pre-bearing palms and replanting with resistant/tolerant varieties *viz*., Kalparaksha (selection from Malayan Green Dwarf), Kalpasree (selection from Chowghat Green Dwarf) and the hybrid KalpaSankara (Chowghat Green Dwarf X West Coast Tall) is recommended. Apart from RWD and YLD, another new lethal wilt disease of coconut, a recently reported phytoplasma disease that killed several coconut palms in small pockets of Thanjavur, Thiruvarur and Puthukotai districts in TamilNadu is of major concern. The symptoms of LWD are akin to the typical symptoms of lethal yellowing in palms. Abnormal shedding of nuts is the initial visible symptom which is followed by inflorescence necrosis and yellowing of outer whorls of leaves. Subsequently, the chlorotic leaves dry and droop down resulting in the skirting of leaves around the trunk. With the progression of yellowing to younger inner fronds, the disease advances and rotting of spear leaves and bud region occurs. This results in crown collapse and the diseased palms die within 3-5 months leaving a bare trunk (Fig.7). '*Candidatus* Phytoplasma asteris'-related strain belonging to subgroup 16SrI-B has been reported to be associated with the disease. Considering the limited distribution on the East Coast of Tamil Nadu in India, periodic surveillance and eradication of diseased palms form the primary management strategy.

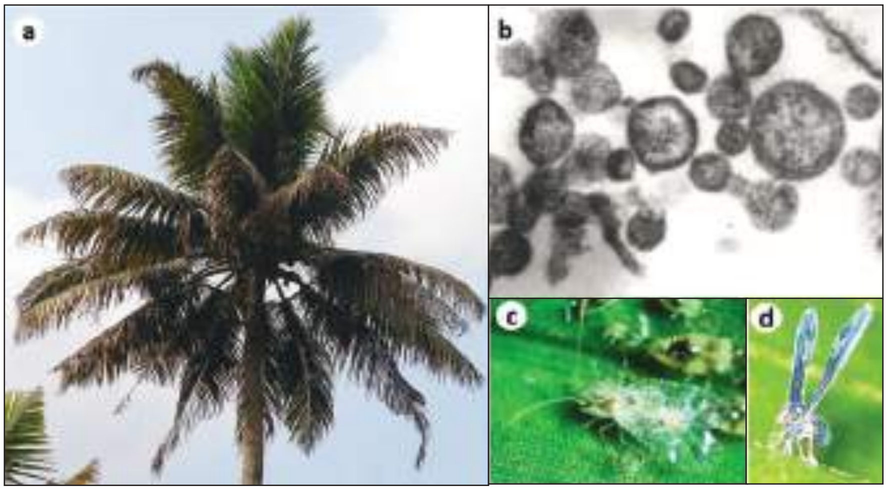

Fig. 6. Root (wilt) disease

(a) Diseased palm (b) Electron micrograph of RWD phytoplasma inphloem cells; vectors (c) Lace wing bug (*S. typica*) (d) Plant hopper (*P. moesta*)

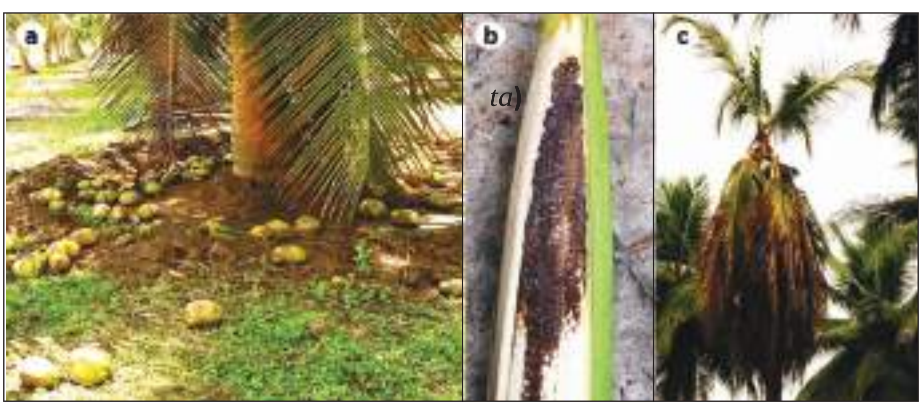

Fig. 7. Lethal wilt disease of coconut caused by *Candidatus* Phytoplasma asteris'-sub group 16SrI-B

(a) Abnormal nut fall (b) Inflorescence necrosis (c) Drying and drooping of leaves

I.2 Other emerging diseases

Some of the minor diseases caused by *Colletotrichum* and *Lasiodiplodia* earlier have been emerged as major diseases. The recent outbreak of leaf blight in certain arecanut growingareas of Karnataka, Kerala and Tripura are found to be associated with different species of *Colletotrichum* (Fig. 8). They produce leaf spot symptoms individually or in combination with other leaf spot-causing fungi *Phyllosticta*. Earlier association of other fungi namely *Curvularia* sp.), *Phomopsis palmicola* (Wint.) Sacc. *arecae* and *Pestalotia palmarum* Cooke, *Helminthosporium* sp. and *Alternaria tenuis* with leaf spots/blights were also reported. The incidence and severity of inflorescence dieback of arecanut caused by *Colletotrichum* sp are also increased over the years. The increase in incidences could be due to climate change, nutrition deficiency or non-adoption of scientific cultivation practices. Initial studies have revealed different species of *Colletotrichum* involved in arecanut leaf blight and inflorescence dieback. The bacterial leaf stripe caused by *Xanthomonas* sp. has also emerged as a major problem in certain non-traditional arecanut growing areas in Shivamogga andChikkamangaluru districts of Karnataka (Fig.9). Root decay of arecanut that lead to death of hundreds of arecanut seedlings in certain gardens of Dakshina Kannada District of Karnataka during 2018 was found to be caused by *Fusarium falciforme* (FSSC 3 +4) and this is the first report of *Fusarium* causing disease in arecanut. Similarly, the leaf blight and nut fall caused by *Lasiodiplodia theobromae* on coconut emerged as major diseases in certain coconut-growing areas of Tamil Nadu, Karnataka and Andhra Pradesh (Fig.10).

Fig. 8. Leaf blight of arecanut caused by *Colletotrihum* spp

(a) Yellow specks in the initial stage,
b) Necrosis and blighting of the whole leaf in the advanced stage,
c) Severely leaf blight affected arecanut garden

Fig. 9. Bacterial leaf stripe of arecanut

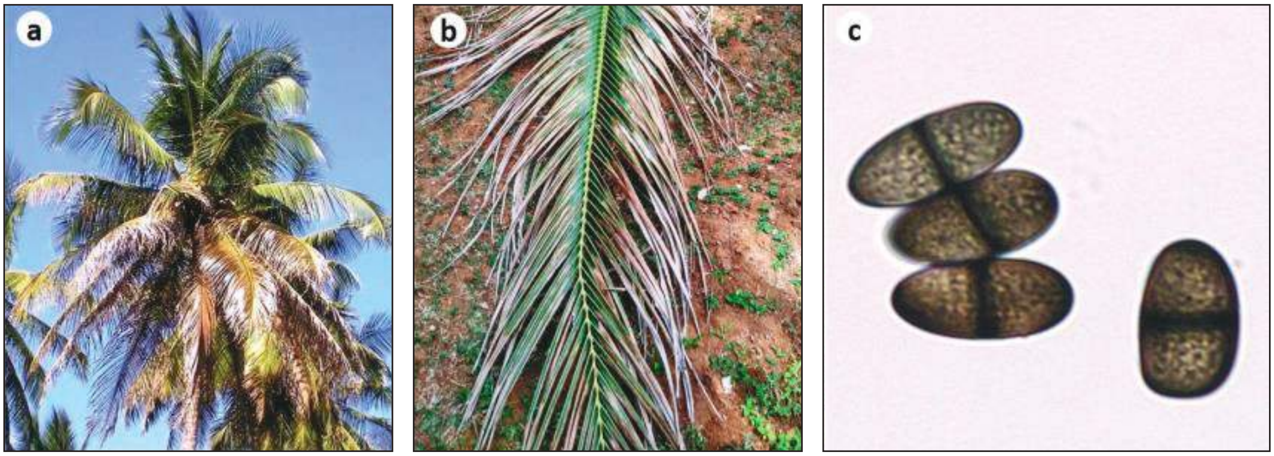

Fig. 10. Coconut leaf blight caused by *Lasiodiplodia theobromae*
(a) Diseased palm (b) Drying of leaflets (c) Conidia of *L. theobromae*

I. Insect Pests of Palms

A number of insect taxa that attack palms have been documented. Pests may feed on foliage, fruit, woody tissue or sap. The cultivated palms namely coconut, arecanut, oil palm, and date palm are the preferred niche for a spectrum of insects, mites, and rodents. Key pests of coconut in India include rhinoceros beetle (*Oryctes rhinoceros* Linn.), red palm weevil (*Rhynchophorus ferrugineus* Oliv.), black-headed caterpillar (*Opisina arenosella*Wlk.), white grub (*Leucopholis coneophora* Burm.) and the invasive pests viz., coconut eriophyid mite (*Aceria guerreronis* Keif.) and rugose spiralling whitefly (*Aleurodicus rugioperculatus* Martin). Rhinoceros beetle, red palm weevil (RPW) and eriophyid mite are widely distributedin all coconut growing regions of India whereas the infestation of black-headed caterpillar and white grubs are limited to certain coconut growing tracts. Adult rhinoceros beetles invade different parts of palms such as spear leaf, inflorescence, collar region of juvenile palms and of late even on tender nuts incurring crop loss as high as 10%. Feeding by coconut rhinoceros beetle on adult coconut palms is not lethal, whereas it has a significant impact on juvenilepalms often affecting the initial establishment of newly planted seedlings Juvenile and pre- bearing palms mostly below 20 years of age are more susceptible to red palm weevil infestation. Since it is a lethal pest even one per cent damage is regarded as an economic threshold level. The defoliator pest *O. arenosella* attack directly affects the chlorophyll content of leaves and a crop loss of up to 45% in terms of nut yield was recorded from infested palms in the succeeding year of severe pest incidence. The black-headed caterpillar infestation is severe during summer which gets worsened in water stress conditions in coastal regions of India. The coconut white grub species *Leucopholis coneophora* occurs mainly in sandy loam soil and attains pest status in discontinuous patches along the Western coastal tracts, especially in Kerala and Karnataka. In India, coconut eriophyid mite spread rapidly toall major coconut-growing regions of the country within a short period after its first report from Kerala in 1998. The sporadic emergence of coreid bug (*Paradasynus rostratus*) infestation of coconuts on a larger scale was noticed in Kerala recently (Fig. 11). (Chowdappa, 2016).

Fig. 11. Coreid bug (*Paradasynus rostratus*) infestation on coconut

a)Adult coreid bug, b) Nymphs feeding on coconuts, c)Gummy exudates on the damaged button, d)damage symptoms on the button and e) Damage symptoms on mature coconuts

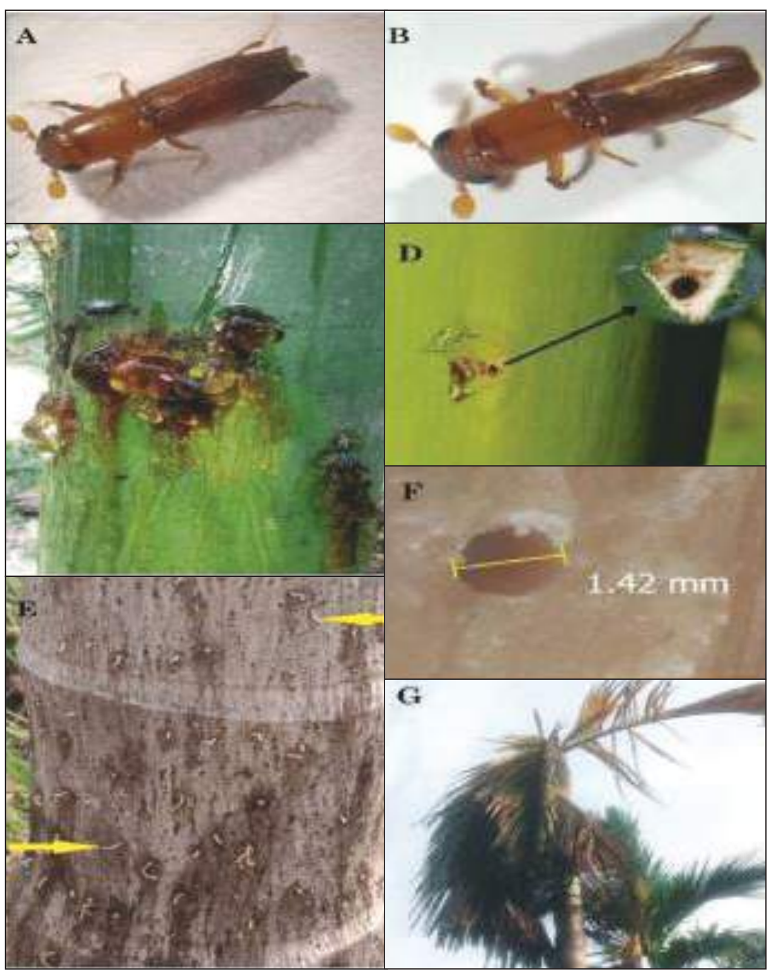

Fig. 12. The ambrosia beetle *Euplatypus parallelus* infesting arecanut

a) Male beetle, b) Female beetle, c) Oozing of yellowish brown resinous exudation,
d) Presence of small pinhead size holes under resinous exudation,
e) Extrusion of sawdust frass in the form of loose, f) cylindrical strings (arrows),
g) Round gallery entrance hole in the center of a stem, h) Yellowing of infested palm

Similarly, in the case of arecanut, root grubs, spindle bugs, pentatomid bugs, inflorescence caterpillars, and leaf mites are the major pests causing various kinds of losses. Recent reports of ambrosia beetle (*Euplatypus parallelus)* and red palm weevil (*Rhynchophorus ferrugineus)*on arecanut in a few areca nut growing areas are also of major concern (Fig. 12). The latest report of a scolytid beetle *Xylosandrus crassiusculus* and its fungal symbiont *Ambrosiella roeperi* associated with arecanut kernel decay is also very important though as of now the pest incidence seen only in a few arecanut gardens in Dakshina Kannada District of Karnataka. The adult female beetle bore the husk by making a gallery of 1.06-2.39 mm and entered the kernel. It will then feed on the internal content and breed in the galleries. Infestation can be identified based on the hole made by the insect and the extrusion of frass noodles from the bored hole (Fig.13). The symbiotic association of fungi, *Ambrosiella roeperi*, with the pest serves as a nutrition-rich food source for larvae and adults. The fungus will cause black staining of kernel tissues and profuse growth of the greyish fungal colony. This will reduce the weight of the nut, and affect its storage life and marketable quality

Fig. 13. Arecanuts showing symptoms of the attack by *Xylosandrus crassiusculus*.

(a,b) Frass noodle produced by the nut boring beetle, (c) Multiple entrance holes and dark staining of the exocarp, (d) Beetle piercing through kernel, (e) eggs of *X. crassiusculus*, (f and g) larvae of *X. crassiusculus* foundin the galleries, (h) longitudinal section of the kernel showing discolouration and the growth of the associated fungus *Ambrosiella roeperi*

Fig. 14. Rugose spiralling whitefly

a) RSW on fronds n) Rugose spiralling whitefly c) Spraying ofneem oil 0.5 %

Fig. 15. Symptoms of Red palm weevil attack on coconut, acoustic-based detection and IPM options
a)Adult beetles, b) Grubs inside damaged trunk c) Damage symptoms,
d) RPW detector installed on coconutstem (inset RPW detector), e) capsule formulation of EPN

Fig. 16. Coconut rhinoceros beetle damage symptom and IPM components

a)Adult beetle, b) "V" shaped cut on coconut fronds characteristic damage symptom,
c) Botanical cake,d) grubinfected with *Metarhizium* e) inoculating adult beetle with *OrNV,*
f) Trapping of adult beetles with pesticide impregnated nylon nets

I. Management of biotic stresses in palms

Managing biotic stresses in palms is a major challenge compare to other annual crops. It is difficult to eradicate the pests or pathogens from the plantations of palms, once they get established. Regular surveillance and monitoring is essential for successful maintenenace of palm trees. Crop protection strategies in palm based cropping systems require a holistic approach that takes into account the integrated management of pests and diseases of main as well as the intercrops. Rhinoceros beetle infestation is very common in most of the palms and the wound caused by the beetle could be considered as one of the major predisposing factorsfor the higher incidence of bud rot and leaf rot diseases. These diseases in turn attract the red palm weevil infestation. Hence a customized integrated management strategy based on the pests /diseases and intercrops in a particular geographic region will yield better sustainable results. The strategy is multipronged giving equal weightage for surveillance, field sanitation, host resistance, intercropping, soil and moisture conservation, crop nutrition along with plant protection for the total enhancement of palm heath. This approach considers the cropping system as a single unit where the intercrops and the bioresources generated in the system will be utilized effectively for pest/disease management.

Pest and disease management through nature-protective technologies including bioagents and botanicals accomplish environmentally responsible farming strategies auguring sustainable development goals.

Mechanization and automation in the delivery of bioagents/pesticides in the small farm holdings of palm-based cropping systems are very much essential for the successful implementation of IPDM. Early diagnosis of pests and diseases in the perennial plantation sector is a real challenge hence, the adoption of unmanned aerial vehicles, internet of things to perform digital surveillance would be of great help. ICAR-CPCRI had standardized techniques for the timely detection of key pests and diseases on palms. Sustained surveillance and strengthening quarantine are key approaches to evade biosecurity risks emanating from invasive pests and diseases. Tackling climate change and the emergence of alien invasive species through heterogenous landscaping, biodiversity

conservation and farmer-participatory deliverance of implementable IPDM technologies provide sustainable and profitable income and reduce carbon footprint as well. Restoring ecosystem vitality and ecological integrity through climate-smart farming is the need of the hour.

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52. Biological approaches in disease management of fruit crops

Gaurav Y. Rakhonde and S. Sriram
Division of Crop Protection, ICAR-Indian Institute of Horticultural Research,
Hesaraghatta Lake Post, Bengaluru 560089
Email: Subbaraman.Sriram@icar.gov.in

Introduction

Fruits hold a crucial place in the human diet due to their rich contribution of essential elements such as vitamins, minerals, organic acids, fiber, and more. They play a vital role in preventing various health issues, including obesity, cardiovascular diseases, cognitive disorders, and promoting well-being in areas such as skin, eye, lung, and bone health. In the present day, consumers expect fruits to meet high standards in terms of appearance and nutritional value. However, the postharvest quality of fruits faces numerous challenges, with fungal diseases being a significant factor. These diseases not only diminish the sensory appeal of fruits but also result in substantial losses during storage. In industrialized countries, they can affect up to 25% of the total fruit production, while in developing countries, the impact can be even more severe, with losses exceeding 50%. Traditionally, the management of these fungal diseases has heavily relied on chemical interventions. However, this approach has raised concerns regarding its environmental consequences, potential health risks, and the development of pesticide-resistant pathogens.

In response to these challenges, there has been a growing shift towards more sustainable and ecologically sound disease management strategies. One prominent approach that has gained prominence in recent years is the utilization of biological methods. These biological approaches harness the power of living organisms, natural predators, beneficial microorganisms, and innovative techniques to suppress and control fruit crop diseases. Biocontrol approaches for disease management offer several significant advantages, making them an attractive and sustainable alternative to chemical interventions. This paradigm shift towards biological disease management not only addresses environmental concerns but also aligns with the broader principles of sustainable agriculture. The pressing need for sustainable agricultural solutions in the face of contemporary environmental challenges is undeniable. Meeting the demands for increased productivity and food security necessitates the sustainable utilization of natural resources and metabolites.

In this exploration, the diverse array of techniques and strategies that harness the potential of nature to protect and enhance fruit crop production. From the application of biopesticides and the cultivation of disease-resistant cultivars, the realm of biological disease management offers a promising avenue for fruit growers to mitigate disease pressures while promoting healthier ecosystems. This holistic approach not only fosters disease resilience but also fosters the creation of fruit crops that are not only safe and nutritious but also sustainable for generations to come. The future of biological approaches in disease management of fruit crops holds great promise as agricultural practices continue to evolve in response to sustainability, environmental concerns, and the need for resilient food production systems. Several trends and developments are likely to shape the future of biological disease management in fruit crops. The future of biological approaches in disease management of fruit crops holds the potential to revolutionize the way we protect and cultivate these essential food sources. As agriculture embraces sustainability and ecological responsibility, biological solutions will continue to play a central role in ensuring the health, quality, and abundance of fruit crops in a changing world.

Biological Approaches

Direct Use of Biocontrol Agents

Conventionally, the study of the mechanisms of action is related to the evaluation of the production of antibiotics, lytic enzymes, or other metabolites in vitro or in co-culture against the phytopathogen. The antagonistic mechanisms of antagonist yeasts is crucial for improving their efficiency against phytopathogens. The use of yeasts as a post-harvest treatment to reduce decay caused by various phytopathogenic fungi in fruit of commercial interest is a sustainable and efficient alternative to the utilization of synthetic fungicides. The application of yeasts will be able to reduce the levels of fruit losses caused by phytopathogens, which will increase economic gains because of a greater volume of production for commercialization. Its implementation in postharvest will improve shelf life of the fruit and may lower crop costs by reducing the use of synthetic products. The acceptance of the consumer for product acquisition—not treated with any chemical—allowed opening new markets since it is a fruit not treated with synthetic fungicides.

Secondary Metabolitesfrom Microbes as Agrochemicals

Secondary metabolites are compounds that organisms produce during the stationary phase of cell growth, and they are not essential for basic growth processes. These molecules are synthesized in response to environmental cues and serve various functions such as aiding in nutrient acquisition, defending against predators, facilitating communication in mutualistic relationships, and providing resistance to toxins. A deeper understanding of their mechanisms of action has led to the identification of metabolites that play active roles in the pathogenicity and harm to host species. Advances in organic and synthetic chemistry have paved the way for the commercial use of these secondary metabolites. Their success as potential agrochemical options can be attributed to their target specificity, unique structures, novel modes of action, and environmentally friendly characteristics (Maharana *et al.*, 2022).

Lichen

Half of the lichens that have been studied are known to produce substances with varying degrees of antimicrobial properties. Certain species of the lichen genus *Xanthoria*have yielded anthraquinones with notable antimicrobial activity, which could potentially influence broader lichen ecology and ecosystem dynamics. However, it's worth noting that this antimicrobial activity does not seem to be connected to other ecological roles, such as herbivory. Additionally, several lichen compounds have been found to impede the growth and development of fungal species. Crude aqueous extracts from lichens are effective in inhibiting wood-decaying fungi, while other lichen-derived substances have been shown to restrain specific pathogenic fungi. Moreover, these extracts can hinder spore germination and even lead to reduced growth. (Dayan and Romagni, 2001)

Fungi

A co-culture approach was employed to investigate potential antifungal compounds generated during the interaction between *Penicillium digitatum*and *Penicillium citrinum*. This study led to the discovery of two tetrapeptides, namely deoxycitrinadin A, citrinadin A, along with chrysogenamide A and tryptoquialanines, which were produced in the zone where these fungi interacted. Antimicrobial tests subsequently confirmed their antifungal activity. Notably, tryptoquialanines were found to inhibit the sporulation of *P. citrinum*. It's noteworthy that the fungal metabolites identified had never been recognized as antimicrobial agents prior to this research. This highlights the value of employing co-cultures involving phytopathogens competing for the same host as a promising strategy for uncovering novel antifungal substances (Costa *et al.,* 2019).

Bacteria

Complete organisms have the potential to function as biopesticides, but the secondary metabolites released by microorganisms are equally crucial in safeguarding plants against pests and pathogens, as well as in stimulating plant growth for the benefit of agricultural crops.

One notable example is the extract from Streptomyces plumbeus strain CA5, which was isolated from soil samples in Chuncheon province. This extract significantly reduced the incidence of gray mold on grapes to just 22.2 percent. The active compound identified in this extract is the polyene macrolide lucensomycin. Lucensomycin exhibited strong inhibitory effects against the spores of *Botrytis cinerea*, with effective inhibition observed at concentrations as low as 1 mg L^{-1}. Furthermore, at a concentration of 100 mg L^{-1}, it completely halted the development of gray mold on grapes (Do Kim *et al.,* 2020).The bacterial endophyte *Bacillus velezensis*strain Bvel1, produces effective metabolites against Botrytis bunch rot, caused by *Botrytis cinerea*. These metabolites include compounds such as iturin A2, surfactin-C13, surfactin-C15, oxydifficidin, bacillibactin, L-dihydroanticapsin, and azelaic acid, among others, that were secreted by Bvel1.In practical applications, treating wounded grape berries with cell cultures of *Bacillus* sp. Bvel1 proved effective in controlling the ingress and expansion of gray mold in vivo. The effectiveness of this biological control agent was dependent on the concentration of the antagonist's cell culture applied, with preventive treatments demonstrating greater efficacy compared to curative approaches(Nifakos, 2021).

Plant derived metabolites

In line with their defensive role, many alkaloids demonstrate fungicidal properties. Pipernonaline, a piperidine alkaloid isolated from the hexane fraction of *Piper longum* L., exhibited strong fungicidal activity against the phytopathogen *Puccinia recondita*. Extracts from *Coptis japonica* (Thunb.) Makino, containing alkaloids like isoquinoline alkaloids, berberine chloride, palmatine iodide, and coptisine chloride, also demonstrated fungicidal activities against various plant pathogens. These included *Botrytis cinerea, Erysiphe graminis, Phytophthora infestans, Puccinia recondita, Pyricularia grisea,* and *Rhizoctonia solani,* as observed in *in vivo* plant models (Ju-Hyun, 2005).

Volatile organic compounds (VOCs)

The agronomic potential of volatile organic compounds (VOCs) emitted by leaves as a natural and environmentally friendly, safeguard plants against stress and bolster crop yields. VOCs have the capacity to shield plants from pathogens and environmental stressors. They prime a plant's defense mechanisms, enhancing its resistance and tolerance to impending stressors, mitigate the harmful effects of reactive oxygen species (ROS), exhibit potent antimicrobial properties, and even possess allelopathic effects.

Moreover, VOCs may play a crucial role in regulating plant growth, development, and senescence through their interactions with plant hormones.

Numerous volatile organic compounds (VOCs) emitted by leaves have been found to effectively impede the germination and growth of plant pathogens, although the precise mechanisms of action remain elusive. Citral, carvacrol, and trans-2-hexenal have been identified as potent inhibitors of *in vitro* growth and germination of *Monilinialaxa*, the causative agent of brown rot in stone fruit, and have shown efficacy in postharvest bio fumigation on apricot, nectarine, and peach fruits (Neri *et al.,* 2007). Additionally, the in vitro growth of *Colletotrichum acutatum*, responsible for citrus post-bloom fruit drop, exhibited moderate inhibition when exposed to linalool (Marques *et al.,* 2014). *Botrytis cinerea,* has displayed high sensitivity to the *in vitro* application of monoterpenes such as (+)-limonene (Simas *et al.,* 2017).

Quintana-Rodriguez *et al*. (2018) conducted a comprehensive screening of 22 different VOCs, commonly emitted by leaves, against fungal pathogens including Colletotrichum lindemuthianum, Fusarium oxysporum, and B. cinerea. The exposure to VOCs like nonanal, (+)-carvone, citral, trans-2-decenal, L-linalool, nerolidol, or eugenol significantly inhibited the growth of all three fungal species, with eugenol demonstrating the highest potency. Other VOCs, including cuminaldehyde and p-cymene, have also demonstrated antifungal activity against B. cinerea, F. oxysporum, Verticillium dahliae, and Alternaria mali (Sekine *et al.,* 2007).

***In vitro* production and formulation**

Nano/microencapsulation

Biological biocides hold substantial promise for mitigating plant biotic stresses and promoting agricultural growth. However, they often suffer from issues of instability and rapid degradation. Beneficial Microbial Control Agents (BCAs) offer a means to combat plant diseases and enhance crop productivity in an environmentally friendly manner. In response to the need for more effective BCAs, research into encapsulation has surged in recent years.

Encapsulation formulations present a solution to the challenges faced by free-form BCAs. They can significantly enhance the efficacy of BCAs by extending their shelf life and allowing for controlled release of the biological components. This innovative approach has the potential to serve as a robust platform for managing biotic stressors, particularly plant pathogens. Two prominent biopolymers, chitosan and alginate, show immense promise in encapsulating BCAs. These biopolymers can also be combined to form composite encapsulation, overcoming individual limitations. However, several other biopolymers, such as gums, gelatin, starch, and pectin, play essential roles in BCA formulation. An example of this type of formulation is the alginate encapsulation of *Gliocladium virens* (Soil Gard) and encapsulations of *B. thuringiensis* in hydrocapsules of shell-core type consisting of a polymer membrane surrounding a liquid center.

These developments hold great potential for expanding the efficacy and application of BCAs, paving the way for future opportunities in plant pathogen management through formulation technologies (Riseh*et al.,* 2022).

To obtain a successful BCA formulation, it is necessary to shorten the shelf life of biopesticides compared to conventional pesticides. Shelf life is a period of time that corresponds, in appropriate storage conditions, to a tolerable decrease in the quality of a packaged product. Storage conditions and packaging will influence the shelf life of any formulated product because they will be barriers to avoiding reactive agents, such as oxygen, moisture, light, microbial contamination, and elevated temperatures, which may damage the formulated product.

Combining BCAs with generally regarded as safe (GRAS)chemicals

An effective strategy to enhance the biocontrol efficacy of Beneficial Microbial Control Agents (BCAs) and reduce performance variability involves combining them with other safe natural compounds or those generally regarded as safe (GRAS). This approach has entailed pairing antagonistic microorganisms with a range of additives, including glycolchitosan, CaCl2, glycine betaine, melatonin, β-glucan, phytic acid, an apple-based polymer, methyl jasmonate, UV protectants, and various food additives. These diverse additives have been employed to amplify and stabilize the biocontrol effectiveness of several yeast antagonists, such as *Candida saitoana, M. guilliermondii, Meyerozymacaribbica, Cryptococcus albidus, Sporidioboluspararoseus, Cryptococcus podzolicus, Pichia caribbica,* and *Metschnikowia pulcherrima*, in combatting postharvest decays in apple fruit (Leng *et al.*, 2022).

Bacteriophages as programmable biocontrol agents

Lysogenic phages, owing to their abundance, hold substantial potential as a valuable resource for natural phages in biocontrol applications. Lysogenic phages follow a unique lifecycle where they integrate into the host genome, entering a dormant state before reactivating to destroy the host cell. However, unlike lytic phages, lysogenic phages have traditionally been considered less suitable for biocontrol and therapeutic purposes due to their limited efficacy and the associated risk of horizontal gene transfer.

Harnessing natural phages for biocontrol applications often requires extensive screening to identify and characterize lysogeny-related functions. This process adds significant time, cost, and uncertainty to product development. To tap into the vast reservoir of natural phages more efficiently, a promising approach is to convert lysogenic phages into obligate lytic phages. This conversion entails removing factors that enable lysogeny, such as recombinases and repressors. The result is phages with heightened lethality and an expanded host range. For instance, phages converted to obligate lytic forms, used to treat *M. abscessus*, demonstrated a remarkable 10,000-fold increase in efficacy upon the removal of lysogeny-related genes.

To facilitate the identification of lysogenic phages and the factors that confer lysogeny, specialized bioinformatics tools have been developed. These tools streamline the screening process by swiftly identifying candidate phages and genes suitable for conversion. The conversion from lysogenic to lytic phages substantially augments the diversity and effectiveness of phages for biocontrol applications (Huss and Raman, 2020).

Hypovirulence

Hypovirulence is a condition characterized by the reduced or weakened virulence of a pathogenic microorganism, especially a fungus, compared to its normal or wild-type state. This phenomenon typically arises due to the presence of a specific type of virus, known as a mycovirus, within the fungal pathogen. When a hypovirulent strain of a pathogenic fungus infects a host plant, it often leads to milder disease symptoms or less damage to the plant. This weakened virulence can be strategically utilized as a biological control method to manage plant diseases. *Colletotrichum gloeosporioides*, which is responsible for causing anthracnose disease, a significant fungal ailment affecting various crops worldwide. Mycovirus *Colletotrichum gloeosporioides* RNA virus 1 strain Ssa-44.1 (CgRV1-Ssa-44.1), has been linked to hypovirulence. CgRV1-Ssa-44.1 exhibits relatively low efficiency in transferring via spores, especially asexual ones, but it can successfully spread horizontally to genetically identical virus-free isolates. Furthermore, this mycovirus exerts a potent biological control effect on *C. gloeosporioides* in mango plants. Therefore, CgRV1-Ssa-44.1 emerges as a promising candidate for use as a biological control agent against *C. gloeosporioides*. It's worth noting that this study represents the first report of a mycovirus from *C. gloeosporioides* in Thailand with such biocontrol traits (Suharto *et al.,* 2022). Similarly, *B. cinerea* □*BcSpd1* could effectively induce the medicinal plant defense and is referred to as the biological control agent in ginseng disease management (Wang *et al.*, 2022).

Cross protection

Cross-protection, also referred to as "pre-immunization," is a plant virus control method where a deliberate infection of a plant is carried out using a mild strain of a virus. This infection aims to shield the plant from damage caused by a more severe or challenging strain of the same virus. Multiple Strain Crop Protection (MSCP) offers a sustainable approach to addressing the need for societal and ecological resilience, with the goal of increasing crop production while reducing unsustainable use of resources such as water, nutrients, and agricultural chemicals. Folimonova has provided a comprehensive guide for achieving cross-protection against Citrus Tristeza Virus (CTV). Their methodology outlines the steps for identifying and isolating protective mild strains, involving the biological characterization of severe and mild isolates and recommendations for segregating individual genotypes. While their approach is tailored to CTV, its principles can be adapted for addressing other plant viruses (Pechinger *et al.*, 2019). The phenomenon of cross-protection has been observed for nearly a century and has been demonstrated in various virus-crop combinations. Over the past decade, there has been a resurgence of interest in MSCP, with proven efficacy observed both in research settings and in real-world field applications.

Challenges in the development and deployment

Efficacy: One of the primary challenges is ensuring that biopesticides are as effective as chemical pesticides in controlling pests and diseases. Biopesticides often have limitations in terms of their spectrum of activity, which can make them less effective in some situations.

Regulatory hurdles: Biopesticides are subject to rigorous regulatory requirements, which can be time-consuming and costly. Obtaining regulatory approval for a new biopesticide can be a lengthy process.

Shelf life and Stability: Biopesticides can have shorter shelf lives and may be less stable than chemical pesticides. Maintaining the viability of the active ingredients in biopesticides can be challenging.

Limited persistence: Biopesticides tend to break down more quickly in the environment compared to chemical pesticides, which can limit their effectiveness, especially in situations where long-lasting pest control is required.

Target specificity: While the specificity of biopesticides is an advantage in terms of reduced harm to non-target organisms, it can also be a limitation if the target pest population is not well-defined or if multiple pests are present.

Cost: Biopesticides can be more expensive to produce and apply than chemical pesticides, which can be a barrier to their adoption by farmers, particularly in low-resource settings.

Resistance management: Just like chemical pesticides, pests can develop resistance to biopesticides over time, necessitating the development of new formulations or strategies.

Education and awareness: Farmers may require training and education to effectively use biopesticides, as their application methods and timing can differ from chemical pesticides.

Limited availability: Compared to chemical pesticides, there may be fewer options and formulations of biopesticides available for specific pests and crops.

Production scalability: Scaling up the production of biopesticides to meet the demands of large-scale agriculture can be a logistical challenge.

Despite these challenges, biopesticides offer numerous benefits, including reduced environmental impact, improved safety for farmworkers and consumers, and the potential for more sustainable pest management. Ongoing research and development efforts aim to address these challenges and expand the use of biopesticides in modern agriculture.

Future thrust area

The future of biological approaches in disease management of fruit crops holds great promise as agricultural practices continue to evolve in response to sustainability, environmental concerns, and the need for resilient food production systems. Several trends and developments are likely to shape the future of biological disease management in fruit crops:

Advancements in biotechnology: Continued research in biotechnology will lead to the development of genetically modified fruit crop varieties that are naturally resistant to diseases. These cultivars will be tailored to specific pathogens, offering robust protection without the need for chemical interventions.

Biological products market growth: The market for biological control agents and biopesticides will expand as growers seek safer and more sustainable alternatives to chemical treatments.

Education and awareness: Growers, researchers, and policymakers will continue to prioritize education and awareness programs to promote the adoption of biological approaches. Training and resources will be readily available to support farmers in implementing these techniques.

Global collaboration: International collaboration and knowledge sharing will play a significant role in advancing biological disease management strategies, as diseases often transcend geographical boundaries.

Resilience to climate change: Biological approaches will become even more critical in building resilience to climate change-related challenges, such as shifting disease patterns and increased stress on fruit crops.

Regulatory Support: Governments and regulatory bodies will likely provide more support and incentives for the development and use of biological disease management methods, reflecting their environmental and health benefits.

In conclusion, the future of biological approaches in disease management of fruit crops holds the potential to revolutionize the way we protect and cultivate these essential food sources. As agriculture embraces sustainability and ecological responsibility, biological solutions will continue to play a central role in ensuring the health, quality, and abundance of fruit crops in a changing world.

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53. Etiology of destructive diseases infecting dragon fruit (*Selenicereus* spp.) in India

Sangeetha Ganesan
Division of Crop Protection, ICAR-Indian Institute of Horticultural Research,
Hessaraghatta- 560 089, Bengaluru, Karnataka, India
Email: G.Sangeetha@icar.gov.in

Dragon fruit are climbing cacti belongs to the genus *Selenicereus* spp. and family Cactaceae. The genus *Selenicereus* spp. has a totally of 14 species which vary in fruit and flesh color. Among them, *S. undatus* (red epicarp with white pulp), *S. monacanthus* (syn:*H. polyrhizus*, red epicarp with red pulp) and *S. megalanthus*(yellow peel with white flesh) are the most cultivated species around the world. Dragon fruit is also known by numerous vernacular names like pitaya, pitahaya, strawberry pear, Buahnaga, etc., and due to its popularity in India it is recently named as 'Kamalam'. Southeast Asia produces the most dragon fruits worldwide, with Vietnam as the top producing and exporting country (Balendres and Bengoa, 2019). The other top dragon fruit-producing countries are Thailand, the Philippines, Taiwan, Malaysia, Australia, Israel, Sri Lanka and South American countries like Ecuador, Mexico, Nicaragua, Colombia, and Guatemala. In India, the dragon fruit is cultivated on around 3,000 hectares. With rising demand for this fruit, the GOI is targeting to expand its cultivation to 50,000 hectares in five years. This fruit is a good source of bioactive compounds such as polyphenols, betalains, and antioxidants. Red pulp varieties have great potential as natural dyes (Lestari, 2016). During the last 5 years, there were a significant number of publications on new disease reports on dragon fruit from world countries including India. Even though, dragon fruit cultivation has gained popularity in India, but it is often challenged by biotic diseases that limit production potential. As dragon fruit is considered one of the potential future fruit crops for India, knowledge on prevailing diseases is need of the hour to develop strategies to tackle them. Diseases like stem rot, anthracnose, canker, grey blight, fruit spotting are prevalent in India are discussed with their diagnostic symptom, causal organisms, and available management strategies.

1. Stem rot of dragon fruit

Causal organism: *Lasiodiplodia iraniensis* and *Lasiodiplodia theobromae*

The stem rot caused by *Lasiodiplodia* species has been reported from Bangladesh (Briste et al., 2022) and Philippines (Evallo et al., 2022) and from India (Sangeetha et al., 2023). Among the two species reported in India *L. iraniensis*is highly virulent while and *L. theobromae* observed to be least virulent. Stem rot incidence has been observed in a high proportion, affecting 26% of red-fleshed plants and 34% of white-fleshed plants under Eastern India condition. Although the disease appeared throughout the year, the manifestation of symptoms peaked during April–June, which correspond to summer months (Sangeetha *et al*., 2023).

Usually, symptoms initiated along the margin or tip of the stem, although instances also observed in the middle of the stem without any physical injury or wounds. The typical symptom of stem rot characterized by yellowing and softening of the stem, followed by rotting, involving partial or complete length of the stem Subsequently, circular to irregular cankerous lesions were observed in the middle or at the margin of the lesions. When the rot became old, the cankerous growth containing fungal fructifications involving host tissues also seen (Fig 1). The cankerous grayish lesions contained black-headed pycnidia arrange in a circular to irregular manner, which expands over a period of time covering the entire lesion. In advanced stages of the disease, the host epidermis became dried and shredded, leaving characteristic circular holes on the stem margin. In some cases, rotten portion get detach from the stem leaving behind only the central core.The symptoms led to a general decline in the vigor of the plant. Eventually, the severely infected plants become less productive in subsequent seasons.

Fig 1. Symptoms of stem rot disease of dragon fruit caused by *Lasiodiplodia iraniensis*

Lasiodiplodia iraniensis: Pycnidia are blister-like, thick-walled, globose, dark brown. It lacks conidiophores whereas paraphyses are present which are cylindrical and hyaline. Initially aseptate, they became septate when matured and very rarely branched. Conidia, which were initially hyaline, aseptate, and ovoid with blunt/rounded ends, became dark brown, thick-walled, with one middle septum and longitudinal striations when matured. The teleomorph remained unknown. As *Lasiodiplodia* species are cryptic in nature, multigene phylogeny using ITS, *EF1-α* and *β-tub* dataset has been employed to identify the species (Fig 2).

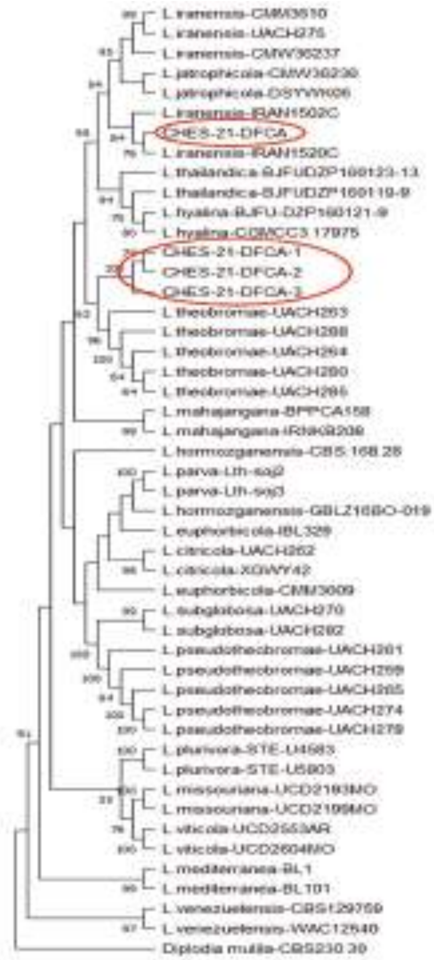

Fig 2. Identification of *Lasiodiplodia* species causing stem rot of dragon fruit based on multigene phylogenetic tree constructed using ITS, *EF1-α* and *β-tub* dataset CHES-21-DFCA is *L. iraniensis* and CHES-21-DFCA-1, CHES-21-

In laboratory studies, fungicide tebuconazole offered 100 percent inhibition at 0.05 as well as in 0.1 percent concentration against *L. iraniensis*. Similarly, hexaconazole 0.1 % offered 70 percent inhibition against this pathogen (Sangeetha, unpublished data). However, these two fungicide molecules have to be evaluated at field level for their efficacy.

2) Anthracnose

Causal organism: *C. siamense, C. tropicale, C. aenigma, C. karstii, C. truncatum, C. boninense, C. gloeosporioides*. *C. truncatum*and *C. fructicola*has been reported to cause anthracnose on dragon fruit.

Even though several of the above *Colletotrichum* species reported to cause anthracnose several dragon fruit growing countries, in India, *C. siamense*from Andaman and Nicobar Islands (Abirami et al., 2019), *C. truncatum* from Maharashtra (Salunkhe et al., 2023), *C. tropicale* from the state of Odisha, eastern India (Sangeetha, unpublished) have been reported employing multigene dataset analysis as taxonomical characters alone are not sufficient to delineate the species in *Colletotrichum*. Anthracnose, affects both dragon fruit stems majorly and also fruits. Stem infections lead to yield reduction, while fruit infections lead to post-harvest threats. Thirty percent anthracnose incidence has been reported from Andaman & Nicobar Islands, India which resulted in the loss of stem portions with consequent yield reduction(Abirami et al. 2019). The occurrence of sporadic rainfall between July and September, as well as unseasonal rain favoured the disease development in Baramati, Maharashtra (Salunkhe et al., 2023). In the state of Odisha, eastern India, stem infection of anthracnose lead to reduction in plant vigour which made the plant less productive (Sangeetha, unpublished).

There is symptom variation reported on dragon fruit species with plant age in response to anthracnose infection at the field level. Affected cladodes exhibited sunken lesions ranging in color from reddish to dark brown. Surrounding these lesions, there were chlorotic haloes, initially appearing yellowish. As the disease advanced, these chlorotic haloes transformed into mature necrotic patches (Fig 3). This disease weakens the plant and make less productive. Notably, mature necrotic patches featured prominent black acervuli, which are characteristic of fungal infections. The availability of plenty of viable spores is posing a big challenge with diseases caused by *Colletotrichum* species and reducing spore load and dispersal will help in alleviating disease epidemics immensely. The fungus overwinters in infected crop debris leftover in the soil.

Fig 3. Anthracnose disease on dragon fruit stem from early stage of infection to later stage

Available management strategies: Mixtures of azoxystrobin (200 g/L) and difenoconazole (124 g/L) have been suggested to manage anthracnose in addition to stem canker in Indonesia. Dietary risk assessment studies suggested that the application of azoxystrobin + difenoconazole combination at recommended dose does not pose any health hazard to dragon fruit consumers (Noegrahati et al. 2019). Field level curative applications of submicron chitosan dispersions (SCD), 1.0 per cent chitosan 600 nm droplet size result in a significant reduction in disease severity without leaving any residual and detrimental effect on fruits. The same treatment at the post-harvest stage reduces fruit anthracnose (Ali et al. 2013).*Bacillusmethylotrophicus*strains such as PB182 and PB257 reduced the anthracnose disease severity in both protective and curative tests undergreenhouse condition. (Meetum et al. 2017).

3. Stem and fruit Canker

Causal organism: *Neoscytalidium dimidiatum*

Stem canker is a destructive disease prevalent in dragon fruit worldwide and reported to havea constant impact on dragon fruit production. On fruits, it causes internal black rot, fruit canker. It is considered a most important pathogen which causes a significant economic impact on dragon fruit cultivation especially in Asian countries (Fullerton et al. 2018). During August to December, 2021, stem cankers were observed in commercial orchards within the Satara, Pune and Solapur districts of Maharashtra, India. The disease incidence of around 40% and severity ranged between 30 and 80% has been recorded in selected locations of Maharashtra, India(Salunkhe et al., 2022).

Canker disease has been reported to produce a defined sequence of symptom appearance on the stem as well as on fruits (Fig4). Initial symptoms on infected cladodes appeared as minute, circular, depressed chlorotic spots often with a brick red fleck followed by elevation of the centre of the lesion. Later the lesions turned necrotic and contained black, erumpent pycnidia, followed by chlorosis and stem rot (Salunkhe et al., 2022). Mostof thelesionshaveclear yellow halo which expands further leading to large, greyzonate dry scabby lesions damaging the large areas of stem. Finally, the matured older lesionsdry and often dropping out leavingbehind big shot-holes in the infected stem (Fullerton et al. 2018).

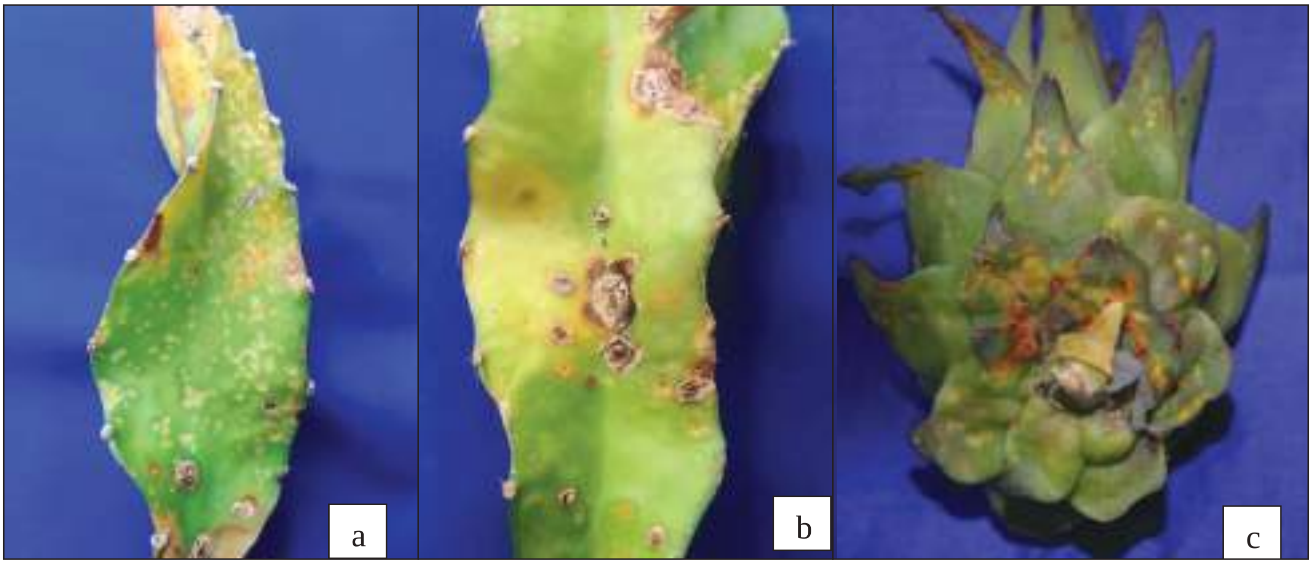

Fig 4. Canker caused by *N. dimidiatum*on dragon fruit stem and fruits

a. early stage depressed chlorotic spots with a brick red fleck b. later stage brownish dry lesion, c. Fruit infection

Early symptom of canker infection on the flower calyx and fruits are identical to stem infection and appear as scattered or clustered yellowish mildly depressed spots. Even though it is reported as superficial spots, in later stage, the small, yellowish spots coalesce and form brownish dry lesions, sometimes ends up in cracking of fruit's peel and become potential entry site for postharvest pathogens. The pathogen produces numerous small black pycnidia embedded in necrotic tissues and these fruiting structures harbour enormous spores that may be spread onto young, healthy tissues and initiate fresh infections. The spores are dispersed by rain splash or overhead irrigation, they may settle on susceptible young stem, flower calyx, or on fruits, germinate and infect.

Available management strategies: The first crucial step in reducing the risk of stem and fruit canker is to maintain low levels of pathogenic inoculum in the field. The cankerous lesions on infected dragon fruit stems must be cut off and removed from the field in order to prevent the spread of infection to fresh stems. Applying fungicides with different modes of action during reproductive growth to better protect the flowers and fruits has been suggested according to prevailing weather conditions. The protective fungicides mancozeb and copper, and the curative fungicides having translaminar activity such as difenoconazole and azoxystrobin are recommended for stem canker management (Fullerton et al. 2018).

The fungicide pyraclostrobin EC (250 g/L) controlled stem and fruit canker up to 80 per cent and 85 per cent, respectively. Tebuconazole (430 g/L) and azoxystrobin SC (250 g/L) also reported have had a similar effect to that of pyraclostrobin EC. In Florida, the fungicides with the active ingredients cyprodinil + fludioxonil and azoxystrobin which were registered for dragon fruit disease management are to be limited to four applications per year (Hong et al. 2019). *Streptomyces fradiae* and *Bacillus polyfermenticus* were reported to possess desired property against *N. dimidiatum* which could be used to reduce infection of canker (Luong et al. 2016). Similarly, potential biological control properties of *T. harzianum*strain T3.13 against *N. dimidiatum* have been identified by (Rusmariniet al.2017) but the commercial application above both biocontrol agents are not known.

4. Grey Blight

Causal organism: *Diaporthe* spp.

Several *Diaporthe* species was reported to cause grey blight in *Hylocereus* species in dragon fruit growing countries. In Bangladesh, incidence of 82percent variable degree of disease severity has been observed in *H. undatus* due to *D. phaseolorum*in selected locations (Karim et al. 2019). Forty percent disease incidence was reported from Malaysia in *H. polyrhizus* plantations due to grey stem blight caused by five *Diaporthe* species in two locations surveyed (Huda- Shakirah et al. 2021).The author of the chapter could also observe typical gray blight symptoms caused by *Diaporthe* species as a small, irregular to large elliptical patch where the minute blackish fruiting and structures are visible clearly, which later become necrotic and infected tissues fall off ((Fig 5) (Sangeetha, Unpublished). Involvement of five *Diaporthe* species with grey blight symptom has been reported from Malaysia who described the advanced symptoms as gray and dry, expanded, tiny black numerous pycnidia on the lesion surface (Huda- Shakirah et al. 2021). *D. passifloricola*, *D. limonicola* and *D. tectonae* has been reported from explants of stem of *S. monacanthus* and *S. undatus* (Cruz et al., 2022). The α- and β-conidia are the important characteristics for the identification of *Diaporthe* species.

As stem blight is reported to be a newly emerging disease of dragon fruit, management practises targeting the pathogen are yet to be developed. However, under laboratory condition, hexaconazole both 0.05 and 0.1 % exhibited 100 percent inhibition of this pathogen. Similarly, tebuconazole at 0.05 % exhibited 97 % inhibition followed by difenoconzaole exhibited 85 % pathogen inhibition (Sangeetha, unpublished). However, these three fungicide molecules have to be evaluated at field level for their efficacy (Sangeetha, unpublished).

Fig. 5. Sequential appearance of symptoms of gray blight on stem of dragon fruit caused by *Diaporthe* species

5. Fruit spotting

Several ant species are observed to cause direct damage to the dragon fruits by boring holes on green as well as ripe fruits and feeding them. This led to severe cometic damage to developing fruits, which results downgrading of fruit quality drastically (Fig 6). By the way, the open wounds created by ants become sites for secondary infection with fungi such as *Curvularia lunata* and make the fruit unfit to marketing. Ant attack observed to be more on the fruits wherein dragon fruit plants situated on the borders of field adjacent to other fruit crops like mango where the ant association/infestation is usually high. Similar kind of fruit damage by ants has been reported in strawberry also. As such ant damage is devastating and management strategy has to be developed.

Fig 6. Fruit spotting due to ant damage followed by secondary infection with fungi

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54. Mitigating Nematode Stress in Future Fruit Crops

R. Umamaheswari* and M. S. Rao
Division of Crop Protection
ICAR –Indian Institute of Horticultural Research, Bengaluru
*Email: UMA.MAHESHWARI@icar.gov.in

Introduction

Plant parasitic nematodes continue to threaten horticultural crops throughout the world, particularly in tropical and sub-tropical regions. Primarily as pathogens by themselves, and secondarily as predisposing agents for easy entry of pathogenic fungi and bacteria from soil into the host plants, nematodes cause huge economic losses quantitatively and qualitatively. Overall average annual yield loss of the world's major horticultural crops due to damage by plant parasitic nematodes is estimated at 13.54% (Reddy, 2012). All India Coordinated Research Project on Nematodes assessed monetary losses in 19 horticultural crops at Rs. 50,224.98 million including citrus (Rs. 9828.22 million) and banana (Rs. 9710.46 million) among fruit crops (Kumar *et al*., 2020).

To contain the nematode damage in horticultural crops, farmers resort to indiscriminate use of chemical nematicides posing serious hazards to the environment and biotic life. Since the horticultural produce especially fruits are consumed afresh, consumers expect residue-free produce both for internal and export markets. This brings into focus the importance of managing the nematode pests with minimal hazard to the ecosystem and ensuring absolute safety to human beings. There is a great need for implementation of integrated nematode management packages by judicial blend of several environment-friendly tactics like use of resistant varieties, biopesticides, botanicals, crop rotation, grafting with resistant root stocks, physical measures like soil solarization, hot water treatment etc. for suppressing the nematode population in horticultural crops.

ICAR- Indian Institute of Horticultural Research, Bengaluru, India is the pioneering Institute in India for its frontier research and commercialization of biopesticides all over India. It has registered five biopesticide products, namely *Purpureocillium lilacinum* (=*Paecilomyces lilacinus*) 1 % W.P., *Pochonia chlamydosporia (=Verticillium chlamydosporium)* 1 % W.P., *Trichoderma viride* 1.5 %, *Trichoderma harzianum* 1 % W.P., and *Pseudomonas fluorescens* 1 % W.P. with the Central Insecticides Bureau & Registration Committee, Faridabad under section 9(3b) of the Insecticides Act, 1968 for successfully managing nematode problems and associated disease complexes in horticultural crops in India (Rao *et al.*, 2016).

Nematode problems in fruit crops

Nematodes constitute one of the major limiting factors in fruit crop production. They cause extensive root galling and/ or necrosis resulting in serious economic consequences *viz*., drastic reduction in fruit or bunch weights, the quality of fruits is impoverished and fields have to be replanted every 2 to 3 years because of significant reduction in plant numbers. Furthermore, roots damaged by nematodes are easy prey to fungi which invade the roots and accelerate root decay. The root-knot nematode *Meloidogyne incognita*, the burrowing nematode *Radopholus similis*, citrus nematode *Tylenchulus semipentrans* and reniform nematode, *Rotylenchulus reniformis* are important nematode pests that cause 20 to 30 per cent yield losses in various fruit crops. These nematodes also breakdown the resistance to fungal diseases and lead to complete crop failure (Reddy, 2012).

More recently, root knot nematodes are reported in kamalam or dragon fruit plants (*Hylocereus* spp.) in China, Brazil and also observed in India. *M. incognita*, *M.enterolobii* and *M. javanica* have been reported to be associated in kamalam crop (Nascimento *et al.*, 2020; De Souza *et al.*, 2022 and Long *et al.*, 2022). Plants infected by root-knot nematodes in the field were found to be weak exhibiting stunting, wilting and yellowing of the stems. Roots of infected plants had moderate to small galls with protruding egg masses on the root surface. The severely infected roots turned dark with epidermis cracked and easy to peel off thereby revealing a number of white females in the vascular cylinder (Fig. 1).

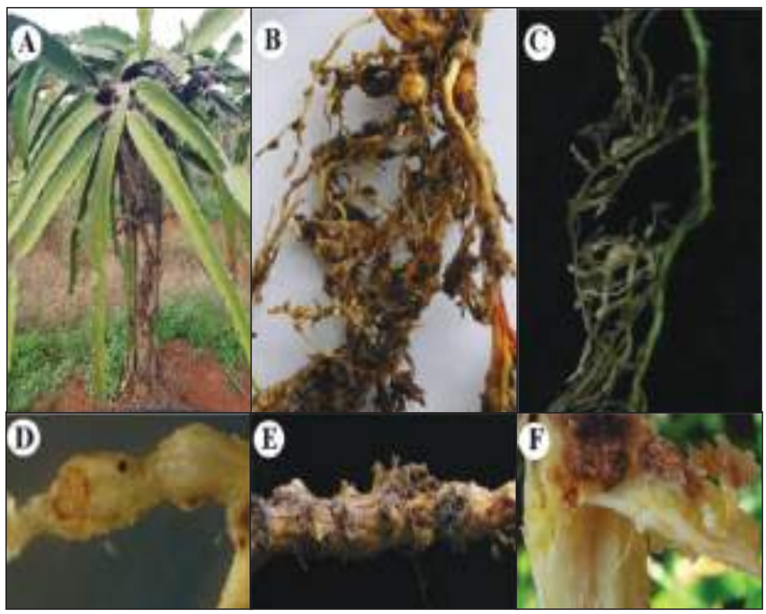

Fig.1: Symptoms induced by root-knot nematodes in red dragon fruit plants.

(A) Infested dragon fruit plant; (B–D) Infected plant roots showing galls and egg masses;
(E,F) Decayed root and pear-shaped females (Long *et al*., 2022)

Nematode problems in fruit crops originate firstly through infected planting materials from nurseries and secondly through the infected main field soil; the former causes more damage.

Nematode damage in nurseries

Nursery seedlings produced in various parts of India are damaged by several plant parasitic nematodes. Root knot nematodes (*Meloidogyne* spp.), burrowing nematode (*Radopholus similis*), reniform nematode (*Rotylenchulus reniformis*) are important among the nematodes attacking the planting materials of horticultural crops especially guava, pomegranate, banana, papaya, dragon fruit etc. in nursery stage (Fig 2 and 3). These nematodes damage the roots and result in very weak seedlings with poor root growth and cannot establish well after transplanting. This damaged root system also becomes vulnerable to secondary infection by soil borne pathogenic fungi and bacteria. Furthermore, nematode infected nursery seedlings facilitate the spread of the nematodes in the main fields making the problem more difficult to manage in a larger area.

Root knot nematodes (*Meloidogyne* spp.) are emerging as a major threat to guava cultivation in India, spreading rapidly through infected nursery planting material. In India, *M. enterolobii* and *M. incognita* are economically important in guava, the former being highly pathogenic. Nematode infection sites in the roots also predispose the roots to easy entry of soil borne pathogenic fungi like *Fusarium* spp. This disease complex, called as 'guava decline' causes extensive root decay and plant death within months. Large scale incidence of this nematode is observed in major guava growing belts in India; the more affected being the nurseries and young orchards. In infected fields, nematode incidence varies from 30 to 60% and in some nurseries, 90 -100% was noticed. About 25 – 30% yield loss is caused due to this nematode and in severe cases, upto 60% is observed in guava orchards.

Securing healthy seedlings from nursery stage is essential to ensure optimum plant population, good growth of the crop and higher yields. Hence, it is inevitable to produce nematode-free clean planting material at nursery stage. For this, testing and certification of planting materials become mandatory for safe movement of plants and avoid loss to farmers.

Fig. 2: Guava nurseries affected by root knot nematodes

Fig. 3: a: Burrowing nematode affected banana tissue culture plants;
b. Root knot nematode affected papaya seedling; c. Root knot nematode affected pomegranate seedling;
d. Root knot nematode affected kamalam fruit seedling

Integrated Nematode Management in fruit crops:

Sanitation:

- Use of nematode free saplings for planting
- Removal and destruction of nematode infected saplings or trees
- Maintaining the orchard free from weeds and alternate hosts

Nematode management in nurseries

Using soil-less medium:

Use of sterilized coir pith, cocopeat or vermiculite instead of native soil for hardening of rooted planting materials will provide absolute nematode as well as disease-free planting materials.

Air layering:

This is a safe method of vegetative propagation and can be used in guava propagation. The soil-less rooting medium can be bio-fortified to ensure further protection. The rooted cuttings can be shifted to sterilized medium for hardening and further growth of plant

Using nematode-free soil for root hardening:

- Solarization of soil in the open by using thin transparent polythene sheets for about 2–3 months during peak summer is effective against nematodes and other soil borne pathogens
- Solarization of soil/polythene bags filled with soil by covering with polythene sheets (double solarization).
- Use of virgin soil (Poornima and Walia, 2021)

Treatment of potting mixture used for raising seedlings/rootstocks

- A ton of soil mixture has to be mixed with 100kg of neem cake or pongamia cake enriched with the bio-pesticides such as *Paecilomyces lilacinus*, *Pseudomonas fluorescens* and *Trichoderma harzianum*.

***Procedure of enrichment of neem cake / pongamia cake with bio-pesticides*:**

Mix 2 - 3 kg of each of *Paecilomyces lilacinus/ Pochonia chlamydosporia*, *Pseudomonas fluorescens* and *Trichoderma harzianum* / *T. viride* in one tonne of neem cake / pongamia cake and leave it under shade for 20 days at 25 – 30% moisture for multiplication of beneficial microbes.

Nematode management in orchards

Use of biopesticides

- Apply 3 – 4 kg of bio-pesticide enriched vermicompost/ Farm Yard Manure per plant before planting and at an interval of 3 months.
- Mix 20 kg of bio-pesticide enriched neem cake / pongamia cake in 200 lit water, leave it for two days. This can be used for drenching at 2 – 3 lit/ plant or filter it thoroughly and use it for sending along the drip, once in an interval of 15 – 20 days.
- The filtered suspension can be used for spraying the crop or can also be used as spray fluid for spraying micro nutrient mixtures (Rao *et al.*, 2015).

Procedure of enrichment of vermicompost/ FYM / compost with bio-pesticides:

Mix 2 – 3 kg of bio-pesticides, *Paecilomyces lilacinus/ Pochonia chlamydosporia*, *Pseudomonas fluorescens* and *Trichoderma harzianum* / *T. viride* in one tonne of vermicompost/ FYM / compost; leave it under shade for 20 days. Maintain optimum moisture of 25 - 30%. Mix it now and then. Cover it with leaf mulch or soil or polythene sheet. After 20 days FYM gets enriched with billions of propagules of bio-agents and it is ready for use (Fig. 4).

4a **4b** **4c**

Fig. 4a –Enriching FYM with biopesticides; 4b – FYM fully enriched with biopesticides;
4c – Preparing suspension of neem cake enriched with biopesticides

Chemical nematicides

- Apply Velumprime (Fluopyram 35%EC) @ 0.3 to 0.5 ml per plant
- Soil application of Furadan (Carbofuran 3G) @ 40 to 60 g per plant in established orchards; 3 g/ plant in nursery rootstocks

Use of resistant varieties/ root stocks:

- Dogridge, Black Champa, 1613, Salt Creek, Cardinal, Banquabad are grape root stocks resistant to root knot nematodes, *Meloidogyne* sp.
- Trifoliate orange (*Poncirus trifoliata*) and its hybrids (Citrumello), rootstocks by crossing Rangpur lime (*Citrus limonia*) with *P. trifoliata* viz., CRH-3, CRH-5 and CRH-41 are highly resistant to the citrus nematodes.
- *Psidium cattleianum* and *P. friedrichstalianum* are the wild guava species resistant to root knot nematodes.

Hot water treatment

- Dipping the bare roots of citrus seedling in hot water at 45°C for 25 min or 46.7°C for 10 min controls citrus nematodes
- Dipping of grape rooted cuttings for 10min. at 50°C or 30min. at 47° reduces nematode damage due to root knot nematode

Future thrusts

Nematode problems in fruit crops are spreading at an alarming rate in India. The basic problem is unawareness about nematode infection in planting materials among nurserymen, orchardists and polyhouse growers; and non-implementation of phytosanitary regulations by the concerned agencies. There is an urgent need to sensitize them on the issue of nematode dispersal through planting materials, and technology packages for its prevention. Compulsory training of State Horticulture Officials should be geared up on nematode diagnosis and remedial measures. Regular monitoring of nursery materials by specially trained staff of State Governments and amendment of nursery laws/regulations to make provisions for issuing mandatory 'Health Certificate' by the concerned District Horticulture Officer to the registered nursery owner/carrier at the time of transporting planting materials from these nurseries should be made mandatory.

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55. Insurgence and Management of Invasive Pests in Horticultural Crops

P D Kamala Jayanthi[1] and Rajeshwari G[2]

[1]Division of Crop Protection, ICAR-Indian Institute of Horticultural Research, Heseraghatta Lake PO, Bangalore 560089, Karnataka;

[2]College of Horticulture, DR YSR Horticultural University, Anantharajupeta 516105, Andhra Pradesh

ABSTRACT

Invasive alien species (IAS) are exotic organisms that become established in natural or seminatural ecosystems or habitats. It is a change agent and endangers natural biological diversity. Invasive insects have posed a serious threat to household goods, human health, agricultural produce, and the environment in India. Because of trade liberalization and more human movement between continents, the invasion of insect pests to India is increasing year by year. Such kinds of biological invasions can be considered as biological pollution, as they cause the greatest loss of biodiversity. The introduction of new pest species in a new location can be reduced by having a fundamental understanding of invasive pest species and developing international collaboration through the sharing of knowledge about invasive pests and their natural enemies. Import regulations should be strictly enforced and international trade & commerce collaboration, early detection, and taxonomic identification at entrance points would keep India safe and secure from such invasive species. Management of new alien species by using different integrated pest management tactics can help to reduce the risk to the biodiversity of the horticultural ecosystems.

Invasive species are non-native or exotic organisms with a high potential for spread and adaption. They are unintentionally transferred into a new location where they live and multiply. Furthermore, the new location will be deprived of its natural opponent, allowing the invasive species to spread uninterrupted. India has a total of 173 invasive species, including 47 invasive agricultural ecosystem species, 23 of which are insects (Rathee and Dalal, 2018; Singh et al., 2020). Often the native biodiversity will be in danger because of the entry of new invasive species thereby posing a serious threat to the biosecurity of a nation (Rao et al., 2018). Recent globalization that facilitated the regular exchanges of planting material across nations enhanced the likelihood of some exotic pests entering unintentionally. These insect pests can spread rapidly and can cause damage to commercially important plant species. The Plant Quarantine (Regulation of Import into India) Order, 2003, which aims to protect horticulture and forest tree plants by preventing the entry, establishment, and spread of exotic plant pests, was implemented in India by the Directorate of Plant Protection, Quarantine, and Storage. Plant Quarantine stations are set up at various points of entry, such as seaports, airports, and land borders, to carry out the regulations of the Plant Quarantine Order, 2003.

Specific characteristics of invasive pests

Invasive pests often have a very high and rapid reproduction rate, even in adverse climatic conditions and have the ability to travel long distances. They are more compatible with the alien ecosystems and ought to be able to survive on a variety of different food sources. Because of their rapid development, they have the potential to outcompete with native species.

Important invasive insect pests of horticultural crops that gained entry into India

Woolly apple aphid, *Eriosoma lanigerum* Hausmann (Aphididae: Hemiptera):

This pest was introduced to India with the export of Chinese apple rootstock in the 18th century. It was first reported in Coonoor in 1889 where the pest nearly destroyed every apple orchard (Atkinson, 1889 cited in Misra, 1920) followed by hilly areas of Utter Pradesh in 1909 and Shimla in 1910 respectively. By 1920, it had established itself as a major pest of apples in Kashmir, where it was introduced by imported nursery stock from China (Misra, 1920). Since then, it has effectively invaded the apple orchards in the country particularly those in the eastern regions where apple farming is a relatively new horticultural enterprise (Rao, 1960; Chacko, 1967). This pest attacks apples during all stages of development. It grows in both the aerial and subterranean parts of the apple tree. Feeding on twigs and branches leads to galls and tissue deformation, whereas feeding on roots results in root galls.

Sanjose scale, *Quadraspidiotus perniciosus* Comstock (Diaspididae: Hemiptera):

This is a serious pest of rosaceous fruit plants and entered India in 1911. It mainly infests the bark and branches, although it can also be found on the fruit, which it discolours. Infested tissues may break and leak gum, followed by desiccation and die-back. In case of severe infestations, the entire plant may die.

Lantana bug, *Orthezia insignis* Browne (Orthezidae: Hemiptera):

This bug was introduced in the year 1915 into the Nilgiris region of India. This scale insect become a serious pest and spreads rapidly due to its parthenogenic nature.

Cottony cushion scale, *Icerya purchase* Maskell (Margarodidae: Hemiptera):

This scale was accidentally introduced into India in 1921 (Nilgiris and Annamalai highlands) and has spread throughout the country. This is one of the important scale insects and its transmission is mainly through trading and agricultural practices.

Potato tuber moth, *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae):

This pest was introduced to India in 1907 together with Italian potatoes and immediately spread throughout the country (Lefroy, 1907). Larva initially mines into leaves and later feeds on tubers in soil. In a single year, it can complete 12 generations (Hill, 1993). After harvesting, the insect continues to develop on tubers or volunteer plants remaining in the field including other solanaceous plants such as tomatoes (Gilboa and Podoler et al, 1995 and Coll et al, 2000).

Diamondback moth, *Plutella xylostella* L. (Plutellidae: Lepidoptera):

The diamondback moth on cruciferous vegetables was first reported by Fletcher in 1914 and was widely disseminated subsequently across India.

Banana skipper, *Erionota torus* Evans (Hesperiidae: Lepidoptera):

This lepidopterous leaf roller was first identified in Southeast Asia and later widely spread in Sikkim, Manipur (Prasad and Singh, 1987); Assam (Deka et al., 1996) including down south in recent years (Kamala Jayanthi et al., 2015). Larva rolls the leaves from the edges by cutting the leaf lamina. In case of severe infestation, complete defoliation of leaves can be seen.

Subabulpsyllid, *Heteropsylla cubana* Crawford (Psyllidae: Hemiptera):

It originated in Central America and was introduced to India in 1988 in Bangalore and the Chengalpattu district of Tamil Nadu. The psyllid completely deforms new shoots by sucking sap from their leaves, inflorescences, and young shoots.

Serpentine leaf miner, *Liriomyza trifolii* Burges (Agromyzidae: Diptera):

The original country of this pest is the United States (Florida), where it was accidentally introduced in the years 1990-1991. In the early 1970s, it was possibly imported to California, USA, along with chrysanthemum cut flowers (Parrella, 1987). The larva mines into the epidermal layers of leaves and tender shoots. Severe infestation may cause complete defoliation.

Coffee berry borer, *Hypothenemus hampei* Ferrari (Scolytidae: Coleoptera):

The first reports of the coffee berry borer in India were recorded in Gudalur, Nilgiris, in 1990. The female beetle bores into the berries through the navel region and feeds on developing beans by making tunnels inside.

Spiralling whitefly, *Aleurodicus disperses* Russell (Aleyrodidae: Hemiptera):

This pest is native to Central America. In India, first reported from Kerala in 1993 (Jhala et al., 2008), and later from all peninsular regions of India (David and Regu 1995). The nymphs and adults suck the sap from plant parts. They secrete white waxy flocculent materials while sucking the sap from plant parts.

Eripohyid mite, *Aceria gurreronis* Keifer (Eriophidae: Arachnida):

It was identified in the Kerala district of Ernakulam in 1997 and later spread to all major coconut-growing regions**.**The microscopic wormlike eriophyid mites are seen in thousands under the inner bracts of the perianth. They also feed in colonies on lower leaf surfaces causing yellow speckling and chlorosis.

Papaya mealy bug, *Paracoccus marginatus* Williams & Graner de Willink (Pseudococcidae: Hemiptera):

It is a native of the Neotropical region (Mexico, Guatemala) and was introduced to Coimbatore (Tamil Nadu) in 2007. Both nymphs and adults suck the sap from leaves and fruits majorly. Photosynthetic activity is reduced due to the secretion of honeydew, sooty mould develops on leaves. It is thought that this pest was spread to Kerala, Karnataka, Maharashtra, and Tripura due to the movement of infested fruits (Muniappan et al., 2008).

Tomato pin worm, *Tuta absoluta* Meyrick (Gelechiidae: Lepidoptera):

T. absoluta was identified for the first time on tomato at the Indian Institute of Horticultural Research (IIHR), Karnataka, India in 2014 (Shylesha et al., 2018). Young larvae mine tomato leaves, apical buds, stalks, and fruits. After feeding, inconspicuous mines (blotches) and galleries form on the leaves, and fruits with pinhole-sized holes from the stalk end are often covered in frass.

Western flower, *Frankliniella occidentalis* Pergande (Thripidae: Thysanoptera):

This pest was first time reported on tomato crops from Bengaluru, Karnataka (Thyagi and Kumar 2015).

In 1970-80, it was a devastating pest on many crops worldwide. Apart from feeding on plant parts, it transmits plant pathogenic viruses in many crops (Macharia et al., 2015).

Chilli black thrips, *Thrips parvispinus* Karny (Thripidae: Thysanoptera):

This invasive pest was initially observed on papaya in Bangalore (Tyagi et al., 2015) and *Dahlia rosea* (Rachana et al., 2018). Now it become a serious problem in chilli-growing areas of India. They drastically reduce productivity in chiles by causing extensive flower loss, fruit malformation, and fruit drop.

Rugose spiralling whitefly, *Aleurodicus rugioperculetus* Martin (Aleyrodiadae: Hemiptera):

This pest was first reported on coconut in Pollachi, Tamil Nadu, 2016 (Sundararaj and Selvaraj 2017). This pest attacks a wide range of host plants, including palms, woody ornamentals, and fruits. Nymphs and adults of the whitefly suck the sap on the under surfaces of the leaflets. Extensive feeding of the insect leads to the excretion of honey dew which subsequently gets deposited on the upper surface of the leaves. Because honeydew excrement is sweet and fluid, it attracts ants and promotes the growth of the fungus *Capnodium* sp., which causes host deformity and reduces plant photosynthesis.

Nesting whitefly, *Paraleyrodes minei* Iacarrino (Aleyrodiadae: Hemiptera):

Species in this genus are known as "nesting whiteflies" because of the unique wax pattern that forms around the pupa on the leaf surface. It has oblique grey banding on its wings and produces loosely woven, soft wax nests. *P. minei* builds several colonies (~30) of the nest on coconut leaflets, causing sooty mold on the leaves (Josephrajkumar et al., 2018).

Bondar'snesting whitefly, *Paraleyrodes bondari* Perrachi (Aleyrodiadae: Hemiptera):

The neotropical invasive BNW was first detected in India on coconut palms in Kerala (Joseph Rajkumar et al., 2019). Young nymphs are surrounded by transparent "wax" while older nymphs are covered in flocculent wax and encircled by fiberglass-like rods. Heavy Bondar's nesting whitefly infestations result in round and white "nests" that contrast with black sooty mold (Stocks, 2012).

Wooly whitefly, *Aleurothrixus floccosus* Maskell (Aleyrodiadae: Hemiptera):

It is a highly polyphagous pest reported for the first time in India in 2019 on guava (Sundararaj et al., 2020). The nymphal stages cause huge damage to the guava by sucking sap from the undersurface of the leaves. Whitefly infestation reduces nut production and yields of copra content.

Neotropical palm whitefly, *Aleurotrachelus atratus* Hempel (Aleyrodiadae: Hemiptera):

This pest infestation was reported in India in 2019. It mainly infests the undersurface of leaves with 97 to 186 nymphs per group. In severe situations, nymphs covering more than 60% of the leaflet cause chlorosis or necrosis, as well as loss of vitality and drying of the leaflets (Selvaraj et al., 2019).

Cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero (Pseudococcidae: Hemiptera):

Cassava mealybug, *P. manihoti* was first reported on cassava in Thrissur, Kerala, in April 2020. They are pink in colour with a mealy covering and usually infest the shoot tips and the under surface of the leaves. Heavy infestation results in leaf drying and complete defoliation (Sampath et al., 2021).

Leek moth, *Acrolepiopsis assectella* Zeller (Acrolepiidae: Lepidoptera):

In the year 2020, an exotic pest leek moth was introduced from Europe to India. The larva mines the epidermis of leaves and may feed on the inner sides of leaves, producing translucent "windows" or bands on the leaf tissue (Dewangan and Deole 2021).

How to prevent invasive species

The first step in prevention of invasive insect pests is identification and paying close attention. These could be listed on a "blacklist" and denied admission according to national law. It is reasonable to consider a species safe (to put it on a "white list") if it has passed a risk assessment examination, but monitoring is still necessary to make sure the prediction holds true over time. Most species in the globe should be put on a "grey list" because it is unknown whether they could become invasive.

Steps in management of new invasive insect pests

The basic steps in management of new invasive pests vary depending on the type of organism, population size, biology, status of pest and available mitigation options.

I) **Identification:** The quarantine professional should appropriately identify invasive insect pests through various methods like traditional taxonomy/DNA barcoding that can help in the unknown species identification.

II) **Risk assessments**: First, determine how much risk the invasive insect problem poses to the neighborhood. Examine the biology of the organism, its local and global distribution, the pest's status, available mitigation measures and the window of opportunity for taking action. Understanding invasive species and the risk they pose in new environments is crucial. It is important to be knowledgeable of the biology, distribution, economic importance, and management alternative options.

(III) Eradication: If an invasive species poses a significant risk, it should be eradicated on a large scale. Public awareness campaigns should be created to educate the public about the invasive pest.

(IV) Monitoring: The survey data for the most species over two years or two generations is considered for the program's success in eradicating the invasive species.

Eco-friendly management practices

Eco-friendly management practices include cultural, mechanical, biological and legal methods. Biological control methods play a vital role in the successful suppression of invasive pest populations that focuses on the intentional use of a living organism – a predator with the aim of controlling a specific undesired alien pest invasion. A biological control agent may be a parasite, parasitoid, pathogen, predator, herbivore insect, antagonist, or competitor. The methods or techniques involved in biological control are:

(i) Importation (Classical biological control): It involves the introduction of a pest's natural enemies to a new locale where they do not occur naturally. Early instances were often unofficial and not based on research, and some introduced species became serious pests themselves. To be most effective at controlling a pest, a biological control agent requires a colonizing ability which allows it to keep pace with changes to the habitat in space and time. Control is most effective if the agent has temporal persistence so that it can maintain its population even in the temporary absence of the target species, and if it is an opportunistic forager, enabling it to rapidly exploit a pest population

(ii) Augmentation: Augmentation involves the supplemental release of natural enemies that occur in a particular area, boosting the naturally occurring populations there. In inoculative release, small numbers of the control agents are released at intervals to allow them to reproduce, in the hope of setting up longer-term control and thus keeping the pest down to a low level, constituting prevention rather than cure. In inundate release, in contrast, large numbers are released in the hope of rapidly reducing a damaging pest population, correcting a problem that has already arisen. Augmentation can be effective, but is not guaranteed to work, and depends on the precise details of the interactions between each pest and control agent.

(iii) Conservation: The main goal is to conserve and enhance the diversity of natural enemies existing already in an area thus decreasing the mortality of the affected species.

Legislative control: To avoid the invasion of alien pests, almost every country has quarantine implications in place on the import of plant/plant material. These quarantine policies are enforced through legal enactments known as quarantine laws. At the port of entry, imported plants and plant materials must be extensively checked for the presence of any invasive insect or its different pheonological life stages. An insect that appeared to be harmless or a minor pest in its original country may become a potential pest in an introduced country. Thus, all pests must be prohibited from entering the country of origin, irrespective of their status, and any infested material must be sterilized by suitable measures at the port of entry.

Plant quarantine structure & policy in India: A total of 35 new plant quarantine stations have been established across the country at all major and minor ports to develop an integrated information management system, national phytosanitary database and advanced molecular diagnostic facilities for rapid pathogen detection and streamlining the phytosanitary support to stakeholders. Computerization and networking of all plant quarantine stations and standardization of the export certification process to ensure uniform and credible certification will help in the prevention of invasive species in the long run.

The use of "integrated pest control methods" is becoming more popular, and there is an extensive literature to support this. This means that several of the methods mentioned above can be knowledgeably combined to accomplish the desired control or eradication of the alien species. The national integrated pest management (IPM) programme is the framework for preventing and controlling the threat posed by invasive species throughout the country.

Conclusion

Insect invasions caused by globalization posed a major threat to local flora and livestock, even leading to the extinction of many indigenous species. The globalization of agriculture has increased global trade and the movement of seeds/ planting materials has increased the risk of invasive pest introduction into India. These species can multiply rapidly and threaten economically important plant species and crop plants if they are not accompanied by the natural enemies that keep them in check in their native habitat. The introduction of new pest species in a new location can be reduced by having a fundamental understanding of invasive pest species and working internationally through the sharing of information on invasive pests and their natural enemies.

The introduction of invasive insect species causes severe production loss in major horticultural crops, as these insect pests have a negative impact on food production. In this regard, timely identification of invasive pests' occurrence, distribution, economic loss and mitigation options can be done by scientific collaboration across vulnerable geographic boundaries, proper quarantine and policy decisions.

Table.1 List of invasive insect pests of horticultural crops in India

Invasive pest	Introduced Country (Year)	Host plants	References
Apple wooly aphid, *Eriosoma lanigerum* (Hausmann)	America/China (1889)	Apple	Mishra (1920)
San Jose scale, *Quadraspidiotus perniciousus* (Comstock)	China (1911)		Singh (2004)
Diamond back moth, *Plutella xylostella* (Linnaeus)	Europe and East Asia (1914)	Cabbage and cauliflower	Fletcher (1914)
Lantana Bug, *Ortheziai nsignis* (Browne)	Sri Lanka/ West Indies (1915)	Lantana	Muniappan and Viraktamath (1986)
Cottony cushion scale, *Icerya purchase* (Maskell)	Australia (1921)	Citrus	Singh (2004)
Potato tuber moth, *Phthorimaea operculella* (Zeller)	Italy (1937)	Potato	Singh (2004)
Banana Skipper, *Erionota torus* (Evans)	South East Asia (1987)	Banana	Prasad and Singh (1987); Deka et al. (1996); Raju et al. (2015)
Subabulpsyllid, *Heteropsylla cubana* (Crawford)	Central America (1988)	Leucaena plantations	Jalali and Singh (1989)
Serpentine leaf miner, *Liriomyza trifolii* (Burgess)	Florida (U.S.A) (1990)	Tomato, Peas, Cucurbits and ornamental plants	Singh (2004)
Coffee berry bean, *Hypothenemus hampei* (Ferrari)	Africa (1990)	Coffee	Vega et al. (1999)
Spiralling whitefly, *Aleurodicus disperses* (Russell)	Central America (1993)	Guava	Palaniswami et al. (1995)
Eriophyid mite, *Aceria gurreronis* (Keifer	Mexico (1997)	Coocnut	Singh (2004)
Papaya mealy bug, *Paracoccus marginatus* (Williams & Granara de Willink)	Mexico (2005)	Papaya	Jhala et al. (2008)
South American tomato leaf miner/ Pinworm, *Tuta absoluta* (Meyrick)	South America (2014)	Tomato	Sridhar et al. (2014)

Western flower thrips, *Frankliniella occidentalis* (Pergande)	Southwestern United States (2015)	Chrysanthemum, Tomato, Capsicum and Cucumber	Tyagi and Kumar (2015)
Chilli black thrips, *Thrips parvispinus* (Karny)	South East Asia (2015)	Chilli	Tyagi et al. (2015)
Rugose spiraling whitefly, *Aleurodicus rugioperculetus* (Martin)	Florida (U.S.A) (2016)	Coconut	Sundararaj and Selvaraj (2017)
Nesting Whitefly (NW), *Paraleyrodes minei* (Iacarrino)	Syria (2018)	Mainly Coconut,	Dubey (2019)
Bondar's nesting whitefly, *Paraleyrodes bondari* (Perrachi)	Central America (2018)	Coconut	Josephrajkumar et al. (2019)
Wooly Whitefly, *Aleurothrixus floccosus* (Maskell)	Neotropical region (2019)	Guava, Citrus	Sundararajet al., (2020)
Palm Whitefly, *Aleurotrachelus atratus* (Hempel)	Brazil (2019)	Coconut,	Selvaraj et al. (2019)
Cassava Mealy Bug, *Phenacoccus manihoti* (Matile - Ferrero)	South America (2020)	Cassava	Sampath et al. (2021)
Leek moth, *Acrolepiopsis assectella* (Zeller)	Europe (2020)	Onion, leek and garlic	Dewangan and Deole (2021)

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56. Emerging Insect Pests and Their Management in Underutilized Vegetables in India

M. Mani * and JaydeepHalder

Ex. Head, Division of Entomology, ICAR-IIHR, Hesaragatta Lake Post, Bangalore-560 089

Underutilized v egetable crops are those which are neither grown commercially on large scale nor traded widely. They include some leafy vegetables, crucifers, solanaceous vegetables, legumes, cucurbits, tuber crops and aquatic vegetables. Not much attention has been given on these 30 lesser-known vegetable crops,in spite of their recognized importance known possibly due to lack of awareness on nutritional and medicinal importance and the lack of information on production and protection techniques of these crops. Some underutilized vegetable crops in its big list are Curry leaf, Drumstick, Amaranthus,Cherrytomato ,Chinesecabbage,wingedbean and aquatic vegetables etc.They are known to be well adapted to existing as well as adverse environmental conditions and generally resistant to pests and pathogens. Moreover, the pests of underutilized/ indigenous vegetables worldwide are seriously under-researched and poorly understood If these vegetables are ogaininprominence, cover greater production areas, itislikely that biotic stresses will increasingly pose serious threats to their sustainable production through out the country. Furthermore, global warming will also influence biotic stresses by allowing more generations of insect store produce in a given time period, it may alter the aggressiveness and dynamics of pests. The major insect pests of some important underutilized vegetables along with their suitable managementare discussed in this paper.

I. **PESTS OF UNDERUTILIZED LEAFYVEGETABLES**

Underutilized leafyvegetables include Amaranthus, Asparagus**,** Celery, Globe artichoke, lettuce, sorrel, parsnip, Leek, Chekurmanis, kakrol, vellarai, sesbania, curry leaf, drumstick etc.

1. AMARANTHUS

Leaf webbing caterpillars - *Spoladea recurvalis*,*Psara basalis*&*Eretmocera impactella*

The larvae web the leaves and feed on the green matter. Severe attack results in complete skeletonizing and ultimate drying of leaves.Managemen**t** involves with collection and destruction of the affected plant parts with caterpillars, setting up of light traps @1/ha to attract and kill the adults, Spray application of azadirachtin 0.03% (300 ppm) @ 1000 ml in 200-400 litre of water/acre or azadirachtin 5% W/W neem extract concentrate @ 80 ml in 160 litre of water/acre. Application of *Bacillus thuringiensis*@ 2 g or 2 ml/L water is also useful to control the leaf webbing caterpillar. If necessary only, application of malathion is recommended.

Amaranthus weevil- *Hypolixus truncatulus*

Grubs bore into the stem and cause gall-like thickenings. Management involves with the collection and destruction of theaffectedplantpartswithcaterpillars, settingupoflighttrap@1/acretoattractandkilltheadults and application of Neem Seed Kernel Extract (NSKE) 4%. or Azadirachtin300 ppm@ 5 ml/Lwater. If necessary only, application of malathion is recommended.

LETTUCE

It is known to be attacked by theAphids*Aphis gossypii*,*Myzus persicae*, *Liaphis erysimi*,*Nasonovia ribisnigri &Aulacorthum solani*, Cutworm *Agrotissegetum*, Beet Armyworm *Spodoptera exigua* and the cabbage looper *Trichoplusia ni*. Aphids are destructive pests of lettucein India. Management involves with spraying of acetamiprid 20% SP @ 0.2 gm per litre of water, M. Mani, Indian Institute of Horticultural Research, Bangalore -560 089, India; Jaydeep Halder Indian Institute of Vegetable Research, Varanasi-221305. In India. Management involves with spraying of acetamiprid 20% SP @ 0.2 gm per litre of water, and setting up yellow sticky traps to control aphid population. Management of the beet armyworm *Spodoptera exigua* involves with setting up pheromone traps and application of neem products and Bt. Spraying the crop with malathion (0.1%) or spinosad 45 SC @ 0.3ml/L. is also useful to control the lepidopterans.

GLOBE ARTICHOKE

1. Armyworms - *Spodoptera exigua, S. ornithogalli*&*Pseudaletiaunipuncta*

Larvae feed on leaves and bracts of floral heads in case of older plants. Management involves with deep ploughing immediately following the harvest, sprays of *Bacillus thuringiensis* and spinosad 45 SC @ 0.3ml/L.

2. Artichoke aphid- *Capitophoruselaeagni*

Aphids cause artichoke leaves to curl and turn yellow and, resulting in the formation of undersize or deformed artichoke buds. Aphids are known to cause 10-15% crop loss. Management involves with the application of insecticidal soaps or oils such as neem or canola oil.

3. Artichoke Plume Moth - *Platyptiliacarduidactyla*

Larvae start tunneling into the leaf stalk after the first molt, they mine the outer bracts by moving toward the leaf petiole or toward the buds. Management involves withcutting of all plants down to ground level for 2 or 3 months once a year, chopping and covering the cuttings with at least 6 inches of soil, removing all thistles and related plants and application of *Bacillus thuringiensis.*

4. Leaf miner- *Chromatomyiasyngenesiae*

Larvae feed between the upper and lower surface of the leaves, making distinctive whitish tunnels or mines. The leaf miner is usually kept in control by naturally occurring parasitoids, and does not require any additional control efforts. Application of spinosad 45 SC @ 0.3ml/l and also botanicals is useful to control the leaf miner.

5. Loopers - *Trichoplusiani&Autographacalifornica*

Young larvae feed primarily on the underside of lower leaves. High population can damage seedlings resulted in stunted growth and inhibit uniform maturity of the crop. Management involves witheffective killing of younger larvae by the application of *Bacillus thuringiensis.*

6. Tarnished plant bug - *Lygus Hesperus*

Nymphs and adults feed mainly on the very young leaves. Management involves with controlling alternate host plants and using the insecticides such as thiamethoxam, bifenthrin and imidacloprid carefully.

SPINACH/PALAK

It is known to be attacked by Spinach blue beetle Altica*caerulescens*, Leaf eating caterpillars *Spoladearecurvalis, Helicoverpa armigera, Spodoptera lituraS, exigua,* Cutworms *A. ipsilon*& *Agrotis segetum*, Aphids – *Liaphis erysimi, Myzus persicae*&*Hydadaphisindobrassica*&*Aphis gossypii,* and the leaf miner *Liriomyzatrifolii*. Management of defoliators involves with the application of Fipronil 5 SC @ 1 ml/L ,emamectin benzoate 5SG @ 0.25g/L, indoxacarb 14.5 SC @ 0.25 ml/L and fipronil 5 SC @ 1ml/L.Spinach blue beetles can be controlled with the application of fenvalerate 20 EC 0.5 ml/L.

CHEKKURMANIS

Scirtothrips dorsalis is known to cause curling and crinkling of leaves making them unfit for use. The brown scale *Saissetiahemisphaerica*infests the tender shoots and leaves. The aphid *Aphis umbrella* and the whiteflies *Aleurodicus dispersus* and*Bemisia euphorbiae* are known to infest chekurmanis.

CELERY

1. Cutworm- *Agrotis* spp.

It is a regular pest of celery**.** Initially larvae feed on leaves make irregular holes at soil level. Older larvae cut off seedlings especially in the night. Management involves with the collection and destruction of infested plant, setting up the black light and pheromone traps and soil drenching with chlorpyriphos is useful to control the cutworms.

2. Aphid- *Acyrthosiphonmalvae*

Aphids suck the sap from tender parts of celery. Plants get devitalized and become unfit for consumption.

PARSLEY

1. Beet armyworm- *Spodoptera exigua*

Caterpillars initially make irregular holes and feed on the leaves, leaving only veins and petioles. Application of *Bacillus thuringiensis* is useful to control the menace of *S.exigua.*

2. Green peach aphid- *Myzus persicae*

Primary damage is by both nymph and adult by sucking of plant sap. Setting up the yellow sticky trap to monitor aphid population and spray dimethoate 0.05% is useful to control aphids if necessary.

CURRY LEAF

It is known to be attacked by Citrus butterfly *Papilio demoleus, P. polytes,* psylla *Diaphorina citri,* Scale insect *Unaspis citri*, Mealybug *Planococcus citri,*Aphid *Toxoptera aurantii* andTortoise beetle *Silana farinose* .

1. Asian citruspsyllid -*Diaphorina citri*

It is one of the major insect pests of curry leaf attacking the new flush causing considerable damage to the crop. Nymphs and adult suck the cell sap from leaves, tender shoots and flower buds causing curling of leaves, defoliation and drying of twigs. Management involves with the pruning of the affected shoots, foliar application of petroleum spray oil @ 2 % or azadirachtin 1% @ 3.7 ml/l or neem soap or pongamia soap @ 5 g/Lor NSKE5%.at bud burst stage. If the psyllid incidence is severe, insecticidal sprays *viz.*, thiamethoxam 0.008% or imidacloprid 0.01% or acephate 0.10% or quinalphos 0.05% or dimethoate 0.06% at bud burst stage twice at 15 days interval effectively check the pest.

2. Lemon butterfly -*Papilio demoleus* Linn. &*Papilio polytes*L. (Lepidoptera: Papilionidae)

This is a major pest of curry leaf.The caterpillars feed voraciously on tender leaves and defoliate the entire plant leaving behind mid ribs. Management involves with hand picking of various stages of the caterpillars, and foliar application of quinalphos 0.05% or fenvalerate 0.02% or cypermethrin 0.025% against the early larval stages at 10 days interval also helps to reduce the infestation levels. Need based application of NSKE 5% and / or Bacillus thur ingiensis @1kg/ha.is also useful to control

3. Citrus blackfly -*Aleurocanthus woglumi* Ashby(Hemiptera: Aleyrodidae)

Nymphs and adults suck cell sap, and excrete voluminous honey-dew on which sooty mould (*Capnodium* sp.) develops covering entire plant parts due to which photosynthesis is affected.Management of blackfly involves with foliar application of neem oil 1% or azadirachtin 1% @ 3 ml/L or neem soap or pongamia soap @ 5 g/L coinciding with adult emergence, and conservation of the key natural enemies by avoiding application of toxic insecticides If the blackfly incidence is severe,foliar application with imidacloprid 0.009% or acephate 0.09% or dimethoate 0.06% or novaluron 10 EC @ 0.008% at adult emergence and 50% egg hatching stage is useful to reduce the blackfly damage.

3. Tortoise beetle- *Silana farinosa*

Both adult and grub scrap on leaves, boreholes and cause defoliation. Larvae scrape the leaf epidermis by leaving a thin upper membrane. Adults exhibit more severe damage by eating all of the leaves. In areas with heavy infestations, leaves turned yellow and defoliation of the plants. Management:spraying of NSKE 5% or Neemoil@ 1-2 % with sticker.

DRUMSTICK

1. Pod fly - *Gitona distigma*

The pod fly causes drying up of fruits from the tip and splitting of fruits. Maggots enter into tender fruits and feed causing the oozing out of gummy fluid from fruits, which ultimately results in the drying and splitting of fruits from tip upwards. The fruit loss goes up to 70% yield loss. Management involves with theperiodical collection and destruction of all the fallen and damaged fruits; and application of emamectin benzoate 5 SG @ 0.25 g/l or spinosad 45 SC at 0.20 ml/l at 50% flower set and 35 days later spraying ofNSKE5% or Nimbecidine3ml/L water at50 % fruitset and 35 dayslater.

2. Moringa bud worm - *Noorda moringae*

Larvae bore into flower buds and cause shedding of buds up to 75 per cent**.** Management involves with thePloughingaroundtreestoexposeandkillpupae;collectionanddestructionofdamagedbudsalongwithlarvae;settinguplighttrap@1-2/hatoattractandkilladults and need based spray of Azadirachtin 300 ppm @ 5 ml/L water.

5. Leaf caterpillar- *Noorda blitealis*

Larvaeinearlystagesfeedgregariouslyon leaflets, scrapping chlorophyll and reducing them into a papery white appearance. Management involves with theploughing around trees to expose pupae to avian predators; provisioning forsitting arrangement for birds in moringa orchard, collection and destruction offallen and damaged leaves, setting up light trap @ 1-2/ha to attract and kill adult moths andneedbasedspray of Azadirachtin300 ppm@ 5ml/Lwater.

6. Aphids - *Aphis gossypii*& *Aphis craccivora*

Nymphs and adults suck vital sap from tender shoots and leaves. Heavy infestation causes complete shedding of leaves. It causes very serious damage at times. Several coccinellid predators appear and clear the aphids. Spraying of dimethoate0.05% is useful when the aphid incidence is heavy.

7. Spiralling whitefly -*Aleurodicus dispersus*

Nymphs and adults suck the sap from leaves and excrete honeydew on which sooty mold develops thereby interfering with photosynthesis of papaya plants. Severe infestation leads to heavy defoliation of leaves.Chemical control of *A. dispersus* is almost impossible due to its wide host range and heavy wax coating. The aphelinid parasitoid *Encarsia guadeloupae* proves to be highly useful in suppressing the spiralling whitefly.

8. Tea mosquito bug - *Helopeltis antonii*

Adults and nymphs feed on petioles, tender shoots and leaf veins causing necrotic lesions. Application of mineral oil 3 per cent, spraying of *Beauveria bassiana* @ $1x10^9$ spores/ml with suitable adjuvants, lambda cyhalothrin 0.005% and neem formulation @ 2ml/L minimizes damage of *H. antonii*. Yellow colour sticky traps are able to attract large number of adult tea mosquito bugs

9. Hairy caterpillars-*Eupterotemollifera,Olepariciniricini,Metanastriahyrtaca* &*Streblotesiva*

Severe infestation results in complete defoliation of the tree.Management involves with the collection and destruction of egg masses and caterpillars by burning or using strong contact insecticide, setting up of light trap @ 1/ha to attract and kill adults immediately after rain, using the burning torch to kill congregating larvae on the trunk and spraying of fish oil rosin soap @ 25-40 g/L or chlorpyriphos 20 EC or quinalphos 25 EC or azadirachtin 2ml/L or emamectin benzoate 5% 4g/10L or abamectinon the trunks and foliage.

II. PESTS OF UNDERUTILIZED CRUCIFEROUS VEGETABLES

The major insect pests of underutilized cruciferous vegetables**(**Chinese cabbage,Brussels sprout, pak-choi, choy sumand Chinese kale encountered under Indian conditions include mainly Diamond back moth, Cabbage butterflies, cabbage looper *Trichoplusiani*, aphids, beet army worm and the Striped flea beetle.

1. Diamondback moth (DBM) - *Plutella xylostella*

The first instar larvae mine the epidermis of the leaves. Later instar caterpillars feed externally making holes on the leaves. Insect pathogens and botanicals help to conserve the naturally occurring parasitoids and also to control the pest. Application of *Bacillus thuringiensis* (Bt) commercial formulations, the fungal pathogen *Paecilomyces farinosus,* neem seed kernel extract, pulverised neem seed powder extract, neem and pongamia soaps are highly useful to reduce the damage by DBM. If necessary application of cypermethrin, fenvalerate or deltamehrin, flufenoxuron, chlorantraniliprole or chlorfenapyr or flubendiamide, emamectin benzoate, indoxacarb 14.5 Sc@ 0.5ml/litre, spinosad 45 SC @ 0.3ml/litre, is to be given once at primordial initiation (22 days after planting) and repeated twice at 10 days interval.

2. Cabbage butterflies - *Pieris rapae*,*P. brassicae* &*P. canidia*

Young larvae are gregarious. They disperse later and skeletonise the leaves or even bore into heads. Control of the pests is achieved with the application of *Bt* formulations and neem products. This pest management practice also helps to conserve the naturally occurring parasitoids *Cotesia glomeratus* and *Hypersota abeninus* causing 60-80% parasitism

3. Cabbage green semilooper - *Trichoplusia ni*

Young caterpillars feed primarily on leaves and cause irregular holes. Application of *Bacillus thuringiensis* is effective suppression of cabbage looper without disrupting populations of beneficial insects. Spray application with Bt,cypermethrin @ 0.025%or malathion 0.10% is also effective.

4. Aphids - *Brevicoryne brassicae, Liaphiserysimi*&*Myzus persicae*

These aphids suck the plant sap and affect the quality of the head and curds formed. sprayofentomopa thogens,*Beauveriabassiana*@5g/Lor*Lecanicillium* (=*Verticillium*)*lecanii*@ 5 g/L water or NSKE5%. If necessary, application of profenophos 0.05% or dimethoate 30EC @ 2ml /L or acetamiprid 20% SP @ 0.2 gm per litre of water is effective against the aphids.

5. Flea beetles -*Manolete stigmata, Phllotreta chotanica, P. downsei,P. vittata*&*P. cruciferae* and*Chaetocnema basalis*

Adults feed on the cotyledons and first true leaves of seedlings making bite holes and causing severe damage to carrot, turnip, knol khol and radish. Seed treatment with imidacloprid @ 5gm/kg of seed helps to control the flea beetles at the seedling stage. Application of Lambda cyhalothrin 5EC @ 0.5ml/L is effective against the flea beetles.

III. PESTS OF UNDERUTILIZED CUCURBITACEOUSVEGETABLES

Major pests of underutilized cucurbits (Sponge gourd, spine gourd, pointed gourd, snake gourd, ivy gourd, spiny gourd/ sweet gourd, chow- chow, Kakrol/Parwal), Gherkin, Summer squash etc.) include *Epilachna* spp., *Aulacophora foveicollis, Diaphania indica*, *Bemisia tabaci*, *Saisettia coffea*, *Saissetia hemispherica* spiralling whitefly, Cucurbit fruit fly *Bactrocera cucurbitae, Epilachna spp. Aulocophoraspp. Diapahania indica, Aphis spiraecola,*Cucumber Beetles *Acalymmavittatum, Diabrotica undecimpunctata Diabrotica balteata), Melittiacucurbitae* and the leaf miner.

1.Gherkin fruit borer -*Diaphania indica*

It is known to damage a variety of cucurbits. The caterpillars feed on the young succulent leaves, flowers, soft stems and fruits. This damage causes blemishes in the fruit, which downgrades the quality.

Management: Application of NSKE 4%, Bt@ 1 g. or 1ml/ L or Metarzhium*anisopliae* @ $1x10^9$ to $1x10^5$ spores/ml and *Paecilomyces farinosis* at 1 x 10^9 spores/ml are also useful to control the gherkin fruit borer. If the pest incidence is severe, one spray application of quinalphos or chlorpyriphos (0.05%) or indoxacarb (0.4ml/l) is enough to control the borer.

2. Serpentine leaf miner - *Liriomyza trifolii*

The adult female makes punctures in the leaf tissue with its ovipositor for both feeding and oviposition. Maggots are minute orange in colour, and mine the leaf surface. Drying and dropping of leaves are common in severe cases. Natural enemies play a major role in the suppression of leaf miner in gourds. Application of neem formulations (2–3 ml/litre) once in 10–15 days or neem seed kernel extract (4%) once in the early stage of the crop is able to reduce the pest incidence. Spraying of imidacloprid or triazophos, cyantraniliprole is highly useful in controlling the leaf miner.

3.Fruit flies -*Zeugodacus* (*Bactrocera) cucurbitae, Bactrocera ciliates, B. zonata, B. diversa*& *B. latifrons*

The female fruit fly lays the eggs in tender fruit tissues by inserting ovipositor. The maggots feed on the contents of fruits and cause premature dropping of fruits and also make them unfit for consumption. The extent of losses varies from 30 to 100%, depending on the cucurbit species and the season. Fruit infestation by melon fruit fly in bitter gourd goes up to 90 per cent. Integrated Pest Management (IPM) involving collection of infested fruits and burying them deep into the soil, bait sprays consisting of jaggery @ 15 g/L mixed with deltamethrin @ 1 ml/L (@ 40 splashes per acre and deployment of cuelure traps @ 15/acre reduces the fruit damage considerably.

4. Pumpkin beetles- *Raphidopalpa (Aulacophora) foveicollis,A. cincta &A. lewisii*

Adult beetles feed voraciously on the leaves, flowers and fruits. The grubs of this pest remain in the soil and feeds on roots and stem of the plant. Spraying with the quinalphos**,** chlorpyriphos**,** lambda cyhalothrin tolfenpyrad**,** fipronil, indoxacarb, flubendiamide, chlorantraniliprole**,**spinosad and acephate is found effective against the red pumpkin beetle .

5.. Melon thrips- *Thrips palmi*

Thrips feed in groups, particularly along the leaf midrib and veins of older leaves. The nymphs and adults are found moving on young shoot tips. In severe infestation, leaves may become yellow, white or brown and finally dry up. Spraying of 1 per cent neem or pongamia soap or 4 per cent neem Seed kernel extract or pulverized neem seed powder extract reduces the thrips damage. In severe cases, spraying with acephate (0.05%) or fipronil (1.5ml/litre) reduces the pest incidence.

6. Snake gourd semilooper- *Anadevidia* (*Plusia*)*peponis*

It is a specific pest of snake gourd and the larvae defoliate the plants considerably, if infestation is serious. Spray application of malathion 50 EC @500 ml/ha, controls the pest.

7. Stem borer or clear winged moth- *Melittia*spp.

Melittiaeurytion is a pest of snake gourd and occurs widely in India.Caterpillar bores into the stem of snake gourd and gourd causing gall formation and death of vines. The larva of squash vine borer *Militia* *cucurbitae*burrow intro stem of *Cocciniaindica*, and feed within the stem. Management involves with the collection and destruction of the damaged plant parts with larvae and spraying with malathion 0.05%.

1V PESTS OF UNDERUTILIZED LEGUMINOUS VEGETABLES

The major insect pests of underutilized leguminous vegetables (leafy cowpea, Yard-long bean, Hyacinth bean/pink dolichos, Winged bean, Jack bean, Sword bean, Broad bean, Tree bean etc) are Stem fly *Ophiomyia phaseoli*, *Aphis craccivora*, *Emposca terminalis*, *Megalurothrips usitatus,Helicoverpa armigera,Maruca testulalis,Etiella zinckenella*, *Lampides boeticus Myllocerus* spp., and pod bugs (*Clavigralla* spp. and *Nezara viridula*) and *Henosepilachna signatipennis*

1.Aphids -*Aphis craccivora*

Aphid colonies are congregated on growing points of the host plant. Both nymphs and adults suck the sap from young plant parts like shoot tips and inflorescence. Curling and distortion of leaves, stunting and malformation shoots occur. Management involves with spray dimethoate 0.05% or imidaclorpid 17.5 EC @ 0.5ml/litre, or Neem seed kernel seed extract 5%.

2. Pod borers –*Maruca vitrata* &*Etiella zinckenella*

The larva webs together the flowers and feeds on them, and also bores into pods and feeds on the seeds resulting in appreciable loss in yield. Control measures have to be initiated at flower bud stage. Cypermethrin 0.008%, deltamethrin and flubendiamide fortnightly sprays given at flower bud stage are effective against the pod borer.

3. Blue butterflies- *Lampides boeticus* &*Euchrysopscnejus*

Larvae bore into young pods. Control measures have to be taken in the early stages of the pest incidence. The first spray is to be given at flowering as soon as eggs are noticed with cypermethrin,chlorpyriphos, indoxacarb 14.5 SC @ 0.5 ml/l. Weekly sprays of neem seed kernel extract 5% are found to reduce the pest damage.

4. Stem flies–*Ophiomyia phaseoli*&*O. centrocematis*

Larvae mine the leaf lamina, veins, midrib& petiole, and enter the stem. Larval feeding in stem results in mortality or reduction of the growth. Application of neem products isto be the best option for managing the stem fly. Spraying of Neem seed kernel extract 5% (NSKE), pulverized neem seed powder extract, neem seed formulation and neem soap is effective against the stem fly. Application of imdacloprid 80.5 SC 0.6ml/L, chloprpyriphos 0.05%, Thiamethoxam 25 WSG 0.6ml/L and profenophos 2ml/L. are also useful to control the stem fly soil application of phorate 10G @ 10 kg/ha is the most effective in reducing the plant mortality and increasing the crop yield.

V. PESTS OFUNDERUTILIZED SOLANACEOUS VEGETABLES

The most common pests of underutilized solanaceous vegetables (Tree tomato and cherry tomato) are aphids, white flies, fruit flies,cut worms and horn worms..

1. Solenopsismealybug-*Phenacoccussolenopsis*

They suck the cell sap, also secret honey dew on which black sooty moulddevelops and thereby reducing the photosynthetic activity of the plants. Management involves with the removal of alternate hosts,selective destruction of the ants'colonies,uprooting and burning the affected plants, spraying off is hoil resin soap (FORS) @ 20 g/L water or *Lecanicilliumlecanii*@ 2.5 g/L water + Neem oil (0.5%) at 1:1 ratio, need based application of Azadirachtin 300 ppm @ 5 ml/L water or NSKE @ 4%.The parasitoid *Aenasiusarizonensis* is highly useful to control the mealybug.

2. Tomato pinworm- *Tutaabsoluta*

The pest has spread from South America to several parts of Europe, entire Africa and has now entered into to India. The larvae make irregular mines on the leaves and produce larger galleries. The mining larvae feed on the mesophyll tissues by feeding inside the mines. It can cause up to 90% loss of yield. The larvae damage the fruits by causing pin holes affecting the marketability of the fruits. Management involves with mass trapping involving the placement of 30-40 pheromone baited water traps per hectare and application of any one of the following insecticides viz., Chlorantraniliprole 18.5% SC @ 60 ml or Cyantraniliprole 10% OD @ 60 ml or Flubendiamide 20% WG @ 60 ml or Indoxacarb 14.5% SC @ 100ml and the spinosad. Bio-rational insecticides such as *Bacillus thuringiensis,* neem oil @ 3%, and Pungamia oil @ 3%, NSKE @ 5% and Azadirachtin are also useful to check the pinworm damage.

VI. PESTS OF UNDERUTILIZED TUBER CROPS

(Chinese Potato, Yams, Taro, Elephant Foot Yam and Tannia)

CHINESE POTATO

The important pests of Chinese potato Coleus parviflorus include amaranthus caterpillar *Spoladearecurvalis*, leaf folder *Pycnarmoncribrata*, top shoot folder *Phostriapiasusalis*, Bihar hairy caterpillar *Spilosomaobliqua,* tussock caterpillar *Olene mendosa*, black tingid *Cochlochilabullita*, the stem borer *Nupserhavexator* and Mealybug *Geococcuscoffeae*, at times, infest roots and tubers in field. White grub *Leucopholisconeophora* is also reported as a pest of local importance. They feed on the tubers and roots in field.

1 Amaranthus Caterpillar*: Spoladea (=Hymenia) recurvalis*

The caterpillars are found damaging the leaves. They form a silken thread and web and leaves and feed on the leaf within. It feeds on the green matter leaving a thin parchment tissue. Only one caterpillar is noted in a fold. The damage results in reduced leaf area by feeding and due to folding of leaves, which in turn, affects photosynthesis of plants. The pest is very common in Tamil Nadu and west coast area. The larvae are heavily parasitised in nature by parasitoids *Apantelesdelhiensis*and *Cardiochiles* sp.

2. Leaf folder -*Pycnarmon cribrata*

It is an important pest of Chinese potato in south India. The caterpillars of this species also fold the leaves and feed within, similar to *H. recurvalis*. In the field, it is often regulated by a braconid parasite *Microgaster psarae*

3. Top Shoot Folder: *Phostria piasusalis*

The larva folds top shoots and leaves with silken webs and feeds within on the green matter of the leaves. The activity of the pest is more during September–December. It is often regulated by a parasitoid *Leptobatopsisindica*.

2 YAMS (*Dioscorea* spp.)

1. Yam beetles– *Galerucidabicolar,Aplocnemusimpressa* and*Lemalacordairei*

Galerucidabicolar is a pest of regularoccurrence in South India. Adults are red / black beetles. *Aplocnemusimpressa*is found in northern India.It is major pest of *Dioscorea*spp. in Kashmir valley, and is also found along the foot hill region of Himalayas extending up to Assam. Adult feeds on mature leaves by perforating leaf blade. In case of severe incidence of leaf feeding beetles, they can be controlled with malathion (0.05%) or chlorpyriphos (0.05%) spray. Carbofuran 3G (at 47 kg/ha) applied at the time of planting significantly reduces the damage done by the beetle pests.

3. White Grub - *Leucopholisconeophora*

During severe incidence of white grubs, field infestation goes up to 40% and the tuber yield loss goes up to 10%. in greater and lesser yams. The damaged tubers loose the quality and culinary taste. Application of chlorpyrifos is recommended against white grubs and termites.

4. Asian sawfly -*Ansioarthracoerulea*

The larvae cause economicdamageto*D.alata*inthestateofMeghalaya,and also in South India on yams. Eggs are laid on young shoots and leaves. Larvae feed gregariously, and cause extensive defoliation (as much as 90%) leading to significant yield reduction. Entomophylic nematodes *Steinernema corpocapsae* and*Heterorr habditis bacteriophora* arefound to be effective in causing the mortality of larvae of saw fly up to 90%.

5. Yam scale - *Aspidiellahartii*(Hemiptera: Diaspididae)

Nymphs and females infest the basal vines and tubers. The field infestation goes up to 100 per cent. In severe cases of infestation, attacked plants show drying due to continuous sucking the sap.The pest multiplies in the field perpetuating the problem in storage.Tubers can be stored in sand, sawdust, paddy husk and wood ash is found to be effective against the insect pests in storage.For the storage of seed materials, amixture of sand and cypermethrin dust (100:1)isfoundto be the best medium for achieving complete control of the scale insects. Dipping setts of Dioscorea in 0.05% chlorpyriphos solution was effective in controlling the scale insect. Storage of yam tubers at low temperatures (but higher than 12. 8^{C}) significantly retards the development of many pests in storage. Five genotypes of D. alata, Sree Keerthi, Sree Roopa, Sree Shilpa, Sree Karthika and Orissa Elite, are resistant to A. hartii .Two parasitoids Adelencyrtusmoderatus and Physcuscomperi often play significant role in regulating the scale insect population on yam tubers. In India, several genotypes of Dioscoreaalata and D. esculenta were found to be susceptible to

6. Striped mealybug -*Ferrisia virgata*

It is known to attack sweet yam *Dioscoreadumetorum.* During heavy incidence, the leaves dry up and wither and the damage caused the drying of entire plants. The Australian lady bird beetle *Cryptolaemus montrouzieri* is useful to control the mealybugs. Storage of yam tubers at low temperatures (but higher than 12. 8^{C}) significantly retards the development of many pests in storage. Neem-based treatments (oil, seed powder and leaf powder) give the best level of protection of pests in storage. Dipping tubers in chlorpyriphos solution (2.5ml/L) with lime and/or ash also help to control the storage pests.

7. Coffee bean weevil - *Araecerusfasciculatus*

They commonly attack the yams in storage. Damaged tubers become unfit for consumption as well as for seed purpose. The larvae dig tunnels into the tubers, pupate inside them and adults emerge boring a hole. Careful selection of yam heads at planting time and destruction of infested tubers during storage is a prophylactic against yam weevil infestation. Storing the tubers in fine sand, sawdust, paddy husk and wood ash is found to be effective against three insect pests including the coffee Bean Weevil.Deltamethrin used as a spray of 2.5 g active ingredient per 100 litres of water, is found to be effective in controlling weevils in storage. Storage of yam tubers at low temperatures (but higher than 12. 8^{C}) significantly retards the development of many pests in storage. Dipping tubers in chlorpyriphos solution (2.5ml/L) with lime and/or ash also help to control the storage pests. For the storage of seed materials, a mixture of sand and deltamethrin dust (100:1) was found to be the best medium for achieving complete control.

8. Taro horn worm-*Theretraoldenlandiae*

The caterpillars are with black head and greyish brown without pink suffusion and the two dorsal lines on the abdomen are silvery white, terminal horn long and black in colour with yellowish white narrow trip. The caterpillar feed voraciously on the leaves.

AROIDS

(Taro,elephant foot yam and tannia)

1. Aphids

Aphids are important pests of elephant foot yam and taro. They include ***Aphis gossypii and Pentalonianigronervosa***

2. Thrips- *Caliothrips indicus, Heliothripskadaliphilus& H. haemorrhoidalis*

Thrips are important pests of aroids including elephant foot yam. Both nymphs and adults lacerate and suck the sap, causing characteristic silverfish white specks with black dots.

3. Lace wing bug -*Stephanitistypicus*

The lacewing bugis an important pest of taro. They colonize and suck the sap from the lower side of leaves. The feeding causes yellowing of leaf on the upper side. Feeding causes small white spots to appear on the upper leaf surface opposite the feeding site.

4. Tobacco caterpillar - *Spodoptera litura*

It is an important pest of taro and elephant foot yam. They hide during the day time in crevices or among plant residues and become active during dusk to dawn. The damage goes up to 16 to 80 per cent.

5. Hornworms - *Rhyncholabaacteus, Hippotionoldenlandiae, H. celerio, Rhyncholabaacteus, Agrius convolvuli,Theretragnoma, T. pinastrina*&*T.oldenlandiae*

Hornworms are stout and greenish to brown in colour with stripes. Caterpillars feed voraciously the leaves of taro and elephant foot yam. Application of malathion @ 0.05% is useful to control the hornworms.

6. White spotted flea beetle - *Monoleptasignata*

The white spotted beetle is an important pest of on leaves of taro. Adults make large holes in leaves by feeding leaf tissues Eggs are laid in soil cracks around the base of the host plant. Grubs live in the soil and feed on small plant roots and root hairs. Application of chorpyriphos@ 0.05% is useful to control the beetles.

7. Rhizome mealybug - *Rhizoecus amorphophalli*

*Rhizoecus amorphophalli*has emerged as a noxious pest both in storage and in the field of elephant foot yam, taro and tannia. It is recommended to maintain a temperature range between 25^0C to 30^0C in the elephant foot yam storage houses. If the elephant foot yam tubers of storage followed by planting purpose, a two-instalment spray/drench application of imidacloprid spaced 3-4weeks apart gives complete control. Dipping of mealybug infested tubers for 10 minutes in insecticide solutions namely chlorpyriphos/Bufrofezin/ imidacloprid/ thiomethoxam**is** also recommended. CTCRI bioformulations namely "SHREYA" and 'NANMA" are also effective against the pests. Spraying neem oil (2%) at 15 days interval is found effective to reduce the incidence. Salt (NaCl) solution (1000 ppm) is effective in reducing mealybug numbers in the storage. Use of the coccinellid predator *Cryptolaemus montruzieri* along withparasitoid*Anomalicorniatenuicornis* contributes to the successful control of mealybug in storage.

8. **Taro corm borer - *Aplosonyxchalybaeus***

Aplosonyxchalybaeus is a regular and endemic pest causing 20-30% damage to the foliage and 80-90% to the corms, resulting in severe losses to the tribal farmers of in the plains and hill slopes as a rainfed crop during April to September in the North Eastern Hill Region (NEH) of India. The adults consume the leaves by damaging up to 20-30%. The adults make circular holes and the damaged leaves exude milky and waxy latex. The local cultivars with purple or pink colouration on the leaves are less preferred by *A. chalybaeus*. The corms were damaged up to 80-90% in the improved varieties and the local genotypes are found moderately resistant to *A. chalybaeus.* Taro varieties Surya Mukhi and Bk-Col-1 are found promising with less than 20% infestation. Predatory insects are also found attacking the *A. chalybaeus*. An unidentified earwig is found predating on the eggs and young ones of *A. chalybaeus* hiding in the leaf sheath. Natural populations of *A. chalybaeus* are found infected with entomopathogenic fungus *Beauveria bassiana* during June to August.

VII. PESTS OF UNDERUTILIZED AQUATIC VEGETABLES

Few major insect pests of underutilized aquatic vegetables (Water lily,water chestnut, water spinach,lotus etc) enumerated are *Rhopalosiphumnymphaeae*, Singhara beetle, *Galerucellabirmanica* and Tortoise beetle *Cassidacircumdata* .

1. Water lily aphid *Rhopalosiphumnymphaea*e

Large colonies of this aphid were observed to infest many aquatic vegetables including water chestnut, water spinach, lotus, water lily, etc. in and around Varanasi region of Uttar Pradesh, India. Collection and destruction of aphid infested plant parts.

2. Singhara beetle- *Galerucellabirmanica*

This is considered as a serious pest of water chestnut in India. This pest has also been recorded from other States of India *viz*., Madhya Pradesh, Assam, Punjab and Kashmir. The leaves, petioles, and occasionally the fruit's integument serve as food for both the adults and the several grub stages. Grubs cause significantly more damage than adults. Collection and destruction of beetle infested plant parts is to be done. The blue beetle *Halticacyanea*is a minor pest which damages leaves as done by the singharabeetle.

3. Tortoise beetle -*Cassidacircumdata*

Its early instar grubs scrap the chlorophyll part of the leaves resulting skeletonizations of the leaves. Later instars make small irregular shot holes and notches on the leaves. Numerous such small holes occurred on a single leaf. Black excreta were often visible on the upper surface of the leaves. Management involves with the collection and destruction of the grubs, adults and severely infested plant parts is advisable.

Future strategies

- Surveillance is the one of the important tool in pest management. Hence, pest survey and monitoring should be done at weekly interval.
- Use of pheromone, sticky and light traps for monitoring and mass trapping of the pest population to be emphasized.
- Search for the potential biocontrol agents, newer plant origin insecticides and novel biorational molecules with green chemistry to reduce the pesticide contamination in the environment.
- Exclusive bio-pest management practices should be developed for exported oriented underutilized vegetables like curry leaf, drumstick, gherkins etc

57. Role of honey bees in enhancing production and productivity of underutilized vegetable crops

P. V. Rami Reddy

Division of Crop Protection, ICAR-Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru – 560089

Email: pvreddy2011@gmail.com

Introduction

Pollination is an essential ecosystem service and insects play a significant role in sustaining the plant biodiversity and enhancing fruit or seed set of several plant species including wild and cultivated ones. Though agriculture in general is benefitted to a great extent by insect pollination, the proportion of commercially important crops that are essentially dependent on entomophily is very high in horticulture including fruits, vegetables, nuts and spices. Among them vegetable crops including melons, gourds, cole crops, onion, onion, legume vegetables are benefitted to a greater extent by insect pollination (Abrol, 1990; Free, 1993). Approximately 70 % of the world's cultivated crops are pollinated by bees, 10 % by flies, 15 % by other insect groups like wasps, beetles, butterflies and moths and the rest by bats and birds (Abrol, 2009). Of late there has been a realization that the numbers of native pollinator fauna have been dwindling which has been attributed to several factors like loss of habitats, use of dangerous agrochemicals, monoculture, displacements by invasive species, climate change etc. This loss would have significant adverse effect on the biodiversity in general and horticultural production in particular. According to an estimate, inadequate pollination would translate into more than 50% reduction in fruit and vegetable production and the loss would be hundred per cent in case of monoecious crops like cucurbits. In this Chapter, attempt has been made to precisely compile the information on the diversity of insect pollinators associated with different vegetable crops with emphasis on underutilized ones and their role in enhancing productivity in terms of quality and quantity.

Cucurbitaceous vegetables

The cucurbitaceous family comprises vine-crops such as cucumber, ridge gourd, bitter gourd, bottle gourd, pumpkin, water melon, musk melon etc. All melons and gourds are monoecious in nature and hence cross pollination is mandatory. In addition, pollen grains are sticky and heavy to be carried by wind, so these crops depend mainly on insects for pollination.

Bottle gourd, (*Lagenaria siceraria)*

Bottle gourd flowers start opening in the evening time, so there are more chances for nocturnal flower visitors. Shrivastava and Shrivastava (1991) studied on bottle gourd (L. siceraria) crop and revealed that flower visitors mainly recorded during night time included lepidopterans and coleopterans. Sihag (1990) found *Xylocopa fenestrate* as a good pollinator of bottle gourd. Bottle gourd flowers are also pollinated by the bug, *Cyrtopeltis tenuis*, sphingid moths, the beetle *Epilachna punctata* and pyralid moths (Shrivastava, 1990).

Since bottle gourd flowers open in the late evening, they are more prone to be foraged by nocturnal insects, mainly lepidopterans including sphingid/hawk moths, pyralids, pierids followed by coleopterans, hymenopterans, orthopterans and dictyopterans. A total of ten insect species belonging to nine families of five Orders was recorded from the bottle gourd flowers. The lepidopterans were the major floral visitors comprising of six species viz., *Arthoscista hilarialis* from Pyralidae and *Diaphania indica* from Crambidae, *Hippotion celerio* from Sphingidae, *Delias eucharis* and *Pieris brassicae* from Pieridae and *Anadevidia peponis* from Noctuidae. These were followed by hymenopteran viz., *Oecophylla smaragdina* (Formicidae), coleopteran, *Aulacophora foevicollis* (Chrysomelidae), orthopteran, *Hieroglyphus banian* and dictyopteran viz., *Mantis religiosa* L. (Subhakar and Sreedevi, 2015).

Ridge gourd (*Luffa* sp.)

Ridge gourd flowers also bloom at late evenings like bottle gourd flowers hence, the composition of flower visitors was more or less similar to bottle gourd as in both the cases, nocturnal visitors plays major role than diurnal visitors. Ramesh (2007) reported that the ridge gourd flowers were visited by twenty one species of insect pollinators, of which twelve species belonged to Order Hymenoptera, four to Diptera, three to Coleoptera and two to Lepidoptera. Honey bee species *viz*., *Apis cerana, A. florea* and *A. dorsata* constituted more than 78 per cent of the total insect Pollinators.

In Andhra Pradesh, lepidopterans were recorded to be the major floral visitors of ridge gourd comprising of six species viz*., Diaphania indica* and *Glyphodes bivitralis* from Crambidae, *Hippotion celerio* from Sphingidae, *Delias eucharis* and *Pieris brassicae* from Pieridae (Subhakar and Sreedevi., 2015). In Karnataka, ridge gourd flowers were visited by thirty three species of insect pollinators, of which, 22 species belonged to Order Hymenoptera, five to Diptera, four to Coleoptera and two to Lepidoptera. The time spent for nectar and pollen foraging by *A. cerana, A. florea* and *T. iridipennis* was maximum at 0900 and 1100 h of the day. Eight bee visits per flower significantly influenced the quantitative parameters such as fruit set, fruit weight, fruit volume, fruit length and number of sound seeds per fruit. Honey bee pollination had shown positive impact on both quantitative and qualitative traits of fruits (Lakshmi and Kuberappa., 2015).

Pointed Gourd, *Trichosanthes dioica* Roxb.

Anthesis commences between 7:00 and 19:00 and continues up to 21:00. Pollen viability is quite high (ca. 98%) at anthesis but gradually declines to zero 54 h after anthesis. In contrast, the stigma remains receptive up to24 hours after anthesis. Pollen grains are sticky and are not suitable for wind pollination. Under natural open pollination, fruit set is low, mainly due to poor pollination (Pathak and Singh 1950), but fruit set can be increased by hand pollination.

Field studies conducted by Das et al. (2009), the beetle, *Haptoncus sp.* (Nitidulidae: Coleoptera) was the major pollinator on pointed gourd. Interestingly the pestiferous pumpkin beetles (*Aulacophora foveicollis* Lucas and *A. lewesi* Baly), epilachna beetle *(Epilachna dodecastigma* Wied. and flea beetle *(Monolepta signata* O.) were also found to play some role in pollen transfer. Larger and heavier fruits were produced as a result of artificial pollination. Water droplet pollination resulted in 25.7, 26.84 and 76.57% increase in the length, circumference and weight of fruits than the natural pollination as against 14.04, 16.29 and 40.29% in hand pollination.

Cucumber (*Cucumis sativus*)

More than 25 species of insects are reported to forage on cucumber flowers of which two-thirds belonged to Hymenoptera and rest to Diptera, Lepidoptera and Coleoptera. Among insect pollinators, *A. dorsata*, *A. cerana*, *A. florea* and *T. iridipennis* comprised more than 82.00 per cent of the total insect pollinators of cucumber crop (Prakash, 2002; Sajjanar *et al.*,2004). The peak foraging activity of *A. cerana* was observed during 0800 to 0900 hours of the day. Cervancia and Bergonia (1989) reported that *Xylocopa chlorina, Xylocopa philippinensis*, *Megachile atrata* and *A. dorsata* were the frequent visitors of cucumber flowers in Philippines.

Rana *et al*. (2006) showed that there was significant increase in the seed weight over open pollination. The cucumber crop pollinated by *A. cerana* enhanced 25.21% and 48.6% higher fruit yield than self-pollinated and pollinated by natural insects, respectively and recommended seven *A. cerana* colonies per ha for optimum yield. Islam and Deka (2009) recorded the maximum fruit yield (74 t/ha) of cucumber with five colonies of *A. cerana* per hectare compared to plots without bee colonies (24 t/ha).

Apis cerana foraging on bottle gourd flower

Apis cerana foraging on pumpkin flower

Carpenter bee on Moringa flowers

Apis cerana on coriander flowers

Fig.1. Pollinators foraging on certain vegetable crop flowers

Cole crops (Cabbage, cauliflower, radish etc.)

In cole crops, though economic yield is constituted by vegetative parts like leaves and underground bulbs, pollination is essential for seed production. They are highly cross pollinated and are fully dependent on insect pollinators. Honey bee, *A. cerana* is a major pollinator of cauliflower seed crop. Open pollination is found to significantly increased seed set, seed weight and yield over exclusion of insect pollinators

(Gupta and Sharma, 1996). Similarly in case of carrot both *Apis mellifera* and *A. cerana* are the main visitors and an intensive bee pollination under caged conditions reported to have enhanced seed yield by 60-74% (Jhajj *et al*., 1996). In case of radish, all the *Apis* species are found to be foragers and there was 84.5% increase in the seed yield in the bee pollinated crop over 22.49% in the pollination exclusion (Brar *et al.*, 2010).

Yield enhancement due to bee pollination was also reported from fenugreek. Honey bee pollination resulted in highest number of pods and seeds (13.38/pod) and seed yield (1194 kg/ha) (Thakur and Kumaranag, 2016).

Table 1. Impact of honeybee (*Apis cerana*) pollination on seed yield of certain cruciferous vegetable crops

Crop	Increase in pod setting (%)	Increase in seed setting (%)	Increase in seed weight (%)
Cabbage	28	35	40
Cauliflower	24	24	37
Radish	23	24	34
Indian mustard	11	14	1`7
Lettuce	12	21	9

(Source: Verma and Pratap, 1993)

Coriander (*Coriandrum sativum*)

The coriander flowers are hermaphrodite and protandrous where pollen release precedes stigma receptivity, so pollen from a different flower is required for seed set. According to several reports, the flowers of coriander attract many groups of insects like Diptera, Coleoptera and Hymenoptera. But among all, honey bees are major pollinators of coriander grown for seed production. Abrol (1985) reported two non Apis bee species viz., Nomoides sp. And Xylocopa fenestrate pollinating coriander. Rahman (2016) found significant increase in seed yield when *Apis cerana* was introduced @ 5 hives per acre. An increase of 29.70% seed yield was recorded from Coriandrum plots pollinated by honeybees over control evidently proving that visits of honeybees at flowering time have contributed in increasing seed yield and yield related components of Coriandrum sativum (Tesfaye *et al.,* 2020).

Moringa (*Moringa oleifera*)

The *Moringa* or drumstick flowers are white to cream coloured, zygomorphic and gullet type. Both geitonogamous and xenogamous pollinations produce fruit, but the latter mode is superior. They open during 03.00-19.00 h, and are visited only by diurnally active insects. Bees are the dominant foragers, of which Xylocopa and Amegilla carry pollen on the head and/or thorax to effect nototribic pollination. Xylocopa was more frequent and proved to be the major pollinator (Jyothi et al.,1990). Sowmiya *et al*. (2018) observed about 27pollinator species in a moringa orchard in Tamil Nādu, comprising Hymenopteran(13species), Dipteran (7 species), and Lepidopteran (7species). The most abundant hymenopteran pollinator was *Apis cerana indica* F., followed by *Amegilla zonata* L. and *Apis dorsata* F.

Srinivasan *et al*. (2021) recorded eight species of hymenopterans, three lepidopterans and one dipteran species on the moringa flowers. The yield parameters viz., fruit length (64.4 cm) and weight (113 g) were significantly higher when four bee colonies per acre were introduced compared to 57.4 cm length and 104 g in control. The treatment with pollinator exclusion recorded significantly lower yield.

Conservation of pollinators

The following measures will be of great help to conserve and sustain the pollinator populations in horticultural ecosystems (FAO, 2009).

- Providing sufficient flora for off-season sustenance of pollinators
- Protecting and conserving nest sites of natural pollinators
- Ensuring connectivity of natural habitats in farming areas, so that bees can more easily disperse and make needed range shifts in response to changing climates.
- Providing more non-crop flowering resources in fields, such as cover crops, strip crops or hedgerows.
- Avoiding insecticide applications during blossom period.
- Spreading the awareness among growers on the importance of pollinator conservation

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58. Developments and prospects in imperative underexploited vegetable legumes breeding with special reference to biotic and abiotic stresses

N. Rai* and Rakesh K Dubey
Division of Vegetable Improvement
ICAR-Indian Institute of Vegetable Research, Varanasi-221305
*Email: nrai1964@gmail.com

Introduction

The term underexploited/underutilized crop refers to the group of cultivated and wild species that have limited global market potential and are sometimes deemed as under-used. Globally, underexploited legumes are known as nutritious resources and can be intended to improve health and minimize disease risks. They have a specific profile with high nutrient and protein content alternatives to maintain farmers' livelihoods and soil protection. Moreover, legumes are characterized by their ability to develop in a symbiotic relationship with nitrogen-fixing bacteria and therefore are also used as soil-enriching green manure. There are many underexploited species of vegetable legumes which are available as local accessions and landraces and are being consumed as vegetables. So, these accessions are the valuable genetic variability basket from which we can extract the traits of interest for the improvement of vegetable legumes. Traits like high yield, early podding, year-round availability, long and large green pods, better shelf life and biotic and abiotic stress resistance are among the most desired characteristics in the vegetable legume breeding programmes. There are currently about 150 cultivated crops, and only 30 edible species are often used for global diets, the majority of which are cereal-based, and which in developing countries rely especially on rainfed agriculture. Almost all of these crops cannot withstand abiotic stresses due to global climate change. However, underexploited legumes have tremendous potential to withstand harsh conditions that cannot be ignored, which will help in mitigating nutritional insecurity. Over the past decade, it has been seen that cultivated legumes having a narrow genetic base and continuous use of a few elite breeding lines are the key causes affecting genetic improvement in breeding programs. To fulfill the needs of plant-based micronutrients and rejuvenation of soil health, breeding programs need to adopt a new approach. Crop wild relatives have become an ideal source of novel alleles for a range of important traits needed for improvement in breeding programs. In this regard, recently, in a pigeon pea breeding program utilizing wild *Cajanus platycarpus* sp., a stable promising trait-specific introgression line (IL) CPL 87119 has been identified. It showed higher potential for yield and nutrient-rich traits with a broad genetic base. Efforts are required in this direction to increase the quality of other underexploited legumes. In recent years, advances in next-generation sequencing (NGS) methods and a steep decrease in sequencing cost offers an incredible opportunity for the improvement of vegetable legumes.

Distribution and importance of underutilized legume vegetables

Many Indian legume species (62 %) contribute to the food and health security of ethnic communities. Lesser-known legume vegetables viz., *Psophocarpus tetragonolobus*, *Mucuna pruriens*, *Canavalia ensiformis*, *C. gladiata*, *Parkia roxburghii*, *Vicia faba*, *Vigna umbellata*, *Vigna unguiculata*, *Vigna unguiculata* var. sesquipedalis are becoming popular considering their nutritional and pharmaceutical importance and other underutilized legumes which have tremendous potential need to be provided more attention. Important wild relatives of cultivated legumes and underutilized legumes distribution in various phyto-geographical zones of Bharat are given in Table 1. Genetic variation in these legumes and their wild relatives is of prime importance for the successful breeding of improved cultivar with added value and desirable resistance of diseases and pest in the light of climate change.

Table 1. Distribution of select underutilized/wild legume diversity in different agro-ecological regions of Bharat

Agro-ecological region	Geographical range	Variability in legumes
Humid Western Himalayan Region	Jammu and Kashmir, Himachal Pradesh and parts of Uttrakhand	*Peas, cowpeas, Common bean, Cicer microphyllum, C. macranthum, Flemingia procumbens, F. strobilifera, Indigofera cedrorum, I. dosua var. simlensis I. gangetica, I. himalayensis Lathyrus aphaca, Moghania vestita, Mucuna capitata, M. pruriens, Trigonella balance, T. emodi, T. gracilis, T. cachemeriana, T. podperae, T. monantha, T. upendrae, Vicia benthamina, V. faba, Vigna capensis, V. radiata var. sublobata, V. umbellate, V. vexillata var* vexillata.
Humid Bengal Assam Basin	West Bengal and Assam	*Indian bean, Butea monosperma, Vigna aconitifolia, V. trilobata, V. dalzelliana, Trigonella occulta, Lathyrus aphaca.*
Humid Eastern Himalayan region and Bay islands	Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya and Andaman and Nicobar Islands	*Cicer soongaricum, Moghania vestita, Mucuna bracteata, Parkia roxburghii, Pueraria thomsonii, Vigna capensis, V. umbellata, V. pilosa Trigonella corniculata, T. polycerata, T. occulta, Lathyrus aphaca, Vicia sativa, Vigna aconitifolia, V. radiata var.* sublobata.
Sub-humid Sutlej Ganga Alluvial Plains	Punjab, Uttar Pradesh and Bihar	*Peas, Pueraria phaseoloides, Trigonella corniculata, T. polycerata, T. occulta, Lathyrus aphaca, Vicia sativa, Vigna aconitifolia, V. radiata var.* sublobata
Humid Eastern and South Eastern uplands	East Madhya Pradesh, Chattisgarh, Odisha and Andhra Pradesh	*Atylosia cajanifolia, Butea monosperma, Canavalia spp., Crotolaria longipes, C. perfoliata, Dolichos purpureus-lignosus types, Mucuna bracteata, M. pruriens, Psophocarpus tetragonolobus, Pueraria tuberose, Rhyncosia minima, Vigna bourneae, V. radiata var. Sublobata, V. capensis, V. trilobata, V. aconitifolia, V. unguiculata var.* sesquipedalis.
Arid Western Plains	Haryana, Rajasthan and Gujarat	*Vigna trilobata, V. mungo var.* sylvestris *V. khandalensis.*
Semi-Arid lava Plateau and Central Highlands	Maharashtra and parts of Madhya Pradesh	*Vigna hainiana, V. Trilobata, V. unguiculata*

Humid to Semi-Arid Western Ghats and Karnataka Plateau	Karnataka, Tamil Nadu, Kerala and Lakshadweep Islands	*Butea monosperma, Canavalia ensiformis var.* virosa, *C. obtusifolia, Dolichos uniflorus, D. bracteatus, Mucuna pruriens, M. minima, Moghania tuberosa, Tamarindus indica, V. radiata var. Sublobata, V. capensis, V. pilosa, V. umbellata, V. dalzelliana, V. mungo var. Sylvestris, V. grandis, V. radiata var. setulosa, V. vexillata, Cajanus lineatus, Canavalia spp., Dolichos bracteatus.*

Crop wild relatives (CWRs)

Comprehending the relationship of crop plants and their wild relatives is a tremendous focus of plant breeders. This expertise is of excellent worth in dissecting the process of crop domestication by determining and employing wild relatives for crop development. Breeding programmes, as well as germplasm characterization research, over the years have discovered that the cultivated plants, generally, have a relatively reduced tolerance to stresses compared to their wild relatives. The one-dimensional prospect for enhanced yield has been hypothesized to guide metabolic supply allocation in the direction of accelerated progress, thereby overlooking other traits. On the other hand, breeding bottlenecks have relatively reduced inherited deviation of contemporary vegetation as well as led to the loss of genes created by crop wild relatives. Although genes are identified for disease and insect pest resistance, they have been seen as negatively correlated with yield. However, it has been discovered that breeding for disease and insect pest resistance traits might be attained without having the demand for crop yield compromised. CWRs present several arrays of attributes with the chance to minimize the amount of yield loss as a direct result of biotic and abiotic stresses. The traits present in the CWRs can be introduced into cultivated varieties using conventional breeding approaches (if there is sexual compatibility), transgenesis, and more. In this direction, introgression of characteristics of interest originating out of CWRs to a cultivated type via consistent breeding would encounter linkage drag.

Strategies for Promotion of underutilized legume genetic resources

Precise evaluation and documentation of legume genetic resources is pre-requisite for their utilization. The following areas of research need to be paid more attention for promoting effective utilization of legume gene resources:

- Focused Identification of Germplasm Strategy
- Pre-breeding
- Gene prospecting and allele mining for a trait of interest from genetic resources.

The development of core set of collection particularly in the crops having large germplasm collection can be a powerful tool for promoting utilization of germplasm. This cost effective approach needs to be implemented for legumes. An alternative approach to core collection is the Focused Identification of Germplasm Strategy (FIGS). The underlying concept of FIGS is the ‘‘*distribution of genetic variation as a function of the relationship between genotype, environment and conscious or un-conscious selection-evolutionary processes*’. Pre-breeding of underutilized legume genetic resources aims *“to introduce new desirable traits/genes into an adapted genetic background. It will broaden the genetic base in a breeding material in pace with environmental changes”*. It is a vital contribution is increasing the total genetic diversity in crops and finding specific genes and traits and a link between conservation of PGR in gene bank collections and utilization of these resources in vegetable crops. The most efficient way to capture specific traits - often rare alleles to enhance utilization of existing genetic variation through biotechnological interventions is gene prospecting and allele mining. These procedures are some of the promising ways to promote effective utilization of legume genetic resources in improvement of underexploited legume vegetable crops.

Molecular markers from diversity to QTLs

The directed evolution towards the improvement of existing germplasm requires tracking the desired traits to bring them together. Earlier, the phenotype served as a tracker of traits which is now replaced by more reliable DNA markers. The complete bouquet of genes, quantitative trait loci (QTLs), and molecular markers linked to traits are put together for reliable marker-assisted breeding. The advancement in marker technology is slower in legumes, particularly for vegetable type than cereals, earning them the title of orphan crops. In the evolutionary line of molecular markers, the first generation markers, namely, restriction fragment length polymorphism (RFLP), random amplification of polymorphic DNA (RAPD), and amplified fragment length polymorphism (AFLP), generating information of many loci in one go, have been employed mainly in diversity analysis of pigeon pea, cluster bean, winged bean, dolichos bean, and cowpea. On the other hand, sequence-based markers, namely, simple sequence repeats (SSRs), single nucleotide polymorphism (SNPs), and their modifications, being more reliable and reproducible, are employed in linkage mapping, trait mapping, and fine-mapping studies. SSR marker systems are available in pigeon pea, cluster bean, winged bean, and cowpea, whereas inter-species SSRs have been used in dolichos bean. SNPs are markers of choice owing to their ubiquitous nature and abundance in the genome. SNPs have been identified in pigeon pea, cluster bean, winged bean, dolichos bean, and cowpea for potent use in genomics assisted breeding. Once the choice of marker system is established, it draws a path for mapping traits of interest leading towards fine mapping and cloning. A selected set of mapped QTLs in pigeon pea and cowpea being comparatively rich in molecular resources along with important marker systems in cluster bean, winged bean, and dolichos bean, which are growing towards mapping. studies are compiled.The pigeon pea crop has a rich set of molecular markers and QTLs for its improvement. Dense molecular linkage maps have been developed using SSR markers and SNP markers. A consensus genetic map was developed using previously published maps and four maps generated from four mapping populations. The consensus map comprised 339 SSRs spanning over a genetic distance of 1059 cM. The consensus map is available, but traits of vegetable pigeon pea such as pod color, pod size, pod weight, and tenderness remained undiscovered on a genomic scale. The SSR and SNP markers can be used for reducing generations for obtaining desired recombinants through marker-assisted backcross breeding and de novo mapping studies. The QTLs mapped in pigeon pea can be transferred to vegetable types such as sterility mosaic resistance, determinacy, earliness, Fusarium wilt resistance and fertility restoration. Three QTLs, namely, qFW11.1, qFW11.2, and qFW11.3 for Fusarium wilt resistance and a candidate gene CcLG11 for sterility mosaic virus were mapped which can serve as potent resistance donors. The development of an efficient marker system is slower in cluster bean, ultimately reducing growth in revealing genetic control of loci across the genome. The orphan crop gained the focus of breeders mainly due to gum produced by it which is useful commercially in textile and other allied industries. Thus, its use as a vegetable crop remained shadowed. However, the advancements in marker technology over the years could be utilized in the improvement of the crop for vegetable purpose. In future, marker development studies in vegetable legumes would need to be explored to generate genomic resources and genic markers as has been done in other crops. Winged bean is a neglected crop in terms of genomic resources and molecular breeding. Molecular characterization was attempted for 24 accessions of winged bean using 13 RAPD and 7 ISSR markers. It was found that ISSR markers were more promising in comparison with RAPD markers. There is still plenty of scope for development of saturated linkage maps of SSR and SNP markers for the improvement of cluster bean.

Genomic and transcriptomic resources

Breeding objectives for crops, including vegetable legumes, are constant over the years but approaches towards achieving the goals are ever-changing. The availability of genomic and transcriptomic resources has changed the ways of shaping genomes and creating innovative possibilities to alter the genome for the desired phenotype. The era of genomics was revolutionary for legumes by sequencing of model legume species such as Glycine max which served as the legume genome reference. The dissection of sequenced genomes of model plants aids the understanding of evolution, important gene families, and re-arrangements in the structure of chromosomes in related crops. Pigeon pea genome, dolichos bean and cowpea have been sequenced providing insights into agriculturally essential genes. The sequenced genomes of legumes and the model species would accelerate genomic advancements through comparative genomics in cluster bean, dolichos bean and winged bean. Resequencing of wild and cultivated germplasm in various crops has been initiated to get closer to genes underlying essential traits. One of the cost-effective resequencing or de novo sequencing strategy is the reduced representation library approach . One of the widely used dimensions of this technology is genotyping by sequencing (GBS); GBS has been used for mapping the traits of interest by deep sequencing of parents and multiplexed sequencing of large mapping populations in one go. Fusarium wilt resistance and fertility restoration was mapped in pigeon pea, and poty virus resistance mapping and mapping aphid resistance in cowpea, using GBS. The technology has enormous potential in mapping and genomic studies of cluster bean, winged bean, and dolichos bean owing to lack of genomic tools, as the platform is flexible. Developed chips can also be employed in the winged bean, cluster bean, dolichos bean, and other orphan legumes for testing their suitability for molecular studies. Adopting such genomics and transcriptomic methods could overcome several limitations of traditional breeding and improve the precision and efficiency of crop breeding procedures.

Transgenics and genome editing

Plant breeding offers extensive opportunities for the creation of desirable variation through hybridization and mutation. The scale of hybridization is limited, and the transfer of genomic information is impossible across reproductively incompatible genotypes by conventional techniques. Genetic engineering serves the purpose of transferring alien genes across species which otherwise are not feasible through conventional breeding. The routinely employed transformation technique in legumes is Agrobacterium-mediated gene transfer owing to their dicot nature. The major bottleneck in legume transgenic is the regeneration of explants due to their recalcitrant nature. Among various explants, the use of young embryonic axes, cotyledonary nodes, and immature tissues and preconditioning of seedling with thidiazuron have proved successful recovery. A few selected examples of economically important traits integrated into legume genome include, rice chitinase pigeonpea, dhdps-r1 (increased lysine) pigeon pea, P5CSF129A (salt-tolerant) pigeon pea, cry1Ac pigeon pea , cry1AcF pigeon pea, cry1AcF dolichos bean, aAI-1 (insect resistant) cowpea, cry1Ab cowpea, and soybean isoflavone synthase gene in cowpea. On the other hand, there are no reports of the transformation of cluster bean and winged bean for economically important traits in the context of vegetable type characteristics. In winged bean, successful organogenesis has been obtained from callus derived from cotyledons, epicotyls, excised segments of leaf, and protoplasts. Further, in cluster bean, cotyledonary nodes, cotyledons, hypocotyls, and epicotyls have reported successful regeneration. In view of available protocols for transformation and improvement, cluster bean and winged bean can be exploited for genetic engineering for useful, economical traits such as biotic and abiotic resistance genes, quality traits, yield-enhancing genes, and growth habit controlling genes. One of the promising techniques of post-transcriptional gene silencing is RNA interference (RNAi) in which ds-RNA molecules prevent gene expression, conferring resistance to pathogenic nucleic acids and regulating the expression of protein translating mRNAs. This technology has emerged as a promising technique in plants to fight against invading pathogenic viruses. The host plant is engineered to express ds-RNA, which inhibits expression of the complementary gene in pathogens. RNAi is a potent technology for insect resistance in legumes through silencing genes essential for insect survival. In tobacco, RNAi mediated gene silencing was achieved against *Helicoverpa armigera* through vector construct carrying HaAce1 gene (*H. armigera* acetylcholinesterase) in the backbone of HaAce1-preamiRNA1 from Arabidopsis controlled by CaMV 35S promoter against H.a armigera. With the availability of cloned sequences of insect and pathogen genes, a similar approach can be employed in vegetable legumes for insect and pathogen resistance. Genome editing is emerging as a widely adopted targeted approach and does not fall under the category of genetically engineered crops. Genome editing can be accomplished by site-specific double-strand breaks in DNA caused by homing endonucleases (HEs), zinc finger nucleases (ZFNs), (TALENs), and clustered regularly interspaced short palindromic repeat and CRISPR-associated protein (CRISPR-Cas type II). The CRISPR-Cas system is ready to be exploited in legumes for desirable mutations in the gene of interest with optimization of the protocol in model species Arabidopsis and Nicotiana benthamiana. The pea early browning virus was used as a delivery system of Cas 9 and guide RNA in model species, and this virus is known to cause disease in 30 species along with the members of family Leguminosae. Therefore, the same virus can be engineered for legume vegetables to express desirable guide RNA sequence homologous to the site to be mutated. In future, using genome editing methods will lead to the development of non-genetically modified crops, with desired traits.

Germplasm enhancement

Germplasm enhancement of underutilized legume genetic resources has not received much attention so far because it is a difficult and strenuous long-term task. But it needs major emphasis so as to bring more diverse genes together in legume varieties. Specific programmes will have to be developed for evaluation and enhancement of wild and weedy relatives of legumes so as to make them usable by plant breeders.

Table 2. Regions identified for in situ conservation of wild legume genetic resources in India

Region	Species
Western Ghats	*Canavalia spp., Vigna spp.*
Eastern Ghats	*Atylosia spp., Mucuna spp., Vigna spp.*
Western Himalayas	*Vigna umbellata*
Eastern Himalayas and NE India	*Mucuna bracteata, Vigna pilosa,* *V.capensis, V. radiata var. sublobata*

National genomic resources repository

Indian Council of Agricultural Research (ICAR) has established National genomic resources repository in the premises of NBPGR as an institutional framework for methodical and centralized efforts to collect, generate, conserve and distribute genomic resources for agricultural research. Current research (including underutilized legumes) (both routine cloning experiments and genome sequencing projects) generates a lot of genomic resources. These genomic resources are indispensable tools for post-genomic research, be it physiological and morphological characterization of a species or functional analysis of genes or comparative genomics or plant breeding. Therefore, it is necessary to maintain an efficient system for conservation and management of spin-off DNA materials. Due to the availability of techniques that help characterize and utilize DNA sequences (without the requirement of whole organism), value added products of gene banks can attract new clients involved in allele-mining and cisgenesis, such as molecular biologists and geneticists alongside the traditional plant breeders. Genomic resources such as cloning vectors, expression vectors, binary vectors, RFLP probes, Cloned genes, promoters fused to reporter genes, Sub-genomic, cDNA, EST, repeat enriched libraries, BAC, YAC, PAC clone set from sequencing projects, Genomic, mitochondrial or chloroplast DNA, Cloned DNA from wild and weedy species produced exclusively for the repository can be stored in the repository.

Use of exogenous protectants in mitigating abiotic stresses

Plant growth regulators serve dual function in plant that offers one of the ways to cope with climatic adversities and are also involve in the regulation of plant growth, developmental and signalling processes. In recent decades, exogenous applications of various plant growth regulators (SA; salicylic acid, ABA; abscisic acid and JA; Jasmonic acid), osmo-protectants (Pro; proline and GB; glycine betaine), signalling molecules (SNP; sodium nitroprusside) have shown to have constructive effect on plant growth as these molecules play significant role in mitigating abiotic stress induced oxidative damages in plants.

Some potential underexploited legume vegetables

Vegetable pigeon pea (*Cajanus cajan* L.)

Vegetable pigeon pea possesses favorable agronomic qualities compared to other main grain legumes, and its wild relatives show promise in providing vital adaptive traits. Higher investment in phenotypic and genotypic characterization and evaluation for the adaptive traits present in the CWR, symbolize equally immediate steps for the improvement of vegetable pigeon pea. Additional unrepresented species like *Cajanus crassus* and *Cajanus scarabaeoides*, are essential for developing germplasm collections for the improvement of important traits of the cultivated pigeon pea. As strategies for the effective utilization of extensive diversity of plant genetic resources, conservation, collection and accessibility of even more distant relatives of vegetable pigeon pea will be rewarding. In this direction, *C. scarabaeoides*, as well as *C. platycarpus*, are recognized as demonstrating potential related to the adaptation to climatic change.

Cluster bean (*Cyamopsis tetragonoloba* L.)

The genus *Cyamopsis* has four important members, *C. tetragonoloba*, *Cyamopsis serrata*, *Cyamopsis senegalensis*, and *Cyamopsis dentata*. It has been accepted that the cultivated *C. tetragonoloba* was developed from *C. senegalensis*, which is a drought tolerant African species. Breeding programs are mainly focused on breeding for high nutrition and dietary fiber, but also for improving the gum content (galactomannans) in the endosperm (90%). Wild relatives *C. serrata*, *C. senegalensis,* and *C. tetragonoloba* are diploid with chromosome number $2n = 2x = 14$. Recently genome size was determined for the three

Cyamopsis species with the help of flow cytometry. It was observed that the genome size of wild species, *C. serrata*, was approximately double (979.6 Mbp) that of cultivated cluster bean *C. tetragonoloba* (580.9 Mbp) whereas *C. senegalensis* (943.4 Mbp) had genome size intermediate between these two species. This information is critical to further implement specific tools for crossing wild relatives, which are the storehouse of many useful genes.

Winged Bean (*Psophocarpus tetragonolobus* L.)

Winged bean is rich in protein (2.5 -3.26 % in green pods, 29.8–37.4 % in seeds, 15.9% in tubers) and oil, and has potential as a multipurpose crop. The immature pods, leaves, young sprouts and flowers are consumed as a vegetable or in soups, seed oil is used for cooking and the oil cake as animal feed. Protein in seeds is comparable with that of soybeans in digestibility. Seeds are rich in the antioxidant, tocopherol, which improves human utilization of vitamin A, often deficient in the tropics. In India, its cultivation is confined to humid, subtropical parts of the north-eastern region, Bengal, Bihar, Western Ghats. The crop can be grown in a range of soil types and is found typically on well drained acid soils (pH 4.3–7.5). It is reported to tolerate annual precipitation of 70–410 cm and annual mean temperature of 15.4–27.5°C. Characterization and evaluation of 266 accessions of winged bean done at ICAR-IIVR, Varanasi and considerable variability for different yield attributes were observed and one variety namely Kashi Annapurna was released and notified for commercial cultivation, and the information has been catalogued. Identifying the true progenitor(s) may assist in the breeding of winged bean and could be necessary to understand the genetic changes associated with domestication. Relatively few studies have investigated the domestication genetics of legumes, except for scientific studies of the winged bean. Therefore, little is known about the genes as well as alleles that were under selection by early farmers. This may contribute to the observation that genetic enhancement of legumes remains slow between distant relative and other crops.

Dolichos bean (*Lablab purpureus* L**.)**

Indian bean or hyacinth bean (*Dolichos lablab* L.or *Lablab purpureus* L.) is a twining herbaceous crop legume with 2n = 22 chromosomes belonging to family Fabaceae which is being maneuverer for various purposes such as a green vegetable, pulse, soil improvement and protection, forage and weed control (Rai et al. 2016). The nutritional composition of hyacinth bean pods varies greatly depending upon the genotypes and pod maturity stages. In general, 100 g of mature green pods contain 86.1 g moisture, 3.8 g protein, 0.7 g fat, 0.9 g minerals, 1.8 g fibre, 6.7 g carbohydrates, 34 mg magnesium, 68 mg phosphorus, 55.4 mg sodium, 0.13 mg copper, 210 mg calcium, 74 mg potassium, 1.7 mg iron, 40 mg sulphur, 0.06 mg riboflavin, 1 mg oxalic acid, 0.7 mg nicotinic acid, 0.1 mg thiamine, 312 I.U. vitamin A and 9 mg vitamin C. ICAR-IIVR, Varanasi has taken led in breeding of Indian bean and accordingly many varieties as pole type and bush type developed and release & notified for commercial cultivation across the country. Varieties Kashi Haritima and Kashi Khushal are popular varieties as resilient to adverse climatic conditions.

Rice bean (*Vigna umbellate L.*)

Rice bean is a promising multipurpose legume crop with good potential as food, fodder, green manure and a cover crop. The dried seeds are usually cooked and eaten with or without rice, young immature pods and leaves are used as a vegetable. The seeds contain a high amount of protein (20.9%) and limiting amino acids, tryptophan (0.79–1.10%) and methionine (0.45–1.18%), which rank it as one of the best among pulses. Though it is suited for the lowland humid tropics, some of the cultivars are also adapted to subtropical conditions in the plains. It does well in sandy loam to heavy soils. It is also reported to be moderately drought tolerant. In India, its distribution is mainly confined to the tribal regions of the hilly areas of north-eastern hills and the Western and Eastern Ghats. Field evaluation of diverse accessions of rice bean revealed a wide range of variation for a number of traits and considerable variation existed between collections from different geographical areas. Analysis of the biochemical constituents of rice bean seeds revealed variation for crude protein (17.8–25.2%), ash (3.8–4.1%), calcium (315–450 mg 100 g_1), phosphorus (197–393 mg 100 g_1), iron (1–5 mg 100 g_1). RBL-1 has been released for cultivation.

Adzuki bean (*Vigna angularis* L.)

Adzuki bean is a legume crop and has a wide variety of uses. The dried seeds are used for human food, either cooked whole or made into a meal used in soups, cakes or confections. In Japan, it is used largely as human food in the form of meal or paste. In India, it is used as a pulse, either whole or split. Sprouted beans are used as a vegetable. The seeds and leaves have medicinal properties. The seeds contain 19.9 g protein per 100 g of seed. Adzuki bean is a short-day plant and requires almost the same climatic conditions as soybeans. It can be grown on all types of soil from light to heavy clay but does not grow well on extremely acidic soil. The crop is more tolerant to heavy rainfall than other grain legumes. It is also reported to be grown as a rainfed crop.

Faba bean (*Vicia faba* L.)

Faba bean has been one of the main sources of protein since ancient times. In India, it is under cultivation as a minor crop in the Himalayan hills, Bihar, eastern Uttar Pradesh, Punjab, Haryana, Jammu and Kashmir. Now, Faba bean is becoming important as a source of protein (26.2%). The nutritive value of the crop is quite high and is regarded as a substitute for meat or skimmed milk. The green pods are used as a vegetable, and the seed is used dried, fresh or canned. It prefers a cooler climate and is grown as a winter annual in warm temperate and subtropical areas. It grows best on rich loamy soils and is tolerant to acidic soils. It is unable to withstand drought. It tolerates annual rainfall of 23–209 cm, annual mean temperature of 5.6–27.5°C and pH of 4.5–8.3. Evaluation of germplasm at ICAR-IIVR,Varanasi, indicated a wide range of variation for a number of important traits. Considerable genetic variation has also been reported for seed protein. ICAR-IIVR, Varanasi, provided the lead function for Faba bean breeding and a variety Kashi Sampada is released for cultivation in Uttar Pradesh.

Lima bean (*Phaseolus lunatus* L.)

Lima bean is grown for its edible seeds and as leafy vegetable. Rich in protein, lima beans are resistant to viral and rust diseases and withstand insect pests, drought, and abiotic stress. The species also tolerates different levels of aluminum and manganese toxicity which can be exploited to advance the sustainable utilization of other legumes.

Jack bean (*Canavalia ensiformis* L.**)**

Jack bean is the most economically important species in the genus *Canavalia*, with enormous potentials to serve as food for both humans and livestock. It is rich in protein and thrives well in poor and acidic soils. Jack bean is mainly grown for its nutritious pods, seeds, and as fodder. It is a forage crop with high green manure capacity to enrich the soils and also to control soil erosion. The crop tolerates adverse environment, drought, heat, and leached soils; also it resists pest attacks. The leaf of jack bean contains crude proteins and fiber comparable to other legumes. Jack bean possesses deep root system which enables the plant to penetrate deeply into the soil which enables it to withstand very dry conditions.

Cluster bean | Faba bean | Winged bean | Dolichos bean | Rice bean

Some potential underexploited legume vegetables

Conclusion

The demand-supply gap for the legumes is perpetually increasing widening day-by-day which will lead to a huge short fall in the supply to the ever-increasing global population in coming years. The only option is to maximize the efforts toward developing improved high yielding cultivars possessing resistance/ tolerance to the major stresses especially in context of climate change. The cost-effective sequencing technologies have introduced a new era in genomics and breeding by pin pointing the genes responsible for distinct phenotypes leading to selection of plants based on genotyping information. The knowledge generated through all the studies need to be integrated in breeding so that breeders can move toward "knowledge - based breeding" from "chance breeding." In addition, important information generated through transcriptomics, proteomics, metabolomics, and epigenomics have greatly benefitted the scientific community in developing better understanding of the traits and crops leading to development of effective strategy for achieving higher genetic gains in less time. It is obvious that the current and the upcoming technologies will further assist underexploited legume improvement programmes in a more cost-effective, user-friendly, and less time-consuming manner in addition to resistance to different biotic and abiotic stresses.

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59. Management of Diseases in exotic vegetables with special reference to Capsicum

Girija Ganeshan
Principal Scientist (Retired)
ICAR-Indian Institute of Horticultural Research, Bengaluru 560089, India
Email: girijaiihr@gmail.com

Cultivation of exotic vegetables in India finds niche market and fetches lucrative returns to the farmers. Globally it is a business of USD 1.9 billion in 2022 and expected to reach USD 6.08 billion by 2031. In India the exotic produce is expected to grow at CAGR of 13.8%. In the present scenariao Capsicum, Broccoli, Lettuce, Chinese cabbage, Red cabbage, English cucumber, Cherry tomato, Zucchini, Leaks, Chives, Fennel, Pakchoi, Celery, etc are grown both in open and protected cultivation. Production of mushrooms and micro-herbs also gaining importance. The disease spectrum observed in these crops are mainly, powdery mildew, downy mildew, Rhizoctonia rots, leaf spots and thrips transmitted viral diseases. Though the cultivation practices are known to the farmers, managing diseases in these crops to harvest pesticide residue free produce is a challenging task. Since these vegetables are grown for the niche market and for exports, pesticide residues need to be under minimal acceptable levels.

Several IDM packges were worked out at IIHR for the safe produce of Capsicum grown under cover. MRL levels were worked out for many pesticide molecules to find out waiting period and was integrated with botanicals and biologicals to reduce the disease pressure, in order to obtain safe produce of Tomato and Capsicum. Few bioformulations of Novozyme company were evaluated and were found encouraging to harvest a healthy crop of Celery and Lettuce. Seed treatment with biopesticides followed by foliar application of emulsified neem and pongamia oil were effective in managing pest problems in many of these crops.

60. Integrated Pest Management interventions in Exotic and Underutilized Ornamentals

V. Sridhar
Principal Scientist
Division of Crop Protection, Indian Institute of Horticultural Research,
Bengaluru - 560089, Karnataka, India
Email: Sridhar.V@icar.gov.in

Introduction

Ornamental plants, also known as decorative or landscaping plants, are cultivated for their aesthetic and decorative qualities. Large scale cultivation of these crops as in case of other commercial crops facing many limitations like attack by insects, mites and other pests. Many of the commercially grown ornamentals are exotic like Orchids, Anthuriums, Carnations, Gerber, Gladiolus, Tuberose, Tulips *etc*. including several cultivars of glass house grown roses *etc*. Several native ornamentals are underutilized like pot marigold, Jasmines etc. which are attacked by different insect and mite pests. Integrated Pest Management (IPM) is a sustainable and environmentally responsible approach to managing pests in agriculture, horticulture, and other settings. The goal of IPM is to effectively control pest populations while minimizing the negative impact on human health, the environment, and non-target organisms. Pest scenario on ornamental crops varies with the growing conditions. Closed structures and uniform growing conditions favors multiplication of pests round the year on protected ornamentals like rose, carnation, gerbera, chrysanthemum, orchids and anthurium which are generally the exotic crops cultivars. Red spider mites, thrips, whiteflies, aphids and leaf miners are serious pests on these crops. Open cultivated ornamentals are mainly damaged by bud borers, foliage caterpillars, beetles and weevils, besides thrips and aphids. Damage by insects causes severe yield loss in terms of quantity by making holes and eating on leaves, buds, flower and fruits. Curling, distortion, discoloration, browning and drying of plant parts as a result of damage cause qualitative loss.

Present strategies adopted to combat pest problems in ornamental crops mainly includes use of insecticides though several other options are available. Cultural methods like pruning, removal and destruction of infested parts and racking of soil are followed in some crops. Plant products such as neem and pongamia oils and kernel extracts are also used to some extent. Biological control is another options wherever feasible. Major pests on various exotic and underutilized ornamentals is discussed in this chapter including different bio control options. Under rose important pests expected and management options are described. These management tactics can be followed in other crops also for similar group of pests.

ROSE (*Rosa* spp.)

1. **Red Scale**, *Aonidiella aurantii* (Mask.) (Diaspididae):

Scales appear in severe form before and after the rainy season. Both young and adult stages suck the sap from stem and mature shoots and deplete vigour of the plant. Infested shoots have reddish brown encrustations, bear few small flowers and dry in case of severe attack.

Management: Selection of planting material free from scales infestation is essential. Cutting and burning or burying of heavily infested shoots is also effective. Application of pongamia oil 10% to infested shoots, immediately after pruning provides effective control (Jhansi and Jagan Mohan, 1999). Spraying of fenthion or chlorpyriphos 0.05% causes significant reduction of the scale.

Thrips, *Rhipiphorothrips cruentatus* Hood; *Scirtothrips dorsalis* Hood (Thripidae):

Thrips attack starts with the new flush after pruning on open cultivated roses. Blackish brown adults and reddish nymphs of *R. cruentatus* are found on underside of tender leaves and beneath sepals and petals of buds and flowers. Cream coloured nymphs and blackish adults of *S. dorsalis* attack roses in polyhouse.

Management: Spraying of acephate or imidacloprid or fipronil along with pongamia oil 0.5 % when early symptoms are observed control thrips on open cultivated roses (Jhansi and Jagan Mohan, 1997). Insecticides *viz.,* Cartap hydrochloride, imidacloprid, ethofenprox, abamectin, spinosad provide excellent control of thrips on roses in polyhouses. The effectiveness of the indigenous predatory mite, *Euseius plumerii* and the predacious insect, *Chrysoperla* sp was measured to suppress the populations of *Tetranychus urticae* Koch, *Macrosiphum rosae* (Linnaeus), *Frankliniella occidentalis* (Pergande) and *Bemisia tabaci* (Gennadius).

Aphid, *Macrosiphum roseae* (Aphididae)

Cool and cloudy weather during October-February favour pest build up. Blackish green coloured aphids cluster around growing shoots and suck cell sap resulting in yellowing and deformation of leaves, retardation of growing shoots. Heavy incidence favours development of black sooty mould.

Management: Spray with liminool 0.1 %.or pongamia oil 1.0% sprays followed by dimethoate 0.05% offers effective control of the pest on open cultivated roses (Jhansi Rani and Jagan Mohan, 1997). Spinosad, Imidacloprid, fipronil or cartap hydrochloride controls aphid damage on rose inside polyhouse. Lady beetles, parasitic wasps, and green lacewing adults and larvae often help keep rose aphids under control. These biological control agents may keep rose aphid populations in check, except during cool weather. Garlic, *Allium sativum* (Linn), was found to be best effective followed by Custard apple, *Annona squmosa* (Linn) and Bullock heart, *Annona reticulata* (Linn.) and closely followed by Neem, *Azadirachta indica*.

Two spotted spider mite, *Tetranychus urticae* Koch. (Tetranychidae)

Heavy incidence of the mite is found from March to May when hot and dry conditions prevail. Mites scrape tissue and suck the sap resulting in discoloration, yellowing, drying and dropping of attacked leaves. Damage to buds and flowers leads to retardation and drying.

Management: Proper ventilation, clean cultivation and frequent watering to bring down temperature keep the pest under check. Cutting and burning of heavily infested shoots should be done. Sprays of dicofol 0.05% or wettable sulphur 0.3% or oxydemeton methyl 0.05% and fluvalinate 0.012% controls mite problem on roses grown in open. New generation miticides like abamectin, flufenoxuron, diafenthiuron etc. are also good against mites under green house conditions.

Foliage caterpillars: **Semilooper**, *Achaea janata* Linn, (Noctuidae); Tobacco caterpillar, *Spodoptera litura* (Fab.) Hairy caterpillar, *Euproctis fraterna* Moore (Lymantridae):

Pest incidence is severe from September to October. Early instars are gregarious in habit and cause skeletonization and drying of leaves. Matured larvae of semilooper, hairy caterpillar and tobacco caterpillar feed voraciously on leaves, buds and flowers resulting in severe defoliation and flower loss.

Management: Collection and destruction of leaves with egg masses and early instars reduces further infestation. Sprays of quinalphos or indoxacarb manages these pests effectively. Spraying of neem oil 1 % or neem seed kernel extract 4% after insecticide sprays effectively checks damage by the caterpillars (Jhansi Rani and Jagan Mohan, 1997). Application of *Bacillus thuringiensis* dust or spray 3 x 10^6 spores also provides good control of these pests.

Bud borer, *Helicoverpa armigera* (Hub.) (Noctuidae):

Infestation of the bud borer is seen on open cultivated roses in severe form from January to March. Hatched larva bore into buds by making holes and feed on growing petals. Caterpillars also damage flowers by eating petals and leaving excreta.

Management: Collecting and killing of grown up larvae reduces further damage and population. Spraying methyl parathion or methomyl 0.05% or ethofenprox 0.01 % controls the pest effectively. Neem seed kernel extract 4% or neem oil 1 % sprays offer protection to plants from borer damage (Jhansi Rani and Jagan Mohan, 1997). Application of NPV 250 LE /ha causes considerable mortality of early instar larvae.

Chafer beetles, *Adoretus* and *Apogamia* spp. (Scarabaeidae)

Black or brown or metallic green-coloured adult beetles emerge from soil with the onset of monsoon showers (May-June) after dusk. They feed on leaves, buds, flowers and tender shoots by making irregular holes and cuts (Rai, 1977) resulting in severe defoliation.

Management: Deep digging after pruning exposes eggs, grubs and pupae to natural enemies. Water extract of neem seed kernel 5% spray inhibits feeding by the beetles (Dohary and Singh, 1981). Fortnightly spraying of quinalphos or chlorpyriphos 0.05% during evening protects foliage from beetle damage (Jhansi Rani and Jagan Mohan, 1997). Light traps also helps to management this insect adults.

CARNATION (*Dianthus caryophyllus*)

Table 1. Major pests of carnations are listed below.

Pest	Scientific name	Reference
Bud borer	*Helicoverpa armigera*	Preetee Kaushal and Usha Chauhan, (1999)
Thrips	*Thrips tabaci, Frankliniella schultzei*	Trujillo, (1989)
Two spotted spider mite	*Tetranychus urticae*	Trujillo, (1989)
Blister beetles,	*Mylabris* spp.	-
Leaf miner	*Liriomyza trifolii*	Akbulut and Zumreoglu, (1992)

Carnation tortrix moth	*Totrix pronubata*	Speyer., 1938
Carnation fly	*Hylemya briennescens*	Speyer., 193

Table 2. Common Pests of other commercially grown ornamentals

Crop	**Pest**	**Scientific name**
GERBERA (*Gerbera jamesonii*)	Whitefly	*Bemisia tabaci*
	Aphid	*Myzus persicae*
	Thrips	*Thrips palmi*
	Leaf miner,	*Liriomyza trifolii*
	Red spider mite	*Tetranychus ludeni* Zacher
Orchids (*Orchid* spp*)*	Armoured scale	*Diaspis boisduvallu*
	Mealy bug	*Pseudococcus maritimus*
	Thrips	*Anaphorathrips orchidii*
	Snail	*Achatina fullica*
ANTHURIUM (*Anthurium andreanum*)	Anthurium whitefly	*Aleurotulus anthuricola*
	Anthurium thrips	*Chaetanaphorothrips orchidii*
	Mites	*Brevipalpus* spp
Gladiolus, (*Gladiolus* spp.*)*		
	Gladiolus thrips	*Taeniothrips simplex*
	Bud borer	*Helicoverpa armigera*
	Tobacco caterpiller	*Spodoptera litura*
	Hollyhock tingid bug	*Urentius euonymus*
	Cutworm	*Agrotis segetum*
	Mite	*Tetranychus equatorius* Mcgregor
CHINAASTER (*Callistphus chinensis*)	Stem borer	*Patyptilia molopias* Meyrick
	Flower caterpillars	*Helicoverpa armigera* ; *Phycita* sp.
	Semilooper	*Ctenoplusia albistriata* (Bremer & Gray)
	Red Pumpkin Beetle	*Aulacophora foveicallis* Lucas
CHRYSANTHEMUM (*Dandranthema grandifloray*)	Aphid	*Macrosiphoniella sanborni* (GiIlette)
	Thrips	*Microcephalothrips abdominalis* (Crawfd.) *Frankliniella* spp., *Thrips* spp.
	Bud borer	*Helicoverpa armigera* (Hub.)
	Leaf folder	*Hedylepta indicata* (Fab.)
	Leaf miner	*Liriomyza trifolii* (Burgess)
	Spider mite	*Tetranychus* sp.

GLADIOLUS (*Gladiolus* spp.)	Thrips	*Taeniothrips simplex* Morison
	Cutworm,	*Agrotis segetum* (Schiff)
	Tobacco Caterpillar	*Spodoptera litura* (Fab.)
	Mite	*Tetranychus equatorius* Mcgregor
TUBEROSE (*Polyanthes tuberosay*)	Weevil	*Myllocerus* spp.
	Bud caterpillar	*Helicoverpa armigera* (Hub)
	Aphid	*Aphis* spp
	Thrips	*Thrips* spp.

Source: Sridhar *et al.* (2022)

Underutilized ornamentals

Crop	**Pest**	**Scientific name**
JASMINE (*Jasminum* spp.)	Budworm	*Hendecasis duplifascialis*
	Gallery worm	*Elasmopalpus jasminophagus*
	Leaf web worm	*Nausinoe geometral*
	Leaf roller	*Glyphodes unionalis*
	Jasmine eriophyid mite	*Aceria jasmine*
	Red spider mite	*Tetranychus cinnabarinus*
	Tingid bug	*Corythauma ayyari*
	Whitefly	*Dialeurodes kirkaldyi*
	Jasmine bug	*Antestia cruciate*
	Flower thrips	*Thrips orientalis*
CROSSANDRA (*Crossandra undulaefoli*)	Spike borers	*Helicoverpa armigera* (Hub)
	Scales	*Saissetia nigra* (Nietn)
	Tingid bug	*Orthezia insignis* (Orthez
	Crossandra bug	*Cynencia affinis* Dist
	Midge	*Contarinia maculipennis*
	Torticid Hairy caterpillar	*Archips epicyrta* Meyrick
Marigold (*Tagetes* sp.)	Bud borer	*Helicoverpa armigera* (Hub)
	Leaf miner	*Liriomyza* sp.
	Aphid	*Aphis gossypii*
	Mite	*Tetranychus urticae*

IPM in Commercial greenhouses: Principles and practices

Integrated pest management (IPM) is a holistic approach to managing diseases, insects, and mites in the greenhouse, using the best tools, tactics, and strategies to control pests with the least disruption to the environment. IPM can decrease pesticide exposure of workers and the environment, and can decrease pest control costs while still maintaining high-quality, pest-free plants. Appropriate use and timing of pesticides and the use of non-pesticide methods is essential, particularly given increasing regulations on pesticide use, decreasing numbers of registered pesticides, and increasing resistance of pests to pesticides.

The most important aspect of IPM is prevention of epidemics. As a consequence, most of this fact sheet is devoted to the prevention of pest problems, such as maintenance of a healthy crop, exclusion of pest access to the facility, close monitoring of plant health, prompt remedial action when pests are detected, and careful documentation of monitoring, pests found, treatments employed, and treatment efficacy. "Integrated" is an essential word in IPM. It means combining a variety of pest management techniques and strategies that can either reduce pest populations or lessen their economic impact while maintaining plant quality. An IPM program is built on several basic components, many of which are already needed to grow a healthy crop. While components may be modified to customize IPM programs for different operations, most components mentioned below should be included for a successful IPM program.

Sanitation

A basic component of IPM is sanitation. Infestations are easier to prevent than to cure. Start with a clean greenhouse. Walkways should be free of soil, organic matter, weeds, and algae. A weed-free zone should be maintained outside the greenhouse.

Cultural practices

A healthy crop is less susceptible to most pests and diseases. Maintaining the proper environment for the crop being grown is the first step to eliminating problems.

Fertilization

Soluble salt levels and the pH of growing media should be tested periodically. Fertilization schedules for each crop should be implemented. Nitrogen should be applied only as needed for optimal growth. Periodic heavy applications will set up nitrogen surpluses that cause excessive growth, which enhance the population growth of aphids, pathogens, and other pests. Slow-release fertilizers are ideal to use when possible.

Irrigation

Watering is another cultural practice that can be manipulated to slow the increase of pest populations. Plants should be watered only as needed, reduced on cloudy days, and avoided late in the day. Plants should be watered thoroughly and then allowed a dry-down period. The length of the dry-down period will vary with the species.

Plant quarantine

Isolate incoming plants, and monitor for pest emergence or disease development. Reject pest-infested or diseased shipments as a part of quarantine measures. Within the greenhouse, personnel should make a habit of caring for infested and/or quarantine areas last, to avoid carrying small insects or pathogen spores on their clothing into the rest of the greenhouse. As some of the ornamentals are imported care should be taken in this direction.

Scouting and monitoring

Monitoring is one of the most important principles of IPM. Pest management systems cannot be implemented if a grower does not know which pests exist and whether populations are significant. Therefore, a scouting and monitoring plan must be devised for each greenhouse. Correct pest identification is essential, and employees must be trained to monitor pests correctly.

Scouting and monitoring should be performed weekly or, preferably, twice weekly during the entire production season. Scouting procedures should be performed as routinely as any other greenhouse operation.

Record keeping

Proper records are critical to effective management. Record incoming plant material inspections, yellow sticky card information, and crop treatments. All production inputs must be noted concisely and accurately. Managers trying to make a diagnosis of a problem without records are at a disadvantage and may overlook potential causes of the problem.

Control options

The goal of IPM is long-term suppression of pest populations below the point at which they cause economic damage. Successful management of pests requires the use of multiple tactics, starting with healthy plants and a clean greenhouse, covered in the previous sections. Reliance on a single method, such as a chemical pesticide, is doomed to failure, if for no other reason than the development of pesticide resistance. Given below is the outline of several of the best pest control options.

Physical barriers

One strategy particularly suited to greenhouse IPM programs is the use of physical barriers to exclude insect pests. Screening vents and doorways can greatly limit the movement of insect pests into the greenhouse. Several factors must be considered when using physical barriers in the greenhouse. These include choosing the proper screen size mesh, assuring adequate airflow, and preventing reintroduction of insects on plant material.

Mesh size depends upon the insect targeted. Mesh with holes less than 200 micrometers is required for complete exclusion of western flower thrips; however, screening with holes as large as 640 micrometers is sufficient for excluding leaf miners.

The smaller the holes in the mesh, the more reduction there will be in airflow. This reduction can be counteracted by increasing the surface area through which air flows. Screening can be stretched from gutter to gutter to increase surface area. An exterior frame may be built and covered with screening to increase surface area.

Biological control

Biological control is the use of one type of living agent to suppress another. While beneficial insects most often come to mind, beneficial organisms also include mites, bacteria, fungi, and nematodes (see Table 1). The use of biological control can reduce or eliminate the necessity of pesticides. Growers must take the time to learn specifics about the biological agent they intend to use and create the proper environment for its use. Limitations of biological agents must be understood. Most predators and parasites perform best at moderate temperatures and humidities. Releases should be made in the morning or evening. When pesticides are required, those with the shortest residual life and highest specificity should be used.

Table 3. Common greenhouse pests and biological control agents

Pest	Agent(s)	Characteristics
Aphids, *Aphelinus abdominalus*	Parasitic wasps	females parasitize and feed upon aphids for several weeks
	Aphelinus ervi	
	Aphidoletes aphidomyza	Aphid gall midge, resembles a fungus gnat; young feed exclusively on aphids
	Ladybird Beetles (Ladybugs)	Young and adults feed on aphids
	Crysoperla sp.	Green lacewings larvae are voracious predators; *C. carnea* recommended for dry areas; *C. refilabris* for humid areas
	Beauveria bassiana	Pathogenic fungi
Mealybugs	*Cryptolaemus montrouzieri*	Small ladybird beetle (Mealybug Destroyer), both adults and larvae attack mealybugs and scales
Fungus Gnats and Shore Flies	*Atheta coriaria*	Voracious rove beetle predator
	Bacillus thuringiensis	controls larvae in soil
	Beauveria bassiana	Pathogenic fungi
	Steinernema feltiae	Parasitic nematode
	Hypoaspis mites	Predatory mite
Spider Mites	*Phytoseiulus persimilis*	Predator mite
	Stethorus punctillum	Small ladybird beetle that feeds specifically on mites
	Ladybird Beetles (Ladybugs)	Young and adults feed on spider mites
Thrips	*Amblyseius cucumeris*	Predatory mite
	Amblyseius degenerans	Works better in flowers than *A. cucumenis* effective in low humidity
	Ladybird Beetles (Ladybugs)	Young and adults feed on thrips
	Orius insidiosus	Pirate bugs; nymphs and adults feed on thrips
	Beauveria bassiana	Pathogenic fungi
Whiteflies	*Encarsia formosa*	Parasitic wasp, eggs develop in body of young whiteflies
	Delphastus pusillus	Ladybird beetle
	Ladybird Beetles	(Ladybugs)
	Eretmocerus californicus	Parasitic wasp
	Chrysoperla spp.	*C. carnea* recommended for dry areas, *C. refilabris* for humid areas
	Beauveria bassiana	Insect pathogen

61. India Preparedness to combat (TR4) in banana : Status and strategies

Selvarajan*, R and Thangavelu, R.
*Director, ICAR-National Research Centre for Banana,
Tiruchirapalli, Tamil Nadu - 620102

1. Introduction

Banana (*Musa* spp.) is the fourth most important global food commodity after rice, wheat and maize in terms of gross value production. At present, it is grown in more than 120 countries throughout tropical and subtropical regions and it is the staple food for more than 400 million people. As the world largest producer, India produces 33.06 million tons from an area of 0.92 million hac, contributing 26.45% to the global production. More than 20 varieties are commercially grown including Cavendish clones in different parts of India. However, the important constraints which acts as impediments in further increasing the productivity is the Fusarium wilt disease caused by *Fusarium oxysporum* f.sp. *cubense* which is the most devastating disease affecting commercial and subsistence of banana production throughout the banana-producing areas of the world (Ploetz, 2005). The disease is ranked as one of the top 6 important plant diseases in the world (Ploetz & Pegg, 1997). The disease almost destroyed the banana export industry, built on the Gros Michel variety, in Central America during the 1950's (Stover, 1962). In addition, the widely grown clones in the ABB 'Bluggoe' and AAA Cavendish groups are also highly susceptible to this disease worldwide. Presently, Fusarium wilt has been reported in all banana-growing regions of the world (Asia, Africa, Australia and the tropical Americas) except some islands in the South Pacific, the Mediterranean, Melanesia, and Somalia (Stover, 1962; Anonymous, 1977; Ploetz and Pegg, 2000). Generally, infected plants produce no bunches and if produced the fruits are very small and only few fingers develop. Fruits ripen irregularly and the flesh is pithy and acidic. The 'fungus survives in soil for up to 30 years as chlamydospores in infested planting material or in the roots of alternative hosts (Ploetz, 2000).

2. Diversity of Pathogen

Fusarium wilt of banana is caused by the fungus *Fusarium oxysporum* Schlechtend.: Fr. f. sp. *cubense* (*Foc*) (E.F.Smith) Snyder and Hansen. The disease is poly-cyclic in nature. There are four recognized races (race1, 2, 3 and race 4) of this fungus, which are separated based on reaction on differential hosts. Race 1 causes disease in the Gros Michel (AAA), Silk (AAB), Lady Finger (AAB), Maqueno (Maia Maoli-Popoulu subgroup, AAB), Pome (AAB) and Pisang Awak (ABB) cultivars, race 2 attacks Monthan, Bluggoe and other closely related cooking bananas and also affects some bred tetraploids (Bodles altafort hybrid between Gros Michel and Pisang lilin) and enset (*Ensete ventricosum*) and race 4 infects Cavendish (AAA) group of bananas and also cultivars susceptible to races 1 and 2. Race 3 is not considered to be a pathogen of banana, as it only attacks *Heliconia* spp. (tropical American banana relatives). Race 4 is further divided into subtropical and tropical strains. Tropical race 4 (*Foc*TR4) is a more virulent form of the pathogen and is capable of causing disease in Cavendish grown under any conditions, whereas subtropical race 4 (*Foc* STR4) generally causes disease only in plants grown under abiotic stress, especially in cold weather [Ploetz , Pegg , 2000]. The Tropical race 4 was reported so far in 23 countries which includes China, Taiwan, Philippines, Indonesia, Malaysia, Australia, and Pakistan and most recently in Jordan, Mozambique, Israel and Myanmar. In Australasia more than 100,000 ha of commercial banana plantations have been devastated by *Foc* -TR4 and because of this strain, there is a global concern not only to multimillion-dollar banana export industry, but also millions of people in rural communities, who depend on bananas for their food security and livelihoods.

With regard to India, *Foc* race 4 has not previously been reported in India. However, in 2015, a visit made based on the information from a banana grower from barari village in the Katihar district of Bihar State, India revealed the occurrence of wilt disease in cvs. Robusta and Grand Naine. The analyses of samples by different methods such as morphological examination of the fungus, vegetative compatibility grouping, volatile odor production, PCR based method using species specific and strain specific primers have confirmed that the *Foc* strains in the diseased samples collected from Bihar state is of *Foc*-TR4 and this is the first report of occurrence of TR4 in India. The spread of this virulent isolate of *Foc* pathogen in major Cavendish growing states like Maharashtra, Karnataka, Tamil Nadu and Andra Pradesh would be more catastrophic as this strain may infect all the commercial cultivars of banana including Cavendish which occupy 52% of the total area under banana cultivation and contribute 64% of the total banana production and the Indian banana trade mainly depends on Cavendish clones.

Recently the analyses of *Foc* samples collected from Bihar, Gujarat, Kerala, Maharashtra, Madhya Pradesh, Tamil Nadu and Uttar Pradesh indicated that among the banana genotypes, *Foc* R4 (which includes, *Foc* STR4 and TR4) was present only in the cv. Grand Naine and not in the cvs. Neypoovan (AB), Karpuravalli (ABB), Rasthali (AAB), and Sennachenkathali (AA). The analysis of *Foc* isolates collected from Bihar and UP indicated the presence of VCGs 01220 and 0125 belongs to *Foc* race-1 found in Grand Naine cultivars grown in Uttar Pradesh and Bihar. In addition, the tropical race 4 (VCG 01213/16) was also identified from the *Foc* samples collected from Bihar and Uttar Pradesh. *Foc* isolates collected from cv Grand Naine grown in Surat also confirmed the presence of VCG 01220 and 0125 of *Foc* race 1. These isolates were further confirmed by molecular analysis using specific markers. Also identified that the *Foc* R1 was distributed in the Tamil Nadu, Kerala, Maharashtra, Gujarat and Madhya Pradesh, while *Foc* STR4 was distributed in Gujarat and Madhya Pradesh based on TEF1α gene sequencing analysis. The race-specific molecular markers (PCR) analysis revealed that VCG 120 was distributed in Gujarat and Madhya Pradesh.

3. Symptoms

Development of a reddish-brown discoloration of the xylem in fine or smaller non-woody feeder roots at the sites of infection and yellowing of lower older leaves are the initial symptoms. Leaf yellowing begins along the margin and advances towards the midrib. Subsequently, the petiole turns brown and buckles. Infected plants frequently develop longitudinal splits on the pseudostem just above the soil level. The typical external symptom is hanging of dead leaves around the pseudostem which appears like a skirt. Eventually, the heart leaf withers and the pseudostem would remain standing until it is removed or collapsed [Stover, 1962; Brandes, 1919; Wardlaw, 1961]. Infection is also passed into young suckers [Su et al., 1986]. Cross-section of the corm and pseudostem shows purplish-brown discolouration of the vascular bundles while in corm, the discolouration appears as a collection of tiny reddish or brownish dots and streaks [Moore et al., 1995]. The discoloration of the rhizome is severe where the stele joins the cortex [Stover, 1962]. Generally, infected plants produce no fruit bunches and if produced, the fruits are very small with few fingers having pithy and acidic flesh [Pushpavathi et al., 2016].

4. Biology, survival and dispersal

The fungus produces macro, micro conidia and chlamydospores. Microconidia are either one or two-celled, oval to kidney-shaped and are produced in false heads. Macroconidia are four to eight celled and sickle-shaped with foot-shaped basal cells. Chlamydospores are usually globose and are formed singly or in pairs in hyphae or conidia [Nelson et al., 1983]. The fungus moves through the conducting vessels acropetally along with the xylem sap by alternating between the sporulating and germinating phase to penetrate the barriers. After the plant wilts completely, the fungus feeds saprophytically on the dead plant parts such as leaves, pseudostem and roots, and produces numerous resting spores called chlamydospores which are resistant to desiccation and unfavorable environmental conditions and enable to remain viable in the soil and on plant debris for more than four decades [Ploetz, 2005;]. These spores could be transported to disease-free soils by the wind, run-off waters and inadvertent dispersal *via* birds, animals, humans and even farm implements [Stover, 1962; Rishbeth and Naylor 1957]. The spread of the pathogen locally, nationally and internationally is through root-to-root contact, infected planting materials (rhizomes or suckers) and also through soil attached to planting materials, farm implements, vehicles, footwear and unsterilized potting compost [Ploetz 1994]. Dispersal could also be effected through soil adhering to other crops planting materials. Aerial dissemination of *Foc* might also be possible since macroconidia or sporodochia of the pathogen were produced on artificially inoculated plants in greenhouse experiments [Ploetz, 2015].

The pathogen survives in the roots of several species of common grasses and weed species such as *Commelina diffusa*, *Chloris inflate/C.barbata*, *Ensete ventricosum*, *Euphorbia heterophylla*, *Tridax procumbens*, *Cyanthillium cinereum, Paspalum, Panicum* and *Ixophorus* which do not express the symptom of the disease [Gowen, 1995; Hennessy *et al.*, 2005]. Soil water content at less than field capacity (0.01 MPa) is favourable to Fusarium wilt development [Stover, 1953]. Also, temperature plays a major role in the progress of *Foc* invasion and symptom development in banana [Beckman *et al.*, 1962] as infection and establishment of *Foc* TR4 in the Cavendish variety takes place at 15°C or below during winter in the subtropics. The greatest disease severity of Fusarium wilt of banana occurred at pH 8 is also noticed [Peng, 1999]. The texture and organic matter content of the soil significantly influenced the survival of the pathogen as wilt disease has been recorded from loose soil to heavy clay soil with the pH range of 4.80 to 8.45 and EC range from 0.12 to 1.10 dsm^{-1} [Thangavelu *et al.*, 2001]. Banana weevil, *Cosmopolites sordidus* seems to be a vector or predisposing agent of *Foc* as *Foc* TR4 was detected on exoskeleton [Meldrum et al., 2013]. Co-infection of nematode *Radopholus similis* and *Foc* in cv. Gros Michel is reported, however, there was no influence on disease severity while co-inoculated plants showed a significant reduction of root weight [Chaves et al., 2014].

5. Management of Fusarium wilt

Since the occurrence of Fusarium wilt of banana, various control strategies like flood-fallowing, application of organic amendments, planting of resistant banana varieties, crop rotation, fungicidal treatment and soil fumigation have been attempted. However, evolution of new race made these disease management practices much more complicated. Planting of resistant varieties is the effective way to control Fusarium wilt disease but it is limited due to consumer preference, extremely poor fertility particularly in the Cavendish subgroup [Aguilar Morán, 2013; Ortiz and Swennen, 2014] and therefore somaclonal variation and genetic transformation are being exploited. Usage of antagonistic microbes, which protects and promote plant growth by colonizing and multiplying in both rhizosphere and plant system, also a potential environment safe alternative approach for the management of Fusarium wilt of banana has been attempted [Weller *et al.*, 2002]. Besides, botanicals with antifungal compounds have been attempted for the management of the disease [Kagale *et al.,* 2004]. Even though there are multiple options for managing Fusarium wilt of banana including prophylactic measures, the perennial nature of this pathosystem and the corresponding polycyclic nature of the disease hindered the advance of long-term management measures [Ploetz, 2007]. Hence, an integrated disease management programme for Fusarium wilt should be undertaken by involving planting disease-resistant varieties and following other strategies such as quarantine measures, cultural, chemical and biological control measures etc.

A. Pathogen Exclusion

Prevention of the spread of fungal propagules is vital since once introduced, the eradication of the fungus from a field could be very difficult by either soil or plant-applied disease control treatments [Ploetz, 2000]. Preventive measures include adopting strict quarantine practices, checking for infected plant materials and thorough cleaning of farm implements which might help in slowing the spread of this disease [Nel, 2004]. Regional awareness and contingency programs have been created in the Western hemisphere to ensure that stakeholders are informed about the symptoms and potential impact of *Foc* TR4 [Pocasangre Enamorado et al., 2011]. When *Foc* TR4 arrived in new areas, early recognition and delineation of the affected areas are desirable.

B. Reduction of inoculum level

Since Fusarium wilt is a soil-borne systemic disease, control strategies are mainly addressed to reduce soil inoculums before planting banana. Flooding the *Foc* infested field for 3 to 4 months with a minimum of 30 cm of water significantly reduced populations of *Foc* in soil and controlled Fusarium wilt [Stover and Waite, 1960] as it creates anaerobic conditions. Removing and burning infected plants and spraying the soil with the fungicide Triadimefon three times at 25-day intervals are found effective in China [Lin, 2004]. Rice hull burning to heat sterilize the soil [Molina, 2010], burning the diseased plant parts such as rhizome, pseudostem, leaves and sterilization of infected soils [Thakker et al., 2013], and elimination of weeds, insect vectors and plant-parasitic nematodes harbouring wilt pathogen are proved to be the effective *Foc* management practices [Ploetz, 2015].

Chemical measures

Chemical control is an essential component of an integrated disease management program. The use of fungicides or surface sterilant is effective in preventing the spread of *Foc*. Fungicides such as cyproconazole, propiconazole and prochloraz showed Fusarium wilt disease reduction of around 80 percent in banana plants [Nel, 2004]. Fungicides belonging to the benzimidazole group such as benomyl, carbendazim and thiabendazole [Uesugi, 1998] have shown effective in controlling *Foc in vitro* and in greenhouse conditions [Nel et al., 2007]. Injection of rhizome with 2% carbendazim in cv. Rasthali was effective in controlling Fusarium wilt but the same was not effective in South Africa. Farmcleanse® containing 10% alkali metal salts of alkylbenzene sulfonic acid, 5% coconut diethanolamide and 1% pyridine-2-thiol 1-oxide sodium salt is found to be the most effective, totally inhibiting germination of conidia when applied at the recommended rate of 10 per cent [Moore *et al*., 2001].

C. Soil amendments

Soils with higher biological diversity and activity, such as natural or organically managed agricultural soils are often more suppressive to root infecting fungi than conventionally managed agricultural soils. Application of bioorganic fertilizers increased the bacterial diversity in the rhizosphere of banana [Shen et al., 2013]. Biocontrol agents when applied in combination with organic materials have shown the enhanced activity of biocontrol microbes, resulting in better disease control than the application of biocontrol microbes alone [Shen et al., 2013; Kavino et al., 2010; Qiu et al., 2012]. Application of chemical amendments in soil also shows some effects on disease control. High lime (CaO) content (175-280 ppm) enhances disease suppression in the soil [Höper et al., 1995] as it reduces germination of chlamydospores. Reduction of iron availability increases soil suppression [Scher and Baker, 1982] as well as reduces chlamydospore germination [Peng et al., 1999]. Soil application of calcium compounds and phosphate salts such as Ca $(OH)_2$, Ca $(NO_3)_2$ $4H_2O$,

$CaCO_3$, $CaSO_4$, K_2HPO_4 and $NaH_2PO_4\ 2H_2O$, strongly inhibits chlamydospore germination and promotes lysis of germ tubes of *Foc*in soil [Sun and Huang, 1985; Huang et al., 1989]. Soil amendment using silicon (Si) is found effective in controlling Fusarium wilt in banana [Henriet et al., 2006; Datnoff et al., 2007; Fortunato et al., 2012]. Influence of soil abiotic factors such as soil pH, N and Mn; on *Foc* race 1 incidence in 'Gros Michel' banana variety showed that a high soil pH, lower Ca and Mg content results in a higher bunch weight from plants under infected condition [Segura et al., 2018].

D. Crop rotation

The monotony in the characteristics of the cultivated soil which might lead to the conditions favourable for pathogen multiplication and spread could be disrupted by following crop rotation. Crop rotation with paddy and flooding for 3 to 4 months before planting banana is found to be effective [Thangavelu et al., 2001; Sun and Huang., 1985] and also inter-planting with cassava lowered the inoculum [Buddenhagen, 2007]. Banana rotation with Chinese leek and paddy could control Fusarium wilt which is speculated that the control is due to release of antifungal compounds from root exudates or leaf leachates such as 1-dimethyl-2-pentenal and dimethyl trisulfide [Zhang et al., 2013]. Two-year crop rotation systems of banana with other crops such as maize, pea, pineapple and cassava observed that pineapple-banana system could reduce *Foc* population and suppresses the disease incidence, which going side with significantly higher abundances of *Acidobacteria*, antagonistic *Burkholderia*, *Planctomycete* and *Chloroflexi* and Basidiomycetes rather than Ascomycetes [Wang *et al*., 2015].

E. Cover crops

Cover cropping followed by incorporation of plant residues into the soil is effective to suppress certain soil-borne pathogens [Davis *et al*., 1996] as they increase the nutrient availability, reduce groundwater contamination and stimulate beneficial microflora in the soil [Baker and Cook, 1974]. In addition to direct effects on plant pathogens, many cover crops impact plant pathogens indirectly by triggering the plants host defense response and induce specific suppression by enhancing individual beneficial organisms such as *Trichoderma harzianum* and mycorrhizae in soils. Several plant species of Fabaceae and Poaceae served as cover crops in banana cropping [Blazy *et al*., 2009]. Addition of *Brachiaria decumbens* as cover crop alters the food web of macrofauna in soil litter which might be helpful in controlling the banana weevil, *Cosmopolites sordidus*, a dispersal agent of Fusarium wilt pathogen [Duyck *et al*., 2011]. Management of ground cover at the base of the banana plantations is found to be a significant factor in reducing the incidence and severity of Fusarium wilt in bananas [Pattison *et al*., 2014] as the cover crops reduces the weed population and plant-parasitic nematode infection [Djigal *et al*., 2012] which are involved in the dispersal of Fusarium wilt pathogen. Application of silicon, *Trichoderma harzianum*, compost, differentiated sources of NPK and growing *Crotalaria juncea* as a cover crop could reduce the Fusarium wilt disease severity index up to 23 percent as compared to that of control (81 per cent), in 14 months old banana plants [Haddad *et al*., 2016].

F. Biological control

Expediting the growth of antagonistic microorganisms, in both rhizosphere and endosphere of the plant is an important approach in the management of Fusarium wilt of banana. Several reports have demonstrated the successful use of different species of *Trichoderma*, *Pseudomonas*, *Bacillus*, *Burkholderia cepacia, Streptomyces*, non-pathogenic *Fusarium oxysporum* (np*Fo*) of both endophytic and rhizospheric in nature against Fusarium wilt disease [Shen *et al*., 2015]. Application of np*Fo* strain Ro-3 three times resulted in the reduction of Fusarium wilt disease severity by up to 89 percent and significant enhancement in plant growth

[Thangavelu and Jayanthi, 2009]. Application of *Bacillus amyloliquefaciens* strain NJN-6 along with the organic mixture of pig manure compost and amino acid fertilizer (2:3 w/w) has also effectively suppressed Fusarium wilt disease in banana [Zhang *et al*., 2014; Xue *et al*., 2015]. In general, the genera *Bacillus* remain the most promising biocontrol agents involved in suppression of various soil-borne pathogens as they form a stable and extensive biofilm [Bais *et al*., 2004] and also secrete many antifungal compounds such as surfactin, bacillomycin and macrolactin [Xue *et al*., 2015].

Biocontrol agents also applied along with botanicals for enhancing protection of plants from various diseases. Combined application of botanical formulation (*Datura metel* Wanis EC and Damet 50 EC) and biocontrol agents (*Pseudomonas fluorescens* Pf1 and *Bacillus subtilis* TRC 54) has reduced the wilt incidence significantly under greenhouse by 64% and field conditions by 75% [Akila *et al*., 2011]. Zimmu (*Allium cepa* x *A. sativum*) leaf extract alone could effectively suppress Fusarium wilt disease under both greenhouse and field conditions in the Cavendish cultivar 'Grand Naine' and enhanced the yield at significant level [Gopi and Thangavelu, 2014].

Several reports have documented that the use of biocontrol agents in combinations are more effective than individual agents for the management of plant diseases [de Boer *et al*., 2003; Domenech *et al*., 2006; Thilagavathi *et al*., 2007; Ganeshamoorthi *et al*., 2008]. Combined application of two endophytes *viz.,Pseudomonas* sp. UPMP3 and *Burkholderia*sp. UPMB3 showed significant reduction of Fusarium wilt disease in susceptible banana cv. Berangan [Fishal *et al*., 2010]. The application of endophytic *Trichoderma asperellum* Prr2 + rhizospheric *Trichoderm*a sp. NRCB3 recorded 100 percent reductions of Fusarium wilt disease under both pot and field conditions [Thangavelu and Gopi, 2015]. There is growing evidence in use of arbuscular mycorrhizal fungi (AMF) for the control of several fungal diseases and also to promote plant growth [Dalpe *et al*., 2004]. Application of *Glomus mosseae* + *Trichoderma harzianum* in plants challenged with *Foc* under field conditions could sustain 61 and 70 percent improvement in plant height and girth, respectively and gain of 75 percent in bunch weight [Mohandas *et al*., 2010] besides reducing the *Foc* population. Application of *Glomus etunicatum* (KPV) + *Pseudomonas aeruginosa* (Ge-A+ Ge-B) or *Glomus mosseae* (TPV) + *Pseudomonas* sp. (Gm-A) combination also significantly suppressed the Fusarium wilt disease under pot culture conditions [Sumathi and Thangavelu, 2016].

G. Host resistance

i. Conventional breeding

Though chemical, cultural and biological means give considerable protection against highly virulent strain *Foc*TR4, complete protection is achieved only through cultivating resistant cultivars. As there is no commercially important Cavendish cultivar (AAA), identification of resistant sources in the related groups of bananas and utilizing them in breeding for obtaining resistant against the wilt is hour of the need. Already a successful cross between 'SukaliNdizi' and 'TMB2X8075-7' denoted complete resistant against *Foc* race 1 and described the gene responsible for resistant is single recessive and the gene was also named as *Panama disease* 1 [Ssali *et al*., 2013]. Recently, wild banana viz., *M. basjoo, M.itinerans* [Li *et al*., 2015] *M. negensium, M. ruiliensis, M. velutina* and *M. yunnanensis* showed resistance to *Foc* TR4 under screening and these can be utilized in breeding programme to obtain desirable resistant cultivars. In addition, *M. acuminata* subsp. *Malaccensis* has shown resistance to *Foc*TR4 [Smith and Hamill, 1999]. In the Caribbean and Mozambique regions, diploids and wild sp. such as Pahang (AA), Calcutta 4 (AA) and *Musa itinerans* showed high degree of resistance to *Foc* TR4 [Zuo *et al*., 2018]. Chinese have developed five different *Foc* TR4 resistant/tolerant varieties and among those, ZJ 9 –triploid was completely resistant to *Foc* TR4 in China (developed by crossing diploid with tetraploid –FHIA 01) (Personal communication)

Some level of resistance to Fusarium wilt has been obtained by using somaclonal variation techniques [Hwang and Ko, 2004] and the resistant cultivars developed from Taiwan Banana Research Institute (TBRI) GCTCV-218 (Formosana) is less susceptible to *Foc* TR4, high yielding with high-quality fruits. Thus the cv. Formosana is having high consumer preference both in local and Japanese markets. Several bred hybrids, especially in those developed by the program at the Fundación Hondureña de InvestigaciónAgrícola (FHIA) in Honduras [Rowe and Rosales, 2000] such as FHIA -01 (Gold finger), FHIA 18, FHIA 2 (Mona lisa), FHIA 25 and SH-3640/10 (High Noon) [De Beer *et al*., 1997] were resistant or tolerant to TR4.

Mutation breeding is also an important approach for the development of resistant cultivars against *Foc* TR4. Ethyl methane sulphonate (EMS) induced mutants of Brazil banana (*Musa* spp. AAA) and Williams 8818-1 showed resistance against *Foc*TR4 [Chen *et al*., 2013; Wang *et al*., 2012]. In our laboratory also, the putative gamma irradiated embryonic cell suspension derived plants of cv. Grand Naine showed resistance to *Foc*TR4 under glasshouse conditions.

ii. Transgenics approach

Genetic modification of banana through appropriate methods is important for developing elite edible banana plants resistant to different races of *Foc*. The cell wall strengthening genes might be important for banana resistance to Fusarium wilt [Van den Berg *et al*., 2007]. Besides, genes encoding antimicrobial peptides (AMPs) are strong candidate for fungal resistance in *Musa* sp.as they are highly inhibitory to *Foc in vitro* [Arinaitwe, 2008].

In banana, increased PMEs and followed by decreased degrees of ethyl esterification (DMs) accompanied by increased low methyl esterified homogalacturonan (HGs) in the root vascular cylinder appeared to play a key role in specifying the susceptibility of banana plant to *Foc* [Ma *et al*., 2013]. The high-level constitutive expression of these defensins in elite banana cv. Rasthali led to significant resistance against infection of *Foc in vitro* and *ex vivo* bioassays [Ghag *et al*., 2012]. Expression of rice thaumatin-like protein gene in transgenic banana plants showed enhanced resistance to *Foc*TR4 [Mahdavi *et al*., 2012]. RNAi-based strategy for banana resistance using dsRNAs of adenylate cyclase, DNA polymerase alpha and delta subunits against *Foc* spores *in vitro* displayed varying degrees of inhibition of spore germination [Mumbanza *et al*., 2013]. Recently two lines of transgenic Cavendish have been developed, of which one was transformed with *RGA*2, a putative nucleotide-binding and leucine-rich repeat (NB-LRR)-type resistance (R) gene, from a seedling of *Musa acuminata* ssp. *malaccensis* and the other with *Ced*9 an anti-apoptosis gene derived from the nematode *Caenorhabditis elegans*, were remained free from *Foc* TR4 disease [Dale *et al*., 2017]. Transgene expression in the *RGA*2 lines was strongly correlated with resistance. However, these transgenic lines are to be tested for their resistance with the *Foc* isolates collected from different parts of the world as the *Foc* strains may differ in its virulence from place to place.

Although development of resistance is achieved normally through conventional breeding or by genetic engineering, recent approach of genome editing using Clustered Regularly Interspaced Short Palindromic Repeats associated protein 9 (CRISPR)/Cas9) tool has shown to achieve desirable traits by modifying plant genome [Haque *et al*., 2018]. Recently banana genome editing using this tool for targeting MaATG8s gene for developing resistance against *Foc* TR4 [296] and *MaSWEET-1a*, *MaSWEET-4b*, *MaSWEET-14b*, *MaSWEET-4c*, *MaSWEET-14c*, *MaSWEET-4d*, *MaSWEET-14d*, and *MaSWEET-14h [*Miao *et al*., 2017] *or MaAPS1* and *MaAPL3* genes for *Foc TR4* and abiotic resistance together have been suggested. Since transcriptional up-regulation of *MaAGPase* genes occurs in response to *Foc* TR4 infection, these genes may play a role in modulating the response to fungal infections in banana [Miao *et al*., 2017]. Thus, CRISPR/Cas9 could, therefore, modify banana gene expression to enhance resistance to *Foc*and further improvement of banana.

H. Integrated approach of Fusarium wilt management

In general, Integration of biocontrol with agronomic practices may improve the efficacy of the biocontrol organisms and the health of the host plants, which may be sensitive to environmental changes. Under this situation, compatible interactions are an important pre-requisite for the successful development of an integrated approach for the control of plant diseases. In the case of banana, integration of multiple control methods was more effective than the single method of controlling Fusarium wilt disease in banana. [Saravanan *et al*., 2003] found that basal application of neem cake at 0.5 kg/plant + sucker dipping in spore suspension of *Peudomonas fluorescens* for 15 min + soil application of *P. fluorescens* at 10 g/plant at 3.5 and 7 months after planting showed the greatest suppression of wilt disease and this was on par with basal application of neem cake at 0.5 kg/plant + soil application of *P. fluorescens* at 10 g/plant at 3.5 and 7 months after planting. They also reported that *Trichoderma viride* applied as soil or sucker dipping or their combinations or along with the neem cake also had a significant reduction in disease index, but less than that of *P. fluorescens*. Kidane and Laing (2010) developed integrated method of controlling Fusarium wilt by integrating biological and agronomic control methods. The combined applications of non-pathogenic, endophytic *Fusarium oxysporum* strains N16 strain by dipping their roots in a spore suspension containing 10^7cfu ml^{-1}, *Trichoderma harzianum* Eco-T® @ 4 L /plant at a concentration of 10^5 conidia ml^{-1} at the time of planting, monthly application of plants with 4 L of silicon solution per plant containing 900 mg silicon per L. silicon and placing coarse macademia husks at the bottom of banana plants as mulching was found effective against Foc TR4. Zang et al. (2011) showed that the application of amino acid fertilizer and mature pig manure compost with the antagonists *Paenibacillus polymyxa* SQR21, *Trichoderma harzianum* T37 and *Bacillus subtilis* N11 was found effective on the suppression of Fusarium wilt of banana. Akila *et al*. (2011) demonstrated that combined application of botanical formulation and biocontrol agents (botanical fungicides from Datura metel- Wanis 20 EC + *Pseudomonas fluorescens* 1, Pf1 + *Bacillus subtilis*, TRC 54) reduced the wilt incidence significantly under greenhouse (64%) and field conditions (75%). The reduction in disease incidence was positively correlated with the induction of defense-related enzymes peroxidase and polyphenol oxidase

6. Conclusion

Among various production constraints, Fusarium wilt of banana is becoming the most devastating disease affecting commercial and subsistence of banana production worldwide. The aggressive strain of *Foc* TR4 which was first detected in Asia in the 1990s is now found most of banana growing regions of the world including India. Because of this, the global banana production is under severe threat which in turn will have calamitous impact on livelihoods and food security of millions of smallholders who grow more than 85 percent of the crop. Since no single method is available to contain the disease effectively, integration of different management strategies such as creation of awareness and sensitization among all the stakeholders including the plant tissue culture companies; quarantine and sanitation measures to prevent the spread of disease to un-infected areas; soil health improvement which includes crop rotation, intercropping, cover cropping, need based application of fertilizers, application of effective microbes and soil amendments such as cakes, organic manures, ashes and banana waste recycling; use of resistant varieties; disease free planting material; good agricultural practices (GAP) have to be followed to effectively manage this lethal disease.

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62. Potential role of farmer's underutilized and exotic horticulture crop varieties in assuring nutritional security and their importance in plant variety protection as per PPVFRA Act, 2001

T. K. Nagarathna*, Javid Iqbal Mir and Varsha Chaudhary*****

*Professor and Scientific Officer, University of Agricultural Sciences, Bangalore & Former Registrar, PPVFR Authority, Ministry of Agriculture and Farmers Welfare, GoI, New Delhi

** Principal Scientist, ICAR-Central Institute of Temperate Horticulture, Rangreth, Srinagar, Jammu & Kashmir-190007

*** Protection of Plant Varieties and Farmers' Rights Authority, GoI, New Delhi-110012

*Email: tk.nagarathna2020@gmail.com

ABSTRACT

The global food system's overreliance on a limited number of plant species with poor nutritional value has detrimental effects on nutrition and food security. There is a growing recognition of the potential of underutilized plants, which are rich in nutrients and offer various health advantages. These often-neglected plants have the capacity to enhance food security, diversify diets, combat malnutrition and improve human health. Furthermore, efforts are being made to address the obstacles hindering the reintegration of underutilized foods into the global food system, along with recommendations for their successful inclusion. PPVFR Act, 2001 promotes the conservation of such plant genetic resources, acknowledges farmers' rights, and ensures equitable benefit-sharing, all of which are essential for the continued preservation and sustainable use of these valuable crops for the future generations and continue to contribute to biodiversity, nutrition and food security.

India's evolving demographics: Growing population amidst stable arable land

India's total geographical area spans 324.73 million hectares, with approximately 155.2 million hectares designated as arable land - a figure that has remained largely consistent for several decades (Statista, 2023; Anon, 2022). In stark contrast, India is home to one of the world's largest and fastest-growing populations. According to the United Nations World Population Dashboard, India's population has surged to 142.86 crores, with a growth rate of 0.81%, effectively surpassing China's population.

A retrospective analysis of the 1991 census reveals a population growth rate of 2.1% per annum during 1981-1991, resulting in a population of 843 million in 1991. Remarkably, India's population has experienced a staggering three-and-a-half-fold increase over the past nine to ten decades (Bhagat, 2000).

According to the United Nations' World Population Prospects-2022, India's population is projected to reach a formidable 166.80 crores by the year 2050, signifying a continued growth trajectory for several decades to come.

Food grain production over the years in India

With almost same available land area, India has to feed 166.8 crores by 2050 though the increase in food production is doubled than the human population since 1951 to 2021. In 2021-22, India's food grain production touched a record 315.7 million tonnes with production of a major crops like rice (127.93mt),

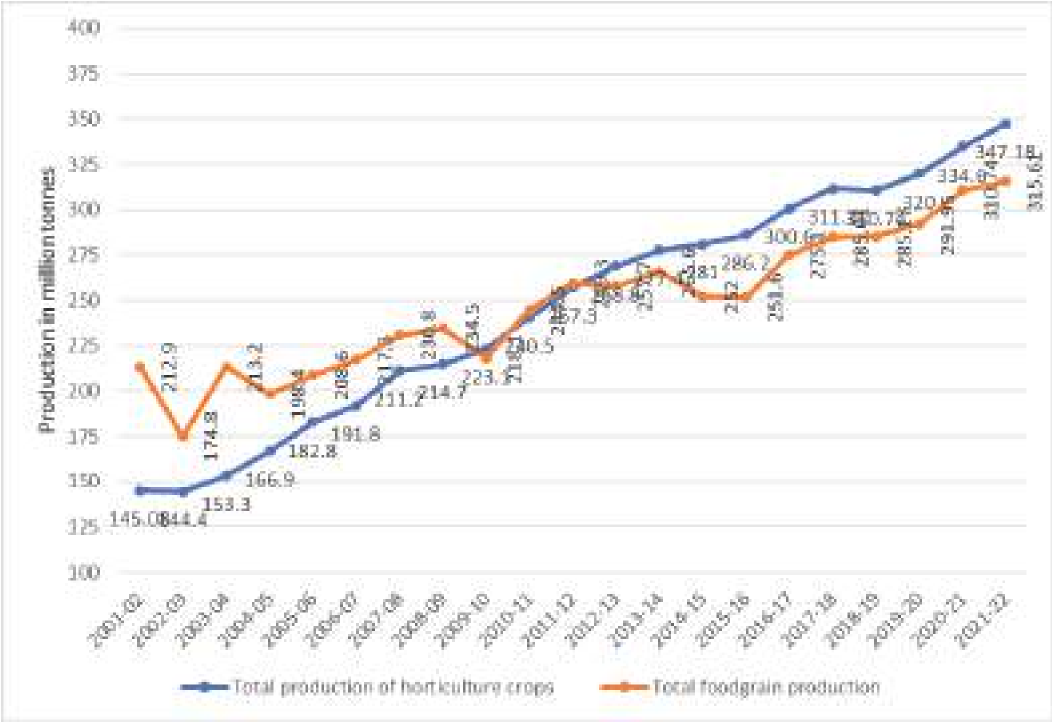

Fig 1: Total horticulture and food grain production in India over the years

wheat (111.32mt), coarse cereals (49.86mt), maize (32.42mt), pulses (27mt), oilseeds (37.15mt) (Anon, 2022). According to the third advance estimate released by the centre on 25th May 2023, total food grain production in India is estimated at a record 330.5mt.

Horticulture production in India

Similar to food grain production, horticulture production in India has more than doubled from 145.8 mt in 2001-02 to 334.60 mt in 2020-21(Fig 1) with fruit production at 107.10mt and vegetable production at 204.51mt (Agriwelfare.gov.in) with only 17% of arable land for the cultivation of horticultural crops (Table 1).

Table 1: Total area, production and productivity of horticulture crops in India

Year	Area (million ha)	Production (million tonnes)	Productivity (million tonnes/ha)
2001-02	16.6	145.8	8.8
2002-03	16.3	144.8	8.9
2003-04	19.2	153.3	8
2004-05	18.4	166.9	9.1
2005-06	18.7	182.8	9.8
2006-07	18.4	191.69	9.9
2007-08	20.2	211.2	10.5
2008-09	20.7	214.2	10.4

2009-10	20.9	223.1	10.7
2010-11	21.8	240.5	11.03
2011-12	23.2	257.3	11.07
2012-13	23.7	268.8	11.35
2013-14	24.2	277.4	11.46
2014-15	23.4	281	12
2015-16	24.5	286	11.69
2016-17	24.9	300	12.1
2017-18	25.4	310	12.25
2018-19	25.7	311	NA
2019-20	26.5	320	NA
2020-21	27.48	334.6	NA
2021-22	27.56	347.18	NA

SDG-2 and SDG-3 initiatives

Despite increases in the ample food grain production and horticulture production, hunger and malnutrition persist as significant global and national challenges. To face these challenges, Sustainable Development Goal (SDG)-2 specifically aims to "end hunger, achieve food security with improved nutrition and promote sustainable agriculture" (UN Conference on Sustainable Development in Rio de Janeiro, 2012) and SDG 3 focuses on ensuring healthy lives and promoting well-being for all the people by addressing various health challenges and achieve universal health coverage (FAO, 2018).

To eradicate hunger and malnutrition as the agenda for SDG is to increase 50 per cent demand for nutritious food between 2012-2050 (Aliza Pradhan *et al*., 2021).

India's 2022 global hunger index: A 'Serious' challenge at 107th rank

The Global Hunger Index (GHI) is a tool for assessing the severity of hunger and malnutrition in countries around the world. A score of 29.1 indicates a 'serious' level of hunger in India in 2022 and its ranking 107th out of 121 countries reflects the ongoing challenges the country faces in addressing food security and malnutrition.

India's malnutrition challenge: Addressing inequality and food security

Hunger and malnutrition are indeed significant global challenges that affect a substantial portion of the world's population. In 2021, approximately 2.3 billion adults suffering from malnutrition. A 2019 report by the UNICEF highlighted that malnutrition caused 69 per cent of under-five children's death in India. One of the most overlooked challenges in India is the issue of nutritional deficiencies resulting from inadequate intake of essential nutrients such as protein, iron and zinc.

According to the National Family Health Survey 5 conducted by the Government of India, the prevalence of anaemia caused by low haemoglobin levels has increased to 67% among children below the age of 5 years, which is higher than the 59% reported in the NFHS 4 survey. Anaemia is more widespread among women, affecting a substantial 57% of Indian women, while a relatively lower 25% of men under the age of 50 years are affected.

The same report also reveals that 19% of women and 16% of men under the age of 50 are experiencing undernutrition, while 24% of women and 23% of men are grappling with obesity. Consequently, it is estimated that roughly 40% of India's extensive population of 1.38 billion people are experiencing some form of malnutrition, be it undernutrition or obesity.

Despite India's achievement of self-sufficiency in food grain production and consistent economic growth in recent years, the persistent problems of nutritional food security continue to persist. To address these issues effectively, India must simultaneously tackle nutrition inequality and food insecurity in order to improve the overall nutritional composition of daily diets.

The role of underutilized and exotic horticulture crops in elevating nutrition and sustainability

The prevalence of malnutrition and various health related issues could be significantly reduced through the expanded availability and consumption of underutilized and exotic horticulture crops (Khoury *et al*., 2014 and Tilman *et al*., 2011). These underutilized horticultural crops, which have been unexploited and the exotic horticultural crops which are grown in relatively small quantities and not cultivated traditionally in the country hold the potential to make significant contributions to nutritional food security, income generation and addressing environmental challenges like climate change (WBG, 2021).

Tapping into underutilized and exotic horticulture crops for nutritional food security

Globally, there are approximately 30,000 identified edible plant species, with over 7,000 of them having been cultivated for food at some point (Garn and Leonard., 1989 & Khoshbakht and Hammer, 2008). Surprisingly, the commercial cultivation of edible crops is currently limited to fewer than 150 species. Even more striking is the fact that just 103 of these crops provide up to 90% of the calories in the human diet (Bioversity International, 2017). An even smaller group of four crops - rice, wheat, maize and potato - contribute to 60% of the world's energy supply. This leaves tens of thousands of edible plant species relatively "underutilized," representing a significant untapped resource that has the potential to address global food requirements and enhance dietary diversity and resilience (Chivenge *et al*., 2015).

Complementing major staple food crops with underutilized and exotic horticulture crops

Promoting the cultivation and consumption of underutilized and exotic horticultural crops is not meant to replace major staple crops but to complement them. A diverse agricultural and dietary landscape can be more effective in addressing the challenges. Incorporating underutilized horticultural crops into diets and agricultural practices can contribute to better nutrition, environmental sustainability, economic development, and cultural preservation. These crops play a valuable role in addressing global food security and promoting healthy, diversified diets.

Consuming underutilized and exotic horticultural crops offers several benefits, both in terms of nutrition and sustainability:

1. **Nutritional diversity:** These crops often contain a wide range of vitamins, minerals, and phytonutrients that can contribute to a more diverse and balanced diet. Incorporating these crops can help combat nutritional deficiencies.

2. **Micronutrient richness:** Rich sources of essential micronutrients like iron, zinc, vitamin A, and vitamin C, which are critical for overall health and can help prevent deficiencies and related health issues.
3. **Dietary variety:** Including these crops in one's diet adds variety to meals, making them more enjoyable and satisfying. This diversity can also encourage better overall dietary habits.
4. **Cultural preservation:** Many of them have cultural and historical significance. Consuming them helps preserve traditional culinary practices and heritage.
5. **Environmental sustainability:** Underutilized crops are often well-adapted to local climates and require fewer inputs like pesticides and fertilizers. This can reduce the environmental impact of agriculture.
6. **Biodiversity conservation:** Promoting underutilized crops supports biodiversity by maintaining genetic diversity in agricultural systems. This can enhance resilience to pests, diseases, and changing environmental conditions.
7. **Income generation:** Growing and selling these crops can provide economic opportunities for small-scale farmers, particularly in regions where these crops are native or well-suited.
8. **Climate resilience:** Some underutilized crops are more resilient to changing climate conditions than major crops. Including them in agricultural systems can enhance food security in the face of climate change.
9. **Reduced food waste:** Diversifying the types of crops grown can reduce the reliance on a few major staples, which can contribute to food security and reduce the risk of crop failures leading to food waste.
10. **Innovation and research:** Focusing on underutilized and exotic crops encourages research and innovation in agriculture and food science, potentially leading to the development of new and more resilient crop varieties.
11. **Improved health:** The diverse nutrients found in these crops can have a positive impact on health, potentially reducing the risk of diet-related chronic diseases.
12. **Local food systems:** Promoting underutilized crops can strengthen local food systems, reducing dependence on global supply chains and enhancing food security at the community level.

The PPVFR Act's role in India's food security by protecting farmers' varieties

The Protection of Plant Varieties and Farmers' Rights (PPVFR) Act of 2001 in India is indeed a critical legislation that aims to protect the rights of farmers and promote the conservation and sustainable use of plant genetic resources, including underutilized and exotic horticultural crops. Legal protection under the PPVFR Act plays a crucial role in safeguarding these crops, ensuring the rights of farmers who conserve them, and promoting their conservation, sustainable use and mainstreaming into modern agricultural practices. This legislation is an essential tool for fostering agricultural diversity and food security in India.

Here are some reasons why legal protection under the PPVFR Act is important for these crops:

1. **Protection of Farmers' Rights:** The PPVFR Act recognizes and protects the rights of farmers who have conserved and developed plant varieties, including underutilized and exotic horticultural crops, over generations.
2. **Registration of farmers' varieties [Section 39 (1) (iii)]:** Under the PPV&FR Act, the registration of farmers' varieties is permissible if they meet the criteria of distinctiveness, uniformity, stability and denomination, without requiring novelty. This provision grants farmers a unique opportunity, starting from the point when a crop species is incorporated into the crop portfolio governed by the PPV&FR Act for potential registration. Once registered, these varieties are entitled to all the rights associated with Plant Breeders' Rights
3. **Exemption from registration fees [Section 44]:** Farmers are exempted from payment of any fees in respect of any proceedings before the Registrar or Authority or High Court and they are also exempted from payment of any fee for inspection of any document or obtaining any decision or order or document under the Act or Rules.
4. **Farmers' recognition and reward for contributing to conservation [Section 39(i)(iii) & Section 45(2)(C)]:** A Farmer who is engaged in conservation of genetic resources of land races and wild relatives of economic plants and their improvement through selection and preservation and that the material so selected and preserved has been used as donors of genes in varieties registerable under PPV&FR Act, 2001 (Section 39(1)(iii) of the protection of plant varieties and farmers' Right Act, 2001). Such farmers are eligible for Plant Genome Saviour Reward/Recognition/Community awards conferred by PPVFR Authority annually.
5. **Incentive for conservation:** Legal protection can incentivize (benefit sharing) farmers to continue conserving and maintaining these crop varieties when they are utilized in plant breeding programmes by the scientists, which might otherwise be at risk of disappearing due to modern agricultural practices favoring commercial crops.
6. **Biodiversity conservation:** By protecting traditional and underutilized crop varieties, the PPVFR Act contributes to the conservation of agricultural biodiversity. This is important for food security and resilience in the face of changing environmental conditions.
7. **Encouraging research and development:** Legal protection can stimulate research and development efforts focused on underutilized crops, leading to their improved cultivation, increased yields, and better adaptation to changing agricultural needs.
8. **Promoting sustainable agriculture:** Underutilized crops are often well-suited to local ecosystems and require fewer chemical inputs. Protecting these crops can promote sustainable and eco-friendly agricultural practices.
9. **Food security:** Diversifying agriculture by protecting and promoting underutilized crops contributes to food security by reducing dependence on a few major staples, which can be vulnerable to pests, diseases and climate change.
10. **Cultural preservation:** Legal protection helps preserve traditional agricultural practices and crop varieties that have cultural and historical significance.

11. **Market access:** Protected varieties can gain better market access, potentially providing economic benefits to farmers who grow these crops.

12. **Research collaboration:** The PPVFR Act encourages collaboration between farmers, researchers and institutions to further the conservation and development of underutilized crop varieties.

13. **Expansion of genetic pool with exotic horticulture crops:** The introduction of exotic horticulture crops into India not only expands the genetic pool with desirable traits including resistance to diseases, improved yields, unique flavors, and adaptability to diverse environmental conditions but also underscores the importance of registering these new varieties under the PPVFRA. This legal protection is instrumental in promoting innovation, conserving genetic diversity, and ultimately contributing to food security and sustainable agriculture in India.

Current status of registration of some underutilized and exotic horticulture crops

The current status of registration for legal protection as per PPVFR Act, 2001 of underutilized and exotic horticulture crop species indicates that only a limited number of these crops have been applied for protection Table 2). There is a notable gap between the total number of crop species available and the number that has been applied for legal protection under various categories.

Promoting the registration and protection of underutilized and exotic horticulture crop species can have several benefits, including biodiversity conservation, farmer rights protection, and sustainable agriculture. Encouraging awareness and support for these efforts can help bridge the gap and ensure that more of these valuable crops receive the legal protection they deserve.

Table 2: List of some of the underutilized and exotic horticulture crops applied for legal protection at PPVFR Authority

Crop Name	Total number of applications received	Number of varieties registered	Number of applications applied under Farmers' Category	Other applicants (Public /Private)
Acid lime	26	-	22	4 (Public)
Ajwain	-	-	-	-
Anise	-	-	-	-
Aonla	-	-	-	-
Apricot	43	30	43	-
As gourd	-	-	-	-
Bael	16	-	16	-
Bakla/Faba bean	8	1	7	1 (Public)
Ber	-	-	-	-
Canna	1	-	-	1 (Public)
Cherry	1	-	1	-
Chironji	-	-	-	-
Chow chow	-	-	-	-

Custard apple	10	1	8	2 (1 Public & 1 Private)
Date palm	3	-	3	-
Elephants' foot yam	3	-	3	-
Ginger	79	3	76	3 (Public)
Isabgol	2	-	2	-
Ivy gourd	-	-	-	-
Jackfruit	18	2	18	-
Jamun	5	-	5	-
Kala jeera	-	-	-	-
Karanj	1	-	1	-
Kokum	-	-	-	-
Lesser yam	-	-	-	-
Mango	273	12	269	4 (Public)
Marigold	15	-	7	8 (Public)
Moringa	-	-	-	-
Mulberry	6	6	-	6 (Public)
Nigella	-	-	-	-
Noni	2	-	-	2 (Public)
Peach	6	-	6	-
Plum	-	-	-	-
Pomegranate	11	3	4	7 (Public)
Pummelo	-	-	-	-
Saffron	-	-	-	-
Sea buck thorn	4	-	4	-
Snake gourd	-	-	-	-
Spinach	2	1	1	1 (Public)
Strawberry	-	-	-	-
Taro	13	-	13	-
Turmeric	166	10	156	10 (Public)
Willow	4	-	4	-
Yam	-	-	-	-
Yam bean	-	-	-	-

Way forward

The proposed strategies for the way forward in promoting the conservation and utilization of underutilized horticulture crops are comprehensive and aligned with sustainable agriculture and biodiversity conservation goals. Here's a breakdown of each strategy:

1. **Collection, purification, documentation and conservation of neglected crops:** Initiating efforts to systematically collect, purify, document, evaluate and conserve the available crops in various agrobiodiversity spots across India is crucial. This will help preserve genetic diversity and ensure the availability of valuable plant resources for future generations by avoiding genetic loss.

2. **Mainstreaming Through Advanced Plant Breeding:** Integrating underutilized and exotic crop species into mainstream agriculture through modern plant breeding and biotechnology tools can enhance their economic and agricultural significance. This includes efforts to improve crop varieties for better yield, disease resistance, and nutritional quality.

3. **Omic Approaches and Nutrigenomics:** Conducting in-depth studies on the genomics, phenomics, and metabolics of underutilized crops using omic approaches and nutrigenomics can provide insights into their biology, nutritional value, and health benefits. This research can inform crop improvement strategies.

4. **Development of DUS Descriptors:** Developing distinct, uniform, and stable (DUS) descriptors is essential for the registration and legal protection of underutilized crop varieties under the PPVFR Act, 2001. These descriptors facilitate variety identification and protection. DUS descriptors are yet to be developed for many exotic horticulture crops like berries, bok choy, parsley, zucchini *etc*. due to non-availability of diversity. It is indeed essential to prioritize development of DUS descriptors for these exotic crops, especially considering increasing demand from private industries and also for the broader agricultural sector, food security, and genetic resource conservation in India. Immediate attention and proactive measures by PPVFRA are essential to harness the potential of these crops for the benefit of the country.

5. **Farmer Awareness:** Raising awareness among farmers about the benefits of conserving and cultivating underutilized crops is vital. Educating farmers on the economic and nutritional advantages of these crops can encourage their adoption.

6. **Utilizing Rice Fallows:** Using rice fallow lands to grow underutilized horticulture crops during non-rice seasons can optimize land use and diversify agricultural production. This approach can also help conserve water resources.

7. **Conservation of Traditional Knowledge:** Incorporating traditional knowledge and practices associated with underutilized horticulture crops into conservation efforts can enhance biodiversity preservation and promote sustainable agriculture.

8. **Consumer Awareness:** Educating consumers about the nutritional and health benefits of underutilized and exotic horticulture crops can create demand and market opportunities for these crops. Increased consumer awareness can drive the adoption of a more diverse and balanced diet.

These strategies collectively address the need to conserve genetic diversity, enhance agricultural sustainability, improve nutrition, protect farmer rights, and raise awareness among both farmers and consumers. Implementing these approaches in a coordinated manner can contribute to the promotion and mainstreaming of underutilized and exotic horticulture crops in India's agriculture and food systems.

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63. Role of FPOs in production and marketing of underexploited vegetables

Venkattakumar R.[1] **and Vasanthi C.**[2]

[1]Principal Scientist and Head, Division of Extension Systems Management, ICAR-NAARM, Hyderabad

[2]Young Professional-II, Division of Social Sciences and Training, ICAR-IIHR, Bengaluru

ABSTRACT

This research paper explores the integral role of Farmer Producer Organizations (FPOs) in the production, and marketing of underexploited vegetables in India. Underexploited vegetables hold substantial potential for bolstering food security, improving nutrition, and advancing sustainable agriculture. These crops thrive in diverse agro-climatic conditions, mitigating the risks of crop failure and addressing malnutrition, particularly among vulnerable communities. Moreover, their cultivation aligns with sustainable agricultural practices, offering economic benefits to small and marginal farmers and enhancing climate resilience. FPOs serve as crucial intermediaries, uniting small-scale farmers and providing access to resources, technology, and markets. They facilitate collective action, promote sustainable farming practices, elevate farmers' economic well-being, foster rural development, and contribute to environmental conservation. Through case study mode, this paper delves into the innovative approaches employed by FPOs to cultivate and market underexploited vegetables. Case studies of Puthari, Palamner, Rajaghatta, and Cheluru FPOs exemplify innovative approaches, including contract farming and direct marketing that have not only boosted farmers' incomes but also strengthened agricultural resilience. The study also highlights the challenges encountered by FPOs and offers insights to support the continued growth and impact of FPOs in enhancing farmers’ income.

Introduction

Underexploited vegetables serve as vital contributors to enhancing food security, nutrition, and sustainable agriculture in India. These often-overlooked crops offer a diverse array of nutrient-rich options that can thrive in various agro-climatic regions, diversifying agricultural systems and mitigating the risks of crop failure due to pests, diseases, or unfavorable weather conditions. With their rich content of essential vitamins, minerals, and dietary fiber, underexploited vegetables are instrumental in addressing malnutrition, especially among vulnerable populations. Their cultivation typically requires fewer synthetic inputs, aligning with sustainable agriculture practices, and their adaptability contributes to climate resilience. Furthermore, underexploited vegetables offer alternative income sources, thus promoting economic well-being among small and marginal farmers. In this context, farmer producer organizations (FPOs) have the potential to make a substantial impact by assisting farmers in cultivating underexploited vegetables in a scientifically sound and profitable manner, while also enabling efficient marketing, both domestically and on a global scale.

Farmer Producer Organizations (FPOs) play a pivotal role in transforming the landscape of Indian agriculture. (Venkattakumar *et al*, 2011; Venkattakumar and Sontakki, 2012; Venkattakumar *et al* 2018; Venkattakumar *et al* 2019 and Venkattakumar *et al* 2020) They serve as a vital bridge, mobilizing and uniting small and marginal farmers, and enabling them to operate within a business-oriented framework across the entire agricultural supply and value chain. This collective approach not only enhances the economic standing of individual farmers but also contributes to the overall sustainability of agriculture in India.

The concept of FPO represents a significant shift from traditional farming practices, where individual farmers often faced numerous challenges such as limited access to resources, fragmented land holdings, and inadequate market linkages. Through FPOs, these challenges are effectively addressed. By pooling resources and knowledge, smallholders can achieve economies of scale, which is essential for reducing production costs and increasing competitiveness. Furthermore, FPOs facilitate access to credit, technology, and modern agricultural practices, ensuring that farmers can adopt the latest innovations and best practices for crop cultivation.

In addition to the economic benefits, FPOs also serve as agents of social and rural development. They empower farmers by fostering a sense of collective responsibility and shared goals. Moreover, these organizations are instrumental in promoting sustainable farming practices, which are essential for long-term environmental conservation and food security. The collaborative nature of FPOs encourages the adoption of eco-friendly farming techniques and the reduction of harmful agricultural practices. This, in turn, contributes to the preservation of natural resources and the promotion of responsible agriculture, aligning with global sustainability goals. (Venkattakumar *et al* 2019)

The emergence and proliferation of FPOs in India represent a transformative force in the agriculture sector. By connecting small and marginal farmers to formal value chains, these organizations not only enhance farm profitability but also drive rural development and contribute to the sustainable future of agriculture in the country. Their role in promoting collective action, sustainable practices, and economic empowerment is pivotal in ensuring the well-being of farmers.

This paper delves into the exploration of the innovative approaches that FPOs have adopted to fulfill their objectives. Additionally, the paper provides an overview of the services offered by these FPOs, underlining their significance in supporting farmers. It discusses the emerging challenges that FPOs encounter during their operations. The paper draws valuable lessons from these FPOs' experiences, offering insights that can be applied by other FPOs with the aim of not only sustaining but also enhancing the income of farmers.

Methodology

The objective of this study was to document the best practices employed by Farmer Producer Organizations (FPOs) that have been promoted by various development departments, research organizations, and non-governmental organizations (NGOs) operating in Karnataka and Andhra Pradesh, India. Specifically, this research focuses on the production and marketing of vegetables.

The study involved several FPOs, including Puthari Horticulture Farmers Producers Company Limited in Kodagu, Palamner Horticulture Farmers Producers Company Limited in Palamner, Rajaghatta Horticulture Farmers Producers Company Limited in Rajaghatta, Venugopalaswamy Horticultural Farmers Producers Company Limited in Hosakote and Cheluru Horticulture Farmers Producers Company Limited in Cheluru.

A structured interview schedule was developed for this study. The data was collected through personal interview, focus group discussions (FGDs) and telephonic surveys conducted with these FPOs. The paper aims to present an overview of the services provided by these FPOs, as well as to highlight the emerging challenges they face in the course of their business operations.

Results and discussion

Initiatives by Farmers Producers Organizations (FPOs)

Model operated by Puthari HFPC, Kodagu, Karnataka

Puthari Horticulture Farmers Producers Company Limited, located in Kodagu district, Karnataka, operates with the primary goal of providing a wide range of services to its farmer-members in the region. This FPO is actively promoted and supported by Krishi Vigyan Kendra (KVK), Gonikoppa, Kodagu, Karnataka, which operates under the administrative jurisdiction of ICAR-Indian Institute of Horticultural Research (IIHR) in Bengaluru. KVK plays a crucial role by offering technological support to the FPO, enabling it to provide valuable services to its farmer-members. Additionally, KVK provides the FPO with a physical space to conduct various agricultural business activities.

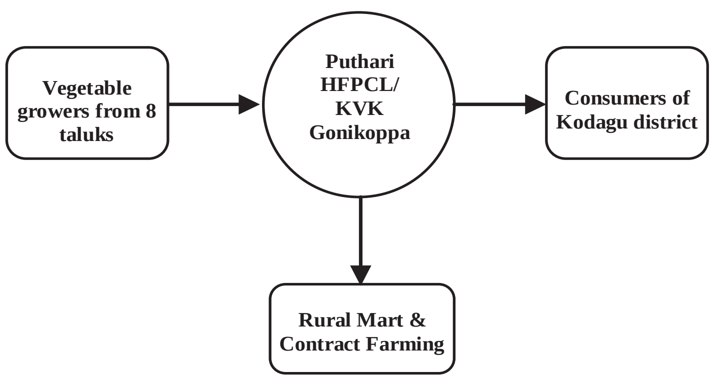

Fig 1. Model operated by Puthari HFPCL, Kodagu

During the lockdown period, the normal supply chain for fruits and vegetables was disrupted, leading to shortages for consumers in Kodagu district. Recognizing the critical need, the FPO took proactive steps to collaborate with horticulturists from eight taluks in Karnataka. They procured produce from these horticulturists and distributed it to consumers within the premises of KVK, Gonikoppa, Kodagu district. This initiative proved highly successful, prompting KVK to allocate a dedicated space for the FPO to operate a Rural Mart regularly.

Moreover, the FPO ventured into contract farming for vegetables in partnership with farmers who had previously collaborated during the lockdown period (Fig 1). The benefits reaped by farmers from selling their produce through the FPO during the lockdown were substantial, with prices ranging from Rs. 2 per kilogram for yard-long beans to Rs. 6 per kilogram for pumpkins (Table 1). This innovative approach, encompassing contract farming and the establishment of an exclusive Rural Mart at KVK, has emerged as a successful model, benefiting both farmers and consumers in the region.

Table 1. Benefit realized by farmers through Puthari HFPCL model

Crops	Net Price realized*		Additional benefit realized (Rs./kg)
	By non-FPO farmers (Rs. Kg)	By FPO farmers (Rs./kg)	
Pumpkin	3	9	6
Sweet potato	6	9	3
Elephant foot yam	6	12	6
Yard long bean	25	27	2

* Arrived at after accounting for transportation charges

Model operated by Palamner FPCL, Andhra Pradesh

Palamner Farmer Producer Company Limited, Palamner serves the farmers in Palamner taluk, Andhra Pradesh, by offering various extension services. These services include the supply of essential inputs such as seeds, planting material, fertilizers, plant protection chemicals, and farm tools, as well as assistance with the procurement and marketing of agricultural products. During the initial lockdown period of the COVID-19 pandemic, the FPO's farmer-members (300 to 400) encountered challenges in marketing their produce, particularly vegetables. In response, the FPO implemented a direct marketing strategy.

To address the demand for vegetables, the FPO identified three companies in Palamner with a workforce of approximately 7,000 employees. The FPO collected the orders from these companies and communicated them to local vegetable growers. The growers supplied the requested vegetables to the FPO, which then procured, graded, packed, and delivered the produce to the designated companies. This initiative not only ensured farmers received better rates compared to the market but also resulted in a profit of Rs. 1 per kilogram for the FPO. Furthermore, farmers benefited from reduced commission costs. This collaborative effort led to diversification in vegetable cultivation, with farmers expanding their crops to include items like green chili, ladies' finger, ridge gourd, bottle gourd, and bitter gourd, in addition to tomatoes, cauliflower, and cabbage. On average, approximately 3 tonnes of vegetables were supplied to the companies daily. Any surplus vegetables were distributed to apartments in Bengaluru and sold through roadside stalls arranged by the FPO. (Fig 2)

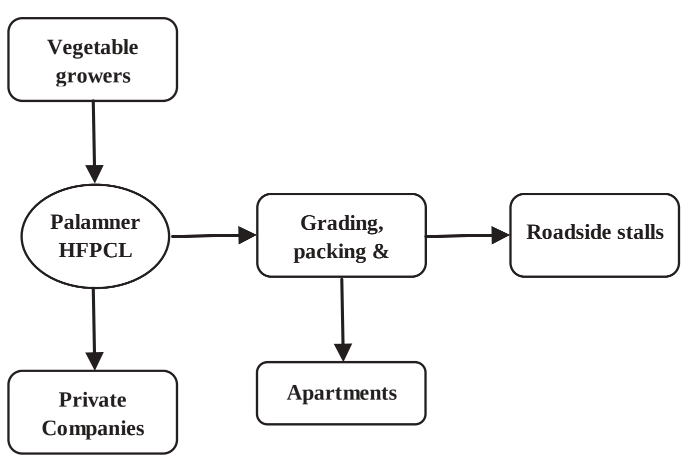

Fig 2. Model operated by Palamner FPCL, Andhra Pradesh

Additionally, vegetable growers gained access to interest-free COVID loans facilitated by the FPO through financial organizations. Consequently, the FPO is now planning to establish a primary processing center and acquire air-conditioned vegetable vending vans as part of the Operation Green project initiated by the Government of India. The data in table 2 provides an overview of the benefits realized by farmers through this model, with profit margins ranging from Rs. -1 per kilogram for bottle gourd to Rs. 9 per kilogram for Gongura, a green vegetable. Key takeaways from this model include branding vegetable sales under the FPO's name and the intention to establish a primary processing center and procure AC vegetable vending vans through the Operation Green project.

Table 2. Benefit realized by farmers through Palamner FPCL model

Crops	Net Price realized*		Additional benefit realized (Rs./kg)
	By non-FPO farmers (Rs. Kg)	By FPO farmers (Rs./kg)	
Ridge gourd	12	20	8
Gongura	18	27	9
Bottle gourd	8	7	-1
Raw banana	22	31	9

* Arrived at after accounting for transportation charges

Model operated by Rajaghatta Horticultural FPCL, Rajaghatta, Karnataka

The Rajaghatta Horticulture Farmers Producers Company Limited, located in Rajaghatta, Karnataka, caters to its producer members by providing essential agricultural inputs, including fertilizers, pesticides, weedicides, fungicides, organic manures, drip systems, sprayers, mulch materials, and more, all at wholesale prices through partnerships with various input companies and dealers. Additionally, the company establishes custom hiring centers for agricultural tools, implements, and machinery, collaborates with research institutes like ICAR-IIHR and UAS, Bengaluru, for technological inputs such as seeds and plantiing materials, and offers technical support through research institutes like the Department of Horticulture, Karnataka, and KVKs.

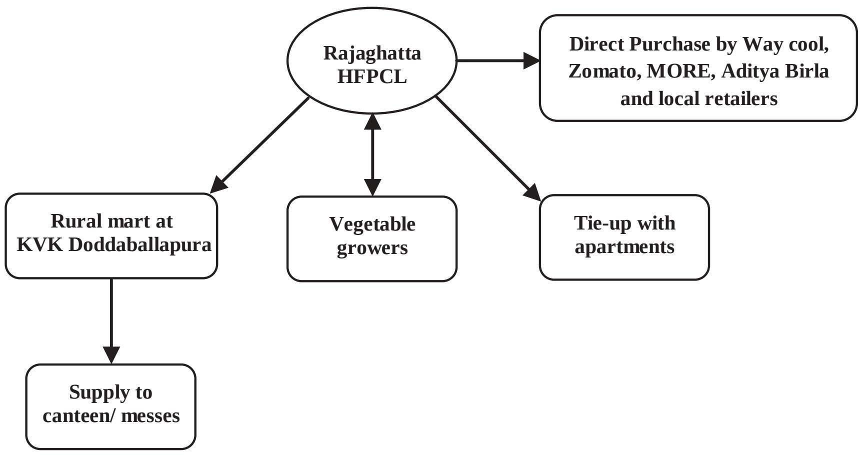

Fig 3. Model operated by Rajaghatta HFPCL, Rajaghatta, Karnataka

Furthermore, this FPO has expanded its support to member-farmers by engaging in output procurement. It has formed partnerships with companies like Waycool, Zomato, MORE, Aditya Birla, and local retailers for the direct purchase of vegetables from its members. In collaboration with KVK, Doddaballapur, Karnataka, the FPO facilitates the sale of producer members' produce at rural marts located at the KVK. These vegetables are then distributed through tie-ups with canteens and food messes within the district. Moreover, the FPO directly collaborates with apartments in Bengaluru to sell vegetables grown by its producer members (Fig 3). As a result of these efforts, FPO members have realized an additional benefit of Rs 4 per kilogram for Dolichos beans (Table 3)**.**

Table 3: Additional benefits realized by the producer members

Crops	Net price realized (Rs. Kg)		Additional benefits realised (Rs.kg)
	Non- FPO farmers (Rs. Kg)	FPO farmers (Rs. Kg)	
Ridge gourd	16	17	1
Dolichos bean	33	37	4

Model operated by Cheluru Horticultural FPCL, Cheluru, Karnataka

The Cheluru Horticultural Farmers Producers Company Limited, situated in Cheluru, Karnataka, is one among the FPOs established and promoted by the Department of Horticulture, Government of Karnataka. This FPO extends valuable support to its producer members through a range of comprehensive extension services. These services encompass the facilitation of input supplies at wholesale rates, through partnerships with fertilizer and pesticide companies and dealers. Furthermore, the FPO collaborates with companies specializing in the distribution of seeds, drip systems, and mulching materials. In conjunction with the Department of Horticulture, Karnataka, the FPO has also set up a custom hiring center, which offers farm tools, implements, and machinery for rent at highly competitive rates.

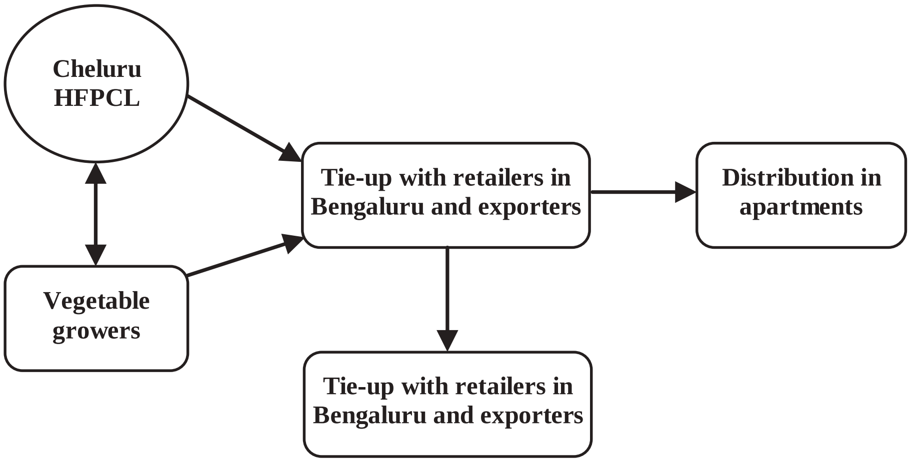

Fig 4. Model operated by Cheluru HFPCL, Cheluru, Karnataka

In the realm of output procurement, the FPO has established partnerships with companies and exporters such as DM Allium Seepa and Natural Rhizomes Pvt. Ltd. These entities undertake the grading, packaging, and distribution or exportation of the produce under their respective brands. This approach ensures that growers receive a more favorable procurement price compared to market rates, leading to substantial benefits for the FPO members (Fig 4). Notably, FPO members have realized additional benefits amounting to Rs. 10 per kilogram for Ridge gourd and drumstick produce (Table 4).

Table 4: Additional benefits realized by the producer members

Crops	Net Price realized		Additional benefits realised by the FPO members (Rs.kg)
	Non- FPO farmers (Rs. Kg)	FPO farmers (Rs. Kg)	
Ridge gourd	18	28	10
Drumstick	28	38	10

Model operated by Venugopalaswamy HFPCL, Hoskote, Karnataka

Venugopalaswamy Horticultural Farmers Producers Company Limited, located in Hoskote, Karnataka, receives vital support from the Department of Horticulture, Government of Karnataka. This FPO extends its assistance to its producer-members by facilitating the procurement of various agricultural inputs like fertilizers, chemicals, drip systems, mulch materials, sprayers, and other essential equipment at wholesale prices. It has established a custom hiring center where farm tools, implements, and machinery can be rented at affordable rates. Additionally, the FPO plays a pivotal role in supporting its members, predominantly vegetable growers by facilitating the marketing of their produce.

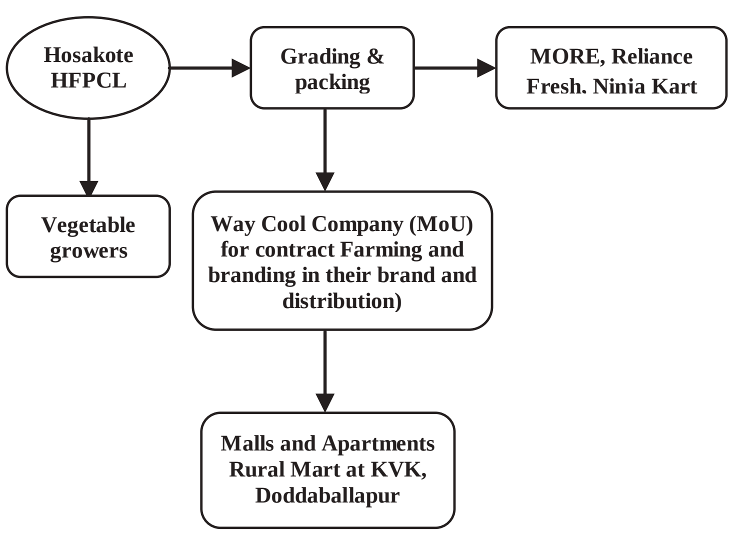

Fig 5. Model operated by Venugopalaswamy HFPCL, Hoskote

The FPO engages in the collection of vegetables from its members, sorting, grading, and packaging them. These vegetables are then distributed to retailers such as MORE, Reliance Fresh, Ninja Kart, and others under the FPO's own brand name. Furthermore, Venugopalaswamy HFPCL has made a partnership with Waycool Company, which, in turn, enters into contracts with the FPO's producer-members for contract farming at mutually agreed-upon procurement prices. The company procures, grades, packages, and distributes these agricultural products under its own brand name to malls and apartments. This symbiotic relationship enables producer-members to reap additional monetary benefits, with the incremental profits ranging from Rs. 5 per kilogram for cabbage to Rs. 10 per kilogram for French beans, enhancing their financial well-being compared to their fellow farmers.

Table 5: Additional benefits realized by the producer members

Crops	Net Price realized		Additional benefits realized (Rs.kg)
	Non- FPO farmers (Rs. Kg)	FPO farmers (Rs. Kg)	
Cabbage	5	10	5
French bean	28	38	10

Challenges faced by FPO and implicative strategies (Venkattakumar and Narayanaswamy, 2022)

Farming Producer Organizations (FPOs) in India play a vital role in supporting and empowering agricultural communities, but they face numerous challenges in their mission. One major issue is the lack of recognition as essential business partners by input companies. This recognition is crucial because it grants FPOs access to vital resources necessary for their operations. To address this, development departments facilitating FPOs should prioritize implementing policy guidelines that establish FPOs as recognized partners of input companies, thus ensuring a smoother flow of resources.

Another obstacle for FPOs is the requirement to own immovable properties as collateral for establishing infrastructure, such as rural marts. Relaxing this collateral requirement can help FPOs receive assistance for infrastructure development, which is essential for promoting the growth of agricultural infrastructure, especially in rural areas.

Market tie-ups with retail operators can be challenging, but FPOs can overcome this by creating a unique brand for marketing their products within the region. This branding strategy can enhance visibility and credibility, increasing the success rate of their market ventures. However, operational costs during the initial years can be a significant hurdle, so providing assistance in meeting these costs is crucial for establishing a strong foundation for long-term sustainability.

FPOs need innovative marketing strategies, but may lack the necessary resources and expertise. Specific support programs can provide financial and licensing support for the effective development and implementation of innovative marketing strategies. Additionally, taxation can be burdensome in the early years, so governments can consider granting tax holidays, particularly in the first five years.

Establishing uniform criteria for providing matching grants across commodities is challenging. However, implementing differential criteria based on factors like landholding size and geographical region can ensure equitable provision of equity matching grants to all FPOs, fostering a more inclusive and fair system.

Social conflicts and differences in ideology among producer members can hinder progress. Collaborative efforts with non-governmental organizations (NGOs) can facilitate social engineering initiatives to promote harmony and cooperation among members. Moreover, many FPOs lack experience in branding and profitable business processes. To address this gap, engaging business consultants to guide clusters of FPOs in developing innovative business strategies, enhancing branding, and maximizing profitability is essential.

Shortage of technical manpower at the grassroots level can impede operations. Encouraging technical manpower support through NGOs can ensure the availability of agro-advisory services and promote business processes at various levels. Furthermore, addressing patronage loyalty among producer members is essential to prevent it from restricting growth and effectiveness. Stringent guidelines can be formulated to mitigate patronage loyalty, ensuring members' commitment to supporting FPOs for collective benefit.

Lastly, arranging credit facilities and crop insurance for FPOs and their members is a challenge. Identifying suitable financial organizations and establishing collaborations with them on a cluster basis can ensure FPOs have access to necessary financial resources and insurance coverage, promoting financial stability and resilience. In conclusion, addressing these challenges through policy support, financial assistance, and collaborative efforts is crucial for the sustained growth and success of Farming Producer Organizations in India.

Conclusion

This research paper highlights the profound interplay between underexploited vegetables and Farmer Producer Organizations (FPOs) in agricultural landscape. The paper underscores the transformative impact of FPOs in shaping the status of underexploited vegetables. These organizations serve as vital conduits, bridging small-scale farmers with essential resources, technology, and markets. Their advocacy of collective action and sustainable farming practices elevates individual farmers' economic prospects and catalyzes rural development. FPOs play a pivotal role in connecting these underexploited vegetables to larger markets, amplifying their impact on food security and farmers' livelihoods.

The case studies of Puthari, Palamner, Rajaghatta, and Cheluru FPOs illustrated how these organizations have effectively addressed challenges and diversified their operations, benefiting both farmers and consumers. Through innovative approaches such as contract farming and direct marketing, these FPOs have not only increased farmers' incomes but also enhanced the resilience of the agricultural sector. To ensure their sustained growth and success, policymakers, development departments, and NGOs must provide support in overcoming challenges, including recognition, infrastructure, market linkages, and financial stability, thereby enabling FPOs to continue playing their vital role in advancing India's agriculture.

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64. Technological Interventions for Improving the Market Potential of Underutilized and Exotic Flower Crops

T. Janakiram[1*], M. Lakshmi Durga[2] and P. Pratyusha[3]

[1]Vice Chancellor, Dr. YSR Horticultural University

[2]Assistant Professor, Dept. of Horticulture, ANGRAU

[3]Ph.D Scholar, BCKV, West Bengal

*Email: vc@drysrhu.edu.in

Introduction

The floriculture industry is constantly striving for new cultivars and species of flowers to enliven the consumers and diversify production. Present over-reliance on mainstream flower crops like rose, chrysanthemum, carnation, gerbera and tulip in cut flowers, marigold, jasmine and tuberose in loose flowers has inherent agronomic, ecological and economic risks and is probably unsustainable in the long run. Modern horticultural systems that promote cultivation of a very limited number of crop species have downgraded indigenous crops to the status of neglected and under-utilized crop species (NUCS). Underutilized flower crops constitute a portion of agro biodiversity that are mainly produced and consumed by local, national or even international communities around the world, and can play an important role in the future of flower industry. They have the potential to build more resilient, climate-smart agriculture, and revitalize local culture and tradition. These underutilized crop species have also been described as "minor", "orphan", "promising" and "little-used". Promotion and the use of 'NUCS' in the diversified farming systems helps in strengthening the flower industry by ensuring aesthetics, value addition and income generation apart from achieving United nations Sustainable Development Goal's. Importantly, NUS, which include crop wild relatives, are an important germplasm resource for future crop improvements for beneficial traits.

The uniqueness of the ornamental flora, either indigenous/exotic has been the focus of international interest, and consumers are showing a growing attentiveness on plethora of features such as flower trade, corporate landscaping as well as value addition. As the income from flowers, is higher than that from food crops, farmers prefer to grow such high value crops. Therefore, there is good opportunity for farmers to take up cultivation of new and underutilised flower crops which can be sold easily, while generating additional income.

1. Cut flowers

The cut flower industry is evolving rapidly as a result of improved transportation facilities and innovative export systems. There is considerable research interest in selecting new species and breeding new cultivars of *Achillea, Aechmea distichantha, Agapanthus, Arctotis, Astilbe, Bulbinella, Crocosmia, Clivia,* Orchid genus *Disa, Eucomis, Erica, Haemanthus, Ixia, Lachenalia, Leucadendron, Leucospermum, Lobelia, Mimetes, Nerine, Nymphaea, Ornithogalum, Osteospermum, Protea, Serruria, Sparaxis, Strelitzia, Tulbaghia, Watsonia and Zantedeschia* for the cut flower industry. The orchid genus *Disa*, comprising of more than 130 species, is increasingly sought after as a cut flower and potted plant, so that research on its cultivation has become an important priority. The orchid sps. *Schomburkgia crispa*, with long and exuberant floral stems, emphasizes its potential use for ornamental horticulture. Delphinium, snapdragon, stock, offer an excellent opportunity to be introduced as cutflowers in local markets because of their easy culture and magnificent flowers with acceptable longevity.

2. Tropical flower and ornamental crops

The tropical families, Zingiberaceae, Costaceae, Heliconiaceae, Musaceae, and Marantaceae has contributed many exotic cut flowers such as Alpinia, Ginger, Curcuma, ornamental Musa, Strelitzia, and foliage Maranta. These large-flowered tropicals are considered as a niche product and finding place in the international Dutch market. They are used in arrangements for special events or where large displays are required such as hotel lobbies and gatherings. Various sps. of heliconia, alpinia and strelitzia are already explored and are being utililsed in the commercial cut flower industry. The *sps.* yet to find their place for their diversified uses are given here under:

Costus

Costus are perennial herbs also known as spiral gingers for their spiral phyllotaxy and twisting stems. The species suitable for indoor plant cultivation are: *C. curvibracteatus, C. amazonicus,* C. *erythrophyllus, C. malortianus, C. cuspidatus and C. lasius*. Individual flowers last for a day, so it is the inflorescence structure that finds use as a cut flower.

Curcuma

Among the underutilized turned commercial cut flower scene, the genus *Curcuma* has risen to be one of the top ten among tropical flowers on the Dutch auction. Floriculturally important species appearing in the markets that have a scope for area expansion are *C. amada, C. angustifolia, C. cordata, C. ornata, C. roscoeana, and C. zedoaria and C. alismatifolia*.

Etlingera

Species of Etlingera tend to be found in shady forests. *Etlingera elatior* is the most widely grown of the genus and finds use as a vegetable (the young inflorescence), cut flower and in the landscape. *E. corneri* (red bracts) and *E. venusta* (pink bracts) are on their way to attain a status from underutilized to commercial cut flowers.

Globba

Globba species has a merit for garden landscapes, potted plants, and cut flowers. *Globba magnifica* and *G. schomburgkii*, has the potential as cut flowers as their bracts last up to six weeks.

Hedychium

H. coronarium, is regarded as tropical and not suited for outdoor culture in temperate regions. The major horticultural use of *Hedychium* species has been as landscape plants. *H. coccineum H. densiflorum, H. flavescens, H. gardnerianum, H. greenii* and *H. spicatum* and *H. gardnerianum* can be explored further for diversified uses.

Marantaceae

With colorful, patterned foliage, *Calathea*, *Maranta*, and *Ctenanthe* species are best known as foliage houseplants, but among the cut flower types the genera *Calathea*, *Stromanthe*, and *Pleiostachya* have yet to be explored. *C. crocata* is noted for colorful foliage as *889-well as an inflorescence siu*porting orange flower could be used as a cut flower.

Musa

Two sections of Musa, Callimusa and Rhodochlamys offer some smaller species with colorful bracts that can be grown in large containers in indoors. *M. coccinea* with scarlet bracts; *M. ornata*, with purplish-pink bracts, and *M. velutina*, with pale purplish bracts *E. lasiocarpum* with rarely red-orange bracts could be used in floral designs.

Tapeinochilos

T. ananassae, known as Indonesian wax ginger or pineapple ginger species is locally used in South Africa for its long lasting cut flowers. Other sps. that have a scope to be researched for ornamental industry are *T. recurvatum, T. dahlii, T. hollrungii, T. palustris, and T. novaebudaensis*.

3. Potted plants

Potted flowers have become an important part of the florist trade and interesting new cultivars are being explored for this expanding market. *Pelargonium zonale* and *P. peltatum*, *Plectranthus* sps., Ornithogalum, Lachenalia opened up their wings to rule the international market. Bulbous plants are likely to become commercially available as potted flowers. The most likely candidates include *Albuca, Androcymbium, Aristea, Babiana, Bulbinella, Cyanella, Cyrtanthus, Daubenya, Empodium, Eucomis, Ferraria, Freesia, Geissorhiza, Gethyllis, Gladiolus, Haemanthus, Hesperantha, Hessea, Hypoxis, Ixia, Lachenalia, Lapeirousia, Ledebouria, Massonia, Moraea, Nerine, Ornithogalum, Ornithoglossum, Polyxena, Rhodohypoxis, Romulea, Sparaxis, Spiloxene, Strumaria, Syringodea, Tritonia, Tulbaghia, Veltheimia, Wachendorfia, Walleria, Watsonia and Wurmbea. Miniature succulents, which are ideally suited for container cultivation, including the genera Argyroderma, Conophytum, Gibbaeum and Lithops (Aizoaceae), Adromischus, Crassula, Kalanchoe and Tylecodon* (Crassulaceae) and *Haworthia* (Xanthorrhoeaceae). *Odontonema strictum* of Acanthaceae family, is an evergreen herbaceous perennial species that was researched and found suitable to be cultivated for pot plant production.

There is a almost limitless potential for developing new horticultural crops for the trade in potted flowers. Some attractive species are presently considered to be unsuitable because of practical difficulties relating to propagation, cultivation, irregular flowering, short flowering periods and poor adaptability. However, it is likely that the premium on novelty will increase in the future and that modern biotechnology will be used to overcome inherent flaws in order to create viable new crops.

4. Foliages/greens

Products marketed as foliage or florist "greens" include bamboos, sedges, reeds, ferns and grasses. *Bouteloua gracilis* (Blonde Ambition Blue grama grass) is highly ornamental appreciated for its beautiful seed heads. Gramma grass is drought tolerant and low maintenance plants making it an excellent choice for xeriscaping and naturalistic landscapes. Cut foliages like *Eucalyptus pulverulenta*, *Nephrolepis exaltata*, *Nephrolepis biserrata*, Nephrolepis cordifolia are used as fillers. *Pteris vittata* fronds can be used in various flower arrangements. *Asparagus densiflorus sprengeri* can be used floral designs and serves as excellent greenery in delicate flower bouquets. *Adiantum*, *Aglaonema*, *Alocasia*, Alpinia, *Arachniodes*, *Rumohra*, *Ardisia*, *Aspidistra*, *Caladium*, *Calathea*, *Chamaedorea*, *Chrysalidocarpus*, *Codiaeum*, *Cordyline*, *Cyrtomium*, *Davallia*, *Dracaena*, *Epipremnum*, *Fatsia*, *Hedera*, *Nageia*, *Philodendron*, *Pittosporum*, *Podocarpus*, *Polyscias*, *Spathiphyllum and Syngonium* are widely used as potted foliage plants and the leaves of these plants have the potential to be used as greens. Some plants listed require further evaluation to be proven and as economical for cut foliage. The commercial cultivation of these cut foliage species can serve as a highly profitable enterprise for improving the livelihood of farmers.

5. Edible plants

The benefits and nutritional profile of edible flowers as sources of fibre, protein and low lipid content make them attractive to vegetarians and align well to the growing consumer demand for vegetarian, natural and healthy foods. The increasing interest in bioactive components makes edible flowers appealing for their potential to be used as nutraceuticals and in the development of functional foods. Edible flowers

Table 1. Exotic and underutilized flora as edible flowers

Scientific name	Common name	Family	Edible use	Medicinal use
Althea rosea	Hollyhock	Malvaceae	Tea	Skin care
Bauhinia variegata	Orchid tree	Fabaceae	Vegetable	Anti-diabetic
Bombax ceiba	Silk cotton tree	Bombaceae	Vegetable	Skin care, haemorrhoids
Clitoria ternatea	Butterfly pea	Fabaceae	Dessert and beverages	Anti-diabetic
Gardenia jasminoides	Cape Jasmine	Rubiaceae	Salad and Tea	Hepato-protective antidepressant, and anti-inflammatory activity
Hemerocallis fulva	Day lily	Liliaceae	Vegetable	Inflammation, indigestion and depression
Hibiscus rosa sinensis	China rose	Malvaceae	Tea, food	Cough, fever and genital urinary troubles
Jasminum sambac	Arabian jasmine	Oleaceae	Teas	Cancer, ulceration, uterine bleeding, skin diseases and wound healing
Lonicera japonica	Honeysuckle	Caprifoliaceae	Teas	Fever, carbuncles and some infection diseases
Madhuca longifolia	Mahuwa	Sapotaceae	Mahua liquor,	Essential oil, syrup, jam, and flour

Nelumbo nucifera	Lotus	Nelumbonaceae	Seasoning, Perfumery	Sleep aid, anxiety remover, anticoagulant
Rhododendron arboretum	Burans	Ericaceae	Squash beverages, preserve	Heart disease, dysentery, diarrhoea, detoxification, inflammation, fever, constipation, bronchitis and asthma
Rosa spp.	Rose	Rosaceae	Tea, salad, cakes, flavour extracts	Cancer, inflammation, ageing, heart diseases
Aponogeton distachyos	Water Hawthorn	Aponogetonaceae	Inflorescence as vegetable	Sun burns
Metroxylan sagu	Sago palm	Arecaceae	Fruit	Healthy urine production, anti-inflammatory and anti-cancer.
Adansonia digitata	Boabab tree	Malvaceae	Stem, leaves and fruits	Cancer, blood pressure, ulcers, inflammation, diabetes, diarrhoea, malaria and fever

6. Shrubs

Jatropha (*Jatropha curcus*)

It is oilseed bearing shrub, planted across the country as a fence plant, which is gaining importance as a biodiesel crop in India, although there are doubts about its tolerance to drought, yield and profitability. Jatropha being a shrub, can be maintained as a fence crop and shrubbery in landscaping.

Safflower *(Carthamus tinctorius),* Asteraceae

It is a multipurpose oil seed crop not only used for its high quality oil, can also be used for its cut flowers, dry flowers, coloring and flavouring foods, making dyes (Carthamin) for the textile industry, varnishes in the paint industry, making herbal teas and for medicinal purposes. In china, it is grown as a medicinal plant for the treatment of cardiovascular diseases, male and female sterility, lowering blood cholesterol, release of retained placenta and still birth, various types of rheumatism, respiratory diseases and gastritis.

Plectranthus (Lamiaceae)

It is a significant, prolific and extensively used genus for its dominant role in both horticulture and traditional medicine. It is an important garden flower for its use as ground cover, hanging baskets, potted plants, rockeries, container gardening and bonsai. *Plectranthus* is a genus with ethno botanical uses such as respiratory, digestive, liver complaints, skin, genitor urinary, and as a cure for nerve related diseases.

Ornamental sun flower (*Helianthus annuus*)

Unleashed its potential for phytoremediation to reduce the harmful effects of chemical pollutants such as metals and organic compounds in contaminated soils apart from its use as ornamental cut flower and landscape plant.

Strobilanthes (Acanthaceae)

It is recently explored as indigenous ornamental shrub suitable for garden display and as border plant in the garden.

Table No. 2: Some underutilized and exotic flowers with their scientific name, family and potential use in floriculture and their ethno botanical uses is given here under:

Common name	Scientific name	Family	Potential use
Ornamental Amaranth, love-lies-bleeding	*Amaranthus caudatus*	Amaranthaceae	Showy flowers used as herbaceous borders. Seeds are roasted, ground into flour, boiled, dried and stored, sprouted, or even fermented for beverages. Leaves are treated as a vegetable
Borage	*Borago officinalis*	Boraginaceae	Edible leaves. Plant is grown in gardens for attractive purple flowers. treats gastro intestinal and cardio vascular problems
Boronia	*Boronia fraseri*	Rutaceae	Perfumery and cut-flower
Christmas bells	*Blandfordia nobilis*	Blandfordiaceae	Pot plant
Geraldton wax flower	*Chamelaucium uncinatum*	Myrtaceae	Home gardens and cut flower industry. Leaves are used as a flavouring agent
Heath	*Epacris impressa*	Ericaceae	Garden plant. Best pollinator plant
Kangaroo paw	*Anigozanthos manglesii*	Haemodoraceae	Cut flower
Lisianthus	*Eustoma russelianum*	Gentianaceae	Cut flower
Lobelia	*Lobelia cardinalis*	Companulaceae	Bedding and borders
Montbretia	*Crocosmia aurea*	Iridaceae	Edge plant, late season summer flowering bulbous plant
Overberg pinchushion	*Leucospermum oleifolium*	Proteaeceae	Garden plant and as cut flowers in floral arrangements
Pink mulla mulla	*Ptilotus exaltatus*	Amaranthaceae	Filler in flower arrangements.

Protea	*P. neriifolia*	Proteaceae	Cut flower
Rice flower	*Ozothamnus diosmifolius*	Asteraceae	Cut Flower
St. Johnswort	*Hypericum perforatum*	Hypericaceae	Herbaceous flowering plant, landscaping. Anti- depressant
Amaryllis	*Amaryllis belladonna*	Amaryllidaceae	Pot plant and bedding. Lycorine and tazetine in leaves and bulbs acts as emetic, analgesic, hypotensice effects
American lotus	*Nelumbo lutea*	Nelumbonaceae	Rhizome is used as a food source. Seeds are edible. Root is grounded to pulp, dried and used as a poultice
Brahma Kamal	*Saussurea obvallata*	Asteraceae	State flower of Uttarakhand. The flowers are used in Ayurvedic medicine. Works against bone ache, respiratory and urinary tract infections and paralysis of limbs
Brazilian pepper	*Schimus terebinthifolius*	Anacardiaceae	Flowering shrub with bright red berries. Astringent, anti bacterial, diuretic, digestive stimulant, tonic and wound healer
Hippeastrum	*Hippeastrum reginae*	Amaryllidaceae	Ornamental indoor pot plant. Bulb is anti depresseant, anti convulsant and anxiolytic property
Lily of valley	*Convallaria majalis*	Asparagaceae	Ground cover, and fragrant cut flower. Cardiotonic, anti spasmodic, emetic, diuretic, febrifuge, laxative and sedative.
Lobster claws	*Heliconia stricta*	Heliconiaceaae	Floral decorations and flower arrangements Rhizome is used against diabetes
Mares tail	*Eregiron canadensis*	Asteraceae	Filler in flower arrangements. Treatment of wounds, swellings, and arthritis
May weed Chamomile	*Anthemis cotula*	Asteraceae	Annual flowering plant. Anti spasmodic, astringent, diaphoretic, diuretic and tonic
Melaleuca	*Melaleuca quinquenervia*	Myrtaceae	Ornamental tree. Aromatic leaves are used to treat colds, cough, Nuralgia, and rheumatism

Rebe flower	*Begonia tessaricarpa*	Begoniaceae	Found in Assam recently by Botanical Survey of India. The juice of the plant is used as leech guard.
Crinum lily	*Crinum woodrowii*	Amaryllideceae	Flowers fragrant and used as bedding, borders and pot plant. *C. asiaticum* is used to treat tonsillitis, mumps, hernia, edema and rheumatism.
Ylang Ylang	*Cananga odorata*	Annonaceae	Extraction of essential oil, perfumery and aromatherapy, flavouring agent and adjuvant.

7. Marketing strategies for utilization of neglected and underutilized crops

Floriculture thrives on novelty and plays a major role in the subsistence of local communities and frequently is of special social, cultural and aesthetic value. To satisfy this demand, there is a constant effort to develop products from diverse sources. In the initial days, the demand may be restricted to local community users, rural areas, or members of a community who use underutilized plant species products in a traditional fashion. There is an utmost need to give guidance and knowledge to new consumers about the use of underutilized crop sps. Market the novel products in the most desired and tempting way by displaying the quality, price and information and mode of usage. To ensure better price for the produce, cool chain facilities and value chain management have to be established in the project areas. Inclusion of these novel crops in local, regional and national agricultural development programmes may raise the awareness of multi faceted benefits that aids in marketing.

Institutional strengthening is also important, and may involve reinforcing farmer associations or cooperatives, or establishing Self-Help Groups (SHG), such as those being promoted in India for the cultivation, processing and marketing of various products and which are opening up micro-credit opportunities for members of poor communities, enabling them to start small entrepreneurial activities for these crops. Of late, Farmer Producer Organizations (FPO’s) plays a pivotal role in promoting the use of NUS and acting as a means for their dissemination in terms of both knowledge and material. Farmer varieties should be exchanged between and among farmer organizations not only within a country but also abroad keeping in view of the climate change. The activities of farmers as practical plant breeders must not be ignored for selecting the elite material in a responsible manner with due respect for seed quality and Phyto sanitation.

National, regional and international synergies are very much needed to strengthen the cooperation among stakeholder groups. Coordination to promote NUS at different levels is necessary in order to share lessons and avoid duplication of work.

Participation of different stakeholders needs to be promoted along the whole value chain from farm to home. Representatives from farmers, civil society organizations (CSOs), non-governmental organizations (NGOs), research agencies, and private- and public-sector representatives, including policy-makers, need to be well represented so as to allow the creation of multi-stakeholder platforms as such platforms have played a strategic role in the promotion of several crops.

As women are often key producers and users of traditional crops, effective research and development of NUS also requires a gender-responsive approach. Mainstreaming the role of women in popularizing the NUS and should be given leadership in conservation of plant material.

As dealing with NUS is an Inter disciplinary approach, several disciplines need to be closely involved with sustainable use and enhancement of NUS. Genetic resources experts need to work in synergy with the florists, livelihood experts, economists, nutritionists, business people, anthropologists, sociologists, environmentalists, economic development specialists, need to be involved.

8. Challenges

Overall, the slow progress and poor popularity in the effective development and utilization of underutilized flower crops results from a number of constraints given here under:

- There is a lack of sustained and informative research on the same field. A spectacular wide strategy has to be developed for underutilized crops for the benefit of mankind. Exploratory research has to be conducted for elite germplasm collection of wild and neglected species, improving the desirable traits in promising species by breeding and biotechnological approaches, ensure the production of superior quality produce, standardization of various agronomic practices for their large-scale exploitation, and the popularization of unpopular crops among farmers, policy makers, and other stakeholders.
- It is essential to validate their adaptability, demand for the produce and profitability in comparison to the alternative crops grown in the region. It is easier to promote food crops because of the local market but difficult to promote non-food crops like flowers and without prior market linkage. Hence, it is advisable to introduce such crops on a small scale, Subsequently, successful species can be replicated on a large scale.
- Production, post harvest handling, processing, products development and storage of fresh and processed products needs to be addressed as inadequate infrastructure facilities cripple the marketing prospects. It would require a strong advocacy, policy support, research and development effort, and resource allocation.
- There is a lack of access to production and utilisation information about these crops that makes their adoption risky. A globally accessible database of NUCS of flower crops may be created that can be used to store information regarding crop, nutrition, agro advisory and marketing information that assist in agricultural diversification.
- Better access of producers to markets, validation and promotion of aesthetic and nutritional benefits, more effective maintenance of genetic and cultural diversity on-farm, sustained capacity building of stakeholders groups, and policies at national and international level for supporting the sustainable conservation and use of these crops
- Lack of relevant extension services and input subsidies and low crop yields as many underutilized crops are grown in agronomically poor areas. Extension activities through Krishi Vigyan Kendras, inline agriculture and horticulture departments and state agri/horti universities should be aimed to popularize the products and government subsidies should be given in support of cultivation and marketing
- Poor economic competitivity: Rural poor areas have little capacity to negotiate with the private

sector, thus excluding the possibility of access to new technologies and markets that could increase the potential of these locally used crops

- National and international policies have so far aimed at the protection mainly of crop varieties that are uniform, distinct and stable (in line with the DUS (Distinctness, Uniformity and Stability. Legal protection of NUS (wild or cultivated) is very limited and should receive greater attention.
- Funding limitations and inadequate access to, or quality of, facilities often constrain NUS researchers. There is much room for improvement of external support, including policy support for NUS research.
- Promotional and educational efforts by food advocates about edible flowers at public events help raise consumer awareness, which is generally lacking. Limited geographic and seasonal availability, perishability, price and quality issues emerged, together with low awareness, as main barriers to more frequent and geographically spread consumption.

Conclusion

International trade in plants and flowers is growing. This trend will continue for the coming years, because of the digitisation and virtualisation of the horticultural world. One of the major gains in India is the upswing in the domestic market. Owing to the present as well as the future preferences in the floriculture industry combined with the alarming menace of climate change, it is high time to realize the importance of under-utilized flower crops. There is an urgent need to promote/revive indigenous crop varieties and reverse the loss of agro-biodiversity caused due to market drivers. The underutilized flora in the commercial trade could be achieved through appropriate, timely documentation of indigenous knowledge, empowerment of local communities to recognize their own identity and culture, giving 'national flower status' to neglected crops and exploring diversified uses of different flora. Encouraging the wider use of these vanishing crops and associated wisdom should be a priority for governments, who should work on how to blend traditional resources with the outcome of scientific experimentation. NUS are neither 'Flowers for the poor' nor 'New' patentable products to the private stakeholders. On-farm and *Ex-situ* conservation programme should be taken up for their valorization and use enhancement in harmony with traditional rights, cultural identity, ecosystem integrity and gender equity principles. The reasons that limit their full use must be identified and scientific community must be engaged to carry out research on all these crops and popularize them as commercial crops. Investments in developing higher education teaching courses and programmes related to biodiversity have to be introduced for scaling-up of innovations on neglected and underutilized flower crops.

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65. Intellectual property rights and plant genetic resource management in underutilized and exotic flower, medicinal and spice crops

Hanchinal R.R.

Former Chairperson,

Protection of Plant Varieties & Farmers Rights Authority, Govt of India

Email: rrhanchinal@rediffmail.com

ABSTRACT

Today we are living in the era of knowledge economy. Innovation is the key for the production as well as processing of knowledge. For converting knowledge in to wealth, protection and evaluation of Intellectual Property (IP) are going to become critically important. The origin of IP is linked with the industrial revolution. The ratification of General Agreement on Tariff and Trade (GATT) led to the establishment of World Trade Organization (WTO). Under the broad umbrella of WTO, the International agreements were signed by convention countries. These agreements of particular significant to seed are: Trade Related Aspects of Intellectual Property Rights (TRIPS); Convention on Biodiversity (CBD); International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA); Nagoya Protocol; International Union for the Protection of New Varieties of Plants (UPOV); The Plant Cooperation Treaty (PCT); Cartagena Protocol and Geographical Indications (GI). India is a signatory to all the treaties except UPOV, India has an observer status for UPOV. Indian Plant Variety Protection and Farmers' Rights Act, 2001 is unique to benefit the national situation yet matching with larger global commitment. It attempts to optimize and balance claims for protection by both plant breeders and farmers. Other agreement also promote sustainable use of PGR and fair and equitable sharing of benefits arising from the utilization of genetic resources.

Introduction

Today the world has undergone great transformation in the recent years that is reflected by the replacement of material based society to knowledge based society. The golden saying in our culture "knowledge will increase when it is shared" has lost its significance. We are currently living in an era of encashing the knowledge. President Lincoln once remarked that "patent system adds fuel of interest to the fire of genius". Monetizing the innovations and invention is beneficial to the inventor and society. Innovation is the key for the production as well as processing of knowledge. A nation's ability to convert knowledge into wealth and social good through the process of invention will determine its future. In this, context, issues of generation, valuation, protection and exploitation of Intellectual Property (IP) are going to become critically important all around the world. Bill Gates used to say "IP has the shelf life of a banana". The saying is true considering the rapid pace of technological development and transfer taking place in the world. The process of globalization has posed major challenges to developing countries in the context of emerging regime of IP protection. In the beginning, in many developing and underdeveloped countries Intellectual Property Rights (IPR) was disadvantages due to the "patent illiteracy", when Trade Related aspects of Intellectual Property Rights (TRIPS) Agreement was implemented.

Protection of IP is extremely important to supporting and driving innovations. IPR have been created to ensure against unfair trade practice. The IPR could be academic credit for creating something new or it might be allowing an investor to recoup his research and development financial investment. As the world becomes more complex, innovations will also become more complex, which in turn leads to research and development, investments becoming more complex and more expensive. IP will no longer be seen as a distinct or self-contained domain, but rather as an important and effective policy instrument that would be relevant to a wide range of socio-economic, technological and political concerns (Mashelkar, 2001).

IPR has emerged as a vital component of global corporate strategy. It provides a means to restrict unfair trade practices owing to the crucial role of IP in knowledge and innovation driven wealth creation, there is an obvious rationale for providing a healthy and global system for protection of IPR. The key drivers of economic growers of technology, investment and trade are also embedded in IPRs Protection. Effective IPR system balances Protection as an incentive for innovation and access to enable the other to further improve plant varieties.

Strong IPR regime would also inhabit diffusion of knowledge and technology in the countries and will institute for greater emphasis on Protection of R&D activities indigenously. Countries around the world have fre-turned their IPR regimes accordingly to their developmental requirement. The IPRs help in tuning the economy of the state with the changing industrial world and proper flourishment of technology to strengthen its position in trade and related areas especially in agriculture sector.

The origin of IP is linked with the industrial revolution. With the progress in industrial sector, the need for a world trade regulation also increases. After the World War-II, to revive the shattered industrial growth and economic disaster, the three international organizations viz., World Bank, International Monetary Fund (IMF) and International Trade Organization (ITO) were established in 1497. Following this a treaty called General Agreement on Tariff, and Trade (GATT) was ratified by many countries including India in 1948. This led to the establishment of worldwide regulatory body the World Trade Organization (WTO) which came in to force in January 1995. India is a founding number of GATT and signed the Marrakesh agreements of the Uruguay round as a permanent developing country member of GATT. As a signatory of this GATT, developing countries are committed to strengthen their domestic laws for Protection to IPR.

The international agreements of particular significance to seed are as follows:-

1. Trade related aspects of Intellectual Property Rights (TRIPS)
2. Convention on Biodiversity (CBD)
3. International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)
4. Nagoya Protocol
5. International Union for the Protection of New Varieties of Plants (UPOV)
6. The Patent Cooperation Treaty (PCT)
7. Cartagena Protocol
8. Geographical Indications (GI)

Trade related aspects of intellectual property rights (TRIPS):

The TRIPS agreement of WTO (1995) makes it mandatory for all nations to provide for IP protection to all inventions including those involving living systems, patents, copyrights, trademarks, geographical indications, industrial designs, layout designs of integrated circuits, and trade secrets. TRIPS incorporate provisions from many existing international IP agreements like the Paris and Berne conventions. It also provides for a transition period of 5 years (till 1/1/2000) to give effect to the provisions of the agreement. In the case of product patents in some areas of technology, this period is extended to 1/1/2005. Prior to this agreement, innovations in living organisms (plant, animals) or the biological processes that produce them were not protectable as intellectual property. In the case of plant varieties, the agreement provides for protection either through patents or through an effective *sui generis* system that can be adopted by individual nations. Protection of plant varieties through patents implies their registration in the breeder's name, so that the breeder has exclusive rights to all uses of that variety. This means that any future use of the variety has to be made against a royalty payment and with the permission of the breeder. In the *sui generis* system, each country is free to impose a wide range of restrictions upon breeders' rights as they see fit for research and for protecting farmers' rights. By 1/1/2000 India had amended its various laws and acts to be in line with the minimum requirements specified by the agreement. However, India continues to restrict patents on plant parts, cells, cell lines, genes and mitochondria- all of which are patentable in developed countries – to keep these basic technologies in the public domain. The patent law also excludes from patentability of agricultural and horticultural methods and all inventions arising out of the use of traditional knowledge. For plant variety protection too, a *sui generis* system was put in place through the Protection of Plant Varieties and Farmers Rights Act on October 30, 2001. The Act provides for protection of both breeders' and farmers' rights.

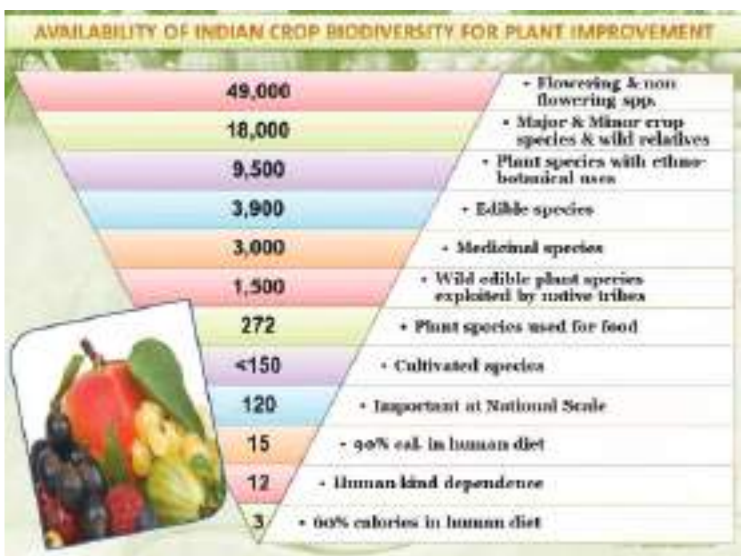
According to TRIPS, WTO members must grant some kind of IP protection for plant varieties, whether through patents, "an effective sui generis system," or both. As of now 73 countries have embraced UPOV. However some of the terms of the Convention on Biological Diversity (CBD), particularly the provisions concerning informed consent to biological materials and equitable benefit sharing following that access, are not covered by TRIPS.

Plant Genetic Resource:

Our ancestors always considered the Plant Genetic Resources as the heritage of humankind and were of the opinion that this treasure chart will provide the foundation for attaining food, nutritional and health security. Though the evolution started over 3.5 billion years on the Earth but it is with human interference coupled with natural process the biodiversity expanded. The human civilization is closely associated with the refinement of biodiversity. Looking to the day to day need of the human being, started selecting plants from the natural biodiversity. In ancient time, when man used to go for hunting, it is woman who developed an art of gathering and selecting Plant species according to the need of the family/society, propagated and conserved the useful Plant Genetic Resources (PGR). Along with the advancement of civilization, natural evolutionary adjustment process, of course with human interference to the different ecology and also to the changing environmental and biotic conditions took place in nature. This plant biodiversity was inspirable and irreplaceable resource and was the life line of the human being for providing sustainable ecosystem to meet food, clothing, shelter, nutritional and health requirement of population.

Amongst developing countries, India is considered as a cradle of agricultural biodiversity known for its rich heritage of PGR, Animal Genetic Resources, Fish Genetic Resources, and Micro Organisms etc., NBFGR (2007), which constitute biodiversity. Forest Genetic Resources (FGR) are the essential and important component of PGR. With 17 percent of the world's population and only 2.4 percent of world's area and 4.0 percent water bodies, India is considered as one of the 17 mega biodiversity countries housed in 12 mega-diversity centers of the world, accounting for 7-8 percent recorded species of the world and is considered as a major centre of domestication of crop plants. This Indian gene centre with three biodiversity hot spots, among the 34 identified across the world has been divided in to eight regions including biodiversity rich zones: viz., Western Himalayas, North-Eastern region and Western Ghats and which largely superimpose over the phyto-geographical regions. The Andaman and Nicobar Islands are rich treasure house of agro-biodiversity which is super imposed with Indo-Burma, Indo-Malaysia and Indo-Indonesian biodiversity. The Protection of Plant Varieties and Farmers' Rights (PPV&FRA) authority has identified 22 agro-biodiversity hotspots across the country. Looking to the rich biodiversity of the country, Vavilov (1951) identified India as one of the eight primary centers of origin of cultivated plants which hosts about 49,000 species of flowering and non-flowering plants (18.8 percent), out of 260000 described across the globe. India is rich in endemic plant species representing 33 percent of its flora. Within the spectrum of crop species and wild relatives, there are thousands of varieties, cultivars, land races and ecotypes which occur in India. It is known to have more than 18000 species of higher Plants including 160 major and minor crop species and 325 wild relatives. Around 1500 wild edible plant species are widely exploited by native tribes. In addition, nearly 9500 plant species of ethno-botanical uses have been reported from the country, of which around 7500 are of ethno-medical purposes and 3900 are edible species. (Census of India's biodiversity 1995). Medicinal plants account for nearly 3000 species (India's 4th national report to CBD 2009). The available Indian plant bioversity is presented in table-1.

Table-1.The available Indian plant bioversity for plant improvement.



In the ICE 19994, there was a detailed discussion on the availability of plant diversity of economic importance and the in the International Ethno biology Congress, the plant diversity of economic importance was sub divided in to seven groups of plant species and reported 6270 economically important species. The details are presented in Table-2.

Table 2. Economically important plant diversity in India as identified in the IV International Congress of Ethno biology, Lucknow, India, 1994 (ICE 1994)*

Economic uses	Number of species
Food	1200
Fodder	2200

Fuel and timber	1000
Medicines	1500
Fiber	150
Spices	120
Oil	100

India is a signatory to both CBD and World Trade Organization (WTO) conventions. The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) is an International Agreement administered by the WTO that sets down minimum standards and regulations for many forms of intellectual property (IP) as applicable to WTO Member Nations. Nations seeking to obtain easy access to the numerous international markets opened by the WTO must enact the strict intellectual property laws mandated by TRIPS. Based on the unique roles played by the geography, soil, water and agro climatic conditions and human know-how in making the products distinguished on the basis of their unique inherent attributes. Geographical Indication (GI), an exclusive community rights, recognizes the community efforts. It acts as an effective tool in protecting and rewarding not only the market potential of elite items but also the traditional knowledge associated with them. Since the enactment of the GI Act during 1999, 99 agricultural items have been accorded with GI tags till recently and among them the share of horticultural crops is more than 90 percent. Among horticultural crops, maximum GIs have been granted to fruit crops (43) followed by Plantation crops (15) and spices and condiments (24) and vegetables 11. Whereas ornamental plants and medicinal and aromatic plants conferred with 5 and 3 GI tags, respectively. Another few crops are in the process of obtaining GI tags. In many crops indigenous to our country dominated in obtaining GI tags. Mango, orange, banana, chilli, tea, cardamom, jasmine, grape, onion and coffee are important horticultural crops with regard to GI tags. The state-wise ownership of GIs in horticultural crops indicates activism of Maharashtra (21), Karnataka (19) and Tamil Nadu (8). The efforts made by public and quasi□public institutions in obtaining GI tags are indeed a significant to protect, exploit market potential and to facilitate better return to legitimate rural producer from origin-linked reputed products as under the TRIPS Agreement unless a geographical indication is protected in the country of its origin there is no obligation under this Agreement for other countries to extend reciprocal protection.

Further, WTO under the Article 27.3 (b) of the TRIPS, for the protection of plant varieties provided different options namely by patents, by an effective *sui-generis* system or a combination of both. As a corollary to this, India opted for the *sui-generis* system for the plant varieties giving importance to farmers' rights compared to the provision of the International Union for the Protection of New Varieties of Plants (UPOV). With intensive and extensive national level consultations and dialogues, the Government of India enacted the "Protection of Plant Varieties and Farmers' Rights Act (PPV&FR Act)" in 2001. The PPV&FR Act recognizes the multiple roles of farmers with respect to their contributions made in conserving, improving and making available PGR for the development of new plant varieties and also evolvers of farmers' varieties. India is the first country to provide substantial rights to farmers and registration of their varieties is one of them. The Act seeks to address the rights of plant breeders and farmers on equal footing and the Indian PPV&FR Act is a model in protecting the interest of the farmers of the agro-biodiversity rich countries.

For registration of varieties, 156 crop species have been notified by Government of India, out of which 108 are horticultural crop species indicating their importance in Plant Variety Protection (PVP) in this category. In flower and ornamental group 19 crop species, spices 8 and in medicinal and aromatic crops 9 crop species have been notified for registration to get IPR. Out of total 2849 applications received in horticultural crops, 1990 belong to vegetables suggesting the importance of vegetable in seed industry. There is slow registration process in flower and ornamentals, though there is a great scope to promote IPR in these crops. Similarly in spices and medicinal & aromatic crops registration process is very slow indicating the need of awareness among the stake holders. In underutilized crops, not a single application is filed and also PPVFR Authority should identify crop species in this category with the support from horticultural scientists. Amongst all horticultural crops, commercial seed industry concentrated their efforts in developing vegetable varieties and applying for IPR mainly due to more profit margin. Breeding efforts seems to be more in crops namely: brinjal(481), tomato(434), chilli(418), okra(248) and potato(120). More number of applications were filed by farmers in fruit crops (669) as they are the custodians of these crops since centuries. Out of 17501 total applications filed for all crops including field crops, the public institution share seems to be less (2324) compare to farmers (11126) and private seed industry (2324). In commercial seed industry, Plant Variety Protection (PVP) process is integral part of product development pipeline. Amongst all the companies, Nuaiveedu (745), Syngenta (421) and Kaveri (295) seed companies are found aggressive in filing the applications for IPR. Out of 4968 IPR certificates issued, in flower and ornamental crops are only 10 out of 87 applications received. Commercial seed industry has filed only 10 applications and obtained 2 IPR certificates. In rose(35), chrysanthemum(16), orchid(11) and marigold(10) more applications were received while in orchid(5) more IPR certificates were granted followed by rose(4). In case of medicinal and aromatic plants, more applications were received in menthol mint (8) followed by Brahmi (3). So far in this category, IPR certificate has been issued only in menthol mint (1). In spices comprising of 8crops only 42 certificates are issued. The data suggests that there is a need to organize more number of awareness programs in this category of crop species.

PVP strategies followed by private seed companies is worth replicating by the public seed industry as global nature of seed business adds to the complexity of PVP registration process. Today, Indian seed industry is growing at the rate of 14 percent with market share of $ 6.3 billion with fourth in ranking globally; India has great opportunity to move forward to become a world leader and it is estimated that by the year 2028 seed industry market share would be $13billion. In this direction favorable policies are needed to promote the seed industry. In this direction, Government of India notified the National IPR policies during 2016 to promote IPR and make the Indian Seed Industry globally competitive. It is suggested that the seed industry to take the advantage to move forward to become globally vibrant industry. Commercial seed industry concentrated their efforts in developing vegetable crop varieties and applying for IPR mainly due to more profit margin. Breeding efforts seems to be more in crops namely: brinjal(481), tomato(434), chilli(418), okra(248) and potato(120). More number of applications were filed by farmers in fruit crops (669) as they are the custodians of these crops since centuries. Out of 17501 total applications filed for all crops including field crops, the public institution share seems to be less (2324) compare to farmers (11126) and private seed industry (2324). In commercial seed industry, Plant Variety Protection (PVP) process is integral part of product development pipeline. Amongst all the companies, Nuaiveedu (745), Syngenta (421) and Kaveri (295) seed companies are found aggressive in filing the applications for IPR. PVP strategies followed by private seed companies is worth replicating by the public seed industry as global nature of seed business adds to the complexity of PVP registration process.

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66. Transformation of urban horticulture in NDMC

S. Chellaiah Sellamuthu
Director (Horticulture)
Archaeological Survey of India, Ministry of Culture, Govt. of India
Dharohar Bhawan, Tilak Marg New Delhi
Email: chellaiahndmc@gmail.com

In our Country, Landscape is generally thought of cosmetic and affordable by only affluent and corporate since many decades. This barrier was started broken while real estate, township, gated society concept gained momentum. People loving plants around their living surroundings, and more green and beauty in outdoor and indoor of their homes; business places and institutional campus etc. today potted ornamental indoor plants got recognition in the kitchen too. In urban area growing pollution, over competition, stressful life, machine like everyday life, hurdles and energy loss in transport, traffic mess etc forcing people make them living environment green and remain touch with plants to evolve from all health issues.

Providing better civic amenities is the responsibility of every Urban Local Body to ensure better liveability condition. In city like area need of happening area is foremost important to create the space to visit and enjoy the city. In the both aspects, urban horticulture plays vital role. If we analyse the growth of every corporations, or major urban cities considerable green area lost gradually however the concept of public green space and conscious about green environment, pollution free, clean are day by day growing that is very good positive indicator to achieve the green city and biodiversity city concept.

Fast growing population, emerging high-density cities are biggest challenges to keep sustainable India as it has drastic requirement of energy, water, natural resources for want of keeping the pace of the city growth. However, India is also striving our best with United Nation to make sustainable India by strict implementation of SDG. This policy changes bringing visible changes even from rural. Education, gender equality, energy and water conservations, Hunger free, good health and well-being, clean water and sanitation, affordable clean energy, reduced inequalities, sustainable cities, peace and justice and strong institutions, etc. Today city transport model towards energy conservation like many ring roads, dedicated freight corridor, elevated flyovers, rapid metro train to connect semi urban cities, CNG vehicles, battery operated car, electrical vehicles, cycling, solar energy promotion, water harvesting, solid waste management policies, sewerage treatment plan, recycling of water and reuse of water etc are mandate to get city star rating and swachh survekshan.

New Delhi Municipal Council is the prime organization, managing as urban local body which is stand high with laurels, reputation and playing role model as well premier role for many example by delivering services in prompt to the seat of the central government which is includes Lutyen’s Delhi, Delhi Imperial Zone and Connaught Place, Mandi House, Parliament, Supreme Court, all Ministerial secretariat, MP residences and rashtrapathi Bhavan etc. NDMC means all remember, recall, take away memory was beautifully maintained green landscape and flowers and mesmerizing features in the garden, avenues, roundabouts etc. which is maintaining nearly 1200 acres with 64.5% green canopy area excluding Bungalows and area of CPWD. None of the country’s capital in the world has 65% green area but New Delhi Municipal Council area has means its matter of proud and credits goes to team NDMC especially

Horticulture team and thanks goes to Lutyens and predecessors those contributed their dedication and devotion to keep NDMC area remain green and beautiful landscape.

NDMC best Horticultures practices are being well followed and adopted by almost most of the cities of our country. Tree preservation and protection practices are well appreciated by Hon'ble Court and asked others to follows like 6ft x 6ft soil surface(kachha) around trees, Tree ambulance, tree surgery, tree pruning, Mechanization, vertical garden concept, Hi-tech Nursery, large scale volumetric Flower beds concepts, shade landscape, composting, Tree census, display pots, tree transplantation, Tulip flower introduction in public green spaces, school of gardening, flower boards displaying during all national and international events, tree washing, pollution mitigation, ground cover usage on dust mitigation, creating bench mark on conducting public functions, high level function flower decorations, celebration of birth anniversary of various freedom fighter leaders statues, landscape on paved area like area infront of NITI aayog, Barakhamba Road central verge, development of various commemorative parks to mark international Summit hosted by India like Indo African Friendship Rose garden, BRICS Friendship rose Garden, Bharat ASEAN Maitri park, Kautilya Park, Ambedkar Vatika, Jelebi Chowk etc.Terrace Garden at Palika Bazar, Palika Parking, NDCC building Convention Centre, Shivaji Stadium, transformation of flower display form, styles in NDMC roundabouts and shantipath and gardens and parks like Nehru Parks, Mandi House Roundabouts, Akbar Roads roundabouts, Windsor Place and Central Park etc. flower blossom showcased in mass and volume to give visual impact and aesthetics.

The most important is team building, team does magic, and dream to reality. Any plan of urban Horticulture/ Landscape needs advance planning eleventh hour plan goes with tension and less success rate hence for better coordination, working team with task, single mind and idea is highly required. NDMC has good team.

Strengthening infrastructure is also one of the core areas, without that getting prominent or premier role position is not possible. Unless strengthen teams hands with required tools, machine, facilities, labour, timely availability of materials effective use of labour strength may not be expected with high productivity. NDMC concentrate to facilitate to get high productivity of each labour by strengthening their hands with machine and more precision, high output, fast operational approach. More machine, less physical energy, less labour interventions are motto in green maintenance. NDMC has introduced much machinery since 2007 onwards like brush cutter, hedge trimmer, ride on lawn mowers, chain saw, pole tree pruner and advance tree pruning machine like SPPM (self propelled platform machine, Digging machine, Leveler, cultivator, anti weed machine, Bobcut, handpilot, trolley etc.

Though we have enough to say about Urban Horticulture, here restrict to certain examples as follows

Vertical garden

First govt body carried more than 2000 sqm area and maintaining successfully at Palika parking, Charkha Museum Connaught Place. This was gone viral and public got more confident to grow green wall on their homes etc. this work built confident and promoted green wall concept and business of commercial nurseries and dedicated vertical garden business entrepreneur too flourished well. Vertical Gardens have been developed in the different location, which are very much appreciated by the visitors, public and also adopted by the other ULBs.

Green waste management

Transportation to landfill site and availability of landfill site are emerging challenges for each city hence local composting, in situ composting, zero waste garden/park concepts are evolved and shown ability and stand of NDMC. Various composting technology are practiced and these all utilized as manuring to recharge the soil or potting media purposes. However its far to say cent percent. We generate more than 60 MT daily but composting is approximately 10 MT.

Tree pruning

For preservation, balancing canopy, preventing fatality, damage of life and property pruning of trees are one of the most important operation. As the canopy area of trees is large in NDMC. The tree pruning required on almost daily basis to clear the visibility of street light, traffic signals and sign boards. The pruning is also required to clear the dark spots pointed out by various organizations. Therefore, the SPPM Pruning Machines has been introduced to do the pruning work smartly. Due to concretization, tree root ratio to the shoot or canopy level are narrow down on the arrest of percolation of water to the subsoil region. Hence the incidence of tree fall, risk of damage and uncertainty prevails.

Mechanization

Due to various innovations, the work pressure has been increased in the Horticulture Department. To meet the gap between labour and public expectation, the mechanization has been improved, in which various smart machines like Ride On Lawn Mowers, Hedge Trimmers, Tree Pruner, Chain Saw, Earth Augur, Wind Blower etc. have been procured and used in the horticultural operations.

Hi-tech nursery

To enhance the self production on the self propagation of plants by overcoming the irregular and erratic weather conditions hi-tech nusery constructed and many herbaceous, rooted semi hardwood shrubs, seedlings of many winter annuals been preparing to meet our requirement considerable level. Lodi garden, Circular Road nursery and Satya Sadan Nursery etc.

Tulip introduction in public spaces

The Tulip Flowers are generally grown and bloom in the J&K in India. The same are also planted and bloomed in the Rashtrapati Bhawan in a protected area. Delhi is highly erratic weather which cannot allows to get required chilling requirement to break the dormancy of Tulip bulbs which was overcome by the intervention of technology i.e pre-programmed and pre-treated bulbous from Holland.

Flower bed

During recent past, the Horticulture Department has changed the winter annual display pattern. The long stretch and wider flower beds in the Shanti Path, Talkatora Garden and various roundabouts were created in which the flower bloom was displayed in very clear manner. This creativity brought joy and happiness to the visitors. Carpeting pattern, mosaic pattern by introducing Petunia different colours, dwarf varieties like Salvia, dianthus, marigold, Verbena, Linum, Alyssum, etc.

Flower boards

The Department has introduced the Flower Boards before 10 years back, which became uniqueness of NDMC. The department create design, sketch etc. through flowers on the boards and display the same on the occasion of various national, international, inaugural events in NDMC area. This is one of the most popular and public could spot and appreciated and posted many selfie in social media , twitter, facebook etc.

Pollution mitigation

As a pollution mitigation step, the Horticulture Department has started tree washing of the existing avenue trees. Further, the open soil surfaces have been covered with suitable ground covers, so that the barren patches may not be visible in NDMC area.

Tree surgery

To save the very old and heritage trees, the department care intensively through a dedicated team called Plant Project Cell**.** This team survey the area, find hollow, cankered trees and treat them by tree surgery. The life of the trees extended/increased after tree surgery. This was widely popularized and appreciated and Honble High Court made it compulsory to all ULB

Tree census

The NDMC has conceptualized and executed the Tree Census with geo tagging and QR Code. The data is fully computerized, which will be readily available to the public through App and NDMC website.

Shade Landscape

One of the difficult and challenges are shade area development and maintenance. In NDMC area, parks, garden large area under shade. Availability of option of plants too very limited and erratic and extreme both end of weather too biggest challenges.with efforts, R&D started Hymenocallis lilly and Jal Bahar (justicia sp), wadlia, Ruellia, Dracenea sp, Syngonium, dwarf grasses etc. today that species self-propagated and multiplied lakhs and lakhs and spread across the NDMC area. Initially done at Shantipath 200m stretch biggest game changer plan of NDMC Horticulture.

School of Gardening

As being the role model and premier in urban horticulture and growing expectation and demand of skilled gardeners etc forced to start school of gardening in NDMC. Its unique kind of it in our country. None of the ULB has School of Gardening. Technology transfer and exchange centre. Its main objectives are to give more hands-on practice and less class room training. So far more than 10000 people got trained including MCD gardeners and DDA gardeners and Officers and NDMC gardeners etc.

Participation in flower shows

NDMC is one of the tough competitors and more prize winner since last one decade either PUSA flower show, Delhi Garden Tourism etc

Development of Commemorative parks:

Indo African Friendship Rose Garden, BRICS Friendship rose Garden, Bharat ASEAN Maitri Park, Kautilya Park, Ambedkar Vatika, Jelebi Chowk

Blooming "Magic on Concrete verge" of BaraKhamba Road:

Last year in the paved concrete central verge a a novel idea started displaying flowers in pre-fabricated frame beds and went viral across the world. Petunia with different colours attracted many corporate, ULBs, visits, public comments, appreciation etc.

Development of new Nurseries and improvement

Apart from existing department nursery, since CWG developed nursery one at Race Course Kushak Nallah, Circular Road, Jor Bagh covered Nallah and Barapullah near INA, Raja Bazar DIZ area, In every nursery of NDMC upgraded to labour friendly and efficient nursery by facilitating beds with perfects line of kerbstone etc, hanging baskets frame, construction of shade net house, introduction of new varieties, hanging baskets, display pots etc.

Introductions of hedge plants

After long study and analysis on the basis of observation, experience, come up with strong decision to get sustainable green I have introduced hedge plants like karonda and for shade area landscape jal Bahar, Asystasia, Ruellia, Milk Weed plant, Daedalacanthus, which is tolerant to many, versatile, survive with less water and resistant to animal vandalism and feed. Delhi facing huge and acute shortage of water for greening and roads situations also cannot be irrigated with plying tankers Sardar Patel Marg wherein introduced 2019-20 thereafter Shantipath and Shankar road survive well to meet our purpose

Butterfly Garden

Spotting butterfly direct indicator of pollution free environment, in Lodi Garden developed Butterfly Garden with many host plants and becoming spot for students and researchers.

Herbal Garden

In NDMC Lodi Garden developed herbal corner with more than 100 herbs similarly Safdarjung Madarasa Nursery at Children parks India Gate with less no of herbal species to create awareness

Garden amenities

Walking Track, Open Gym, Fountain, Garden Huts, Children Play area, Bio Aesthetic etc facilitated due to synthetic walking track people enjoying the morning and evening walking as well as open gym. Nehru park and Bharat Asean Mairi Park synthetic walking track are best example.

Tree plantation

The department has planted large numbers of trees saplings in NDMC area by organizing Van Mahotsav or Mass Plantation Drives. The department has planted the following quantum of various species during last five years: -

Year	Trees (Nos.)			Shrub (Nos.)	
	Target	Achieved	Survival Rate %	Target	Achieved
2015-2016	2319	16156	-	-	20540
2016-2017	5000	25127	72.42	-	474165
2017-2018	5619	100873	65.83	279415	502223
2018-2019	8000	38622	-	300000	243811
2019-2020	10000	10851	-	250000	342133
2020-2021	5116	3322	-	150675	328570
2021-2022	3828	2582	-	502955	571869
2022-2023	2847			271295	

NDMC-IUGM (Innovative Concept)

I have proposed this unique concept, As growing demand of skilled gardeners, organized, formal institute is required. By creating strong network of various direct and indirect landscape professional for conducting on site hands on practices by utilizing the existing their resources available. Due to informal sector, unorganized sector this is still unexplored and untapped potential area for creating more than 5million ready jobs in our Country. Due to social stigma, low self esteem, respect, low pay wages, high physical work are the main reasons for this field remain untapped. Therefore smart working styles has to be created by giving complete hands on practice and internship or industrial tie-up intensive –internship practices with smart tools, machine, kits, smart dress etc create more confident and attractive of non-matriculate, matriculate etc. they are biggest assest of human resource. Once creating skilled gardeners landscape, nursery and greening works florish, demands too increases and greening also increase. This kind of institute not only train them will also get more benefits on their physical engagement on their working or contract sites also. Symbiosis relation. “Sabke saath sabka vikas, sabka pryaas, sabka viswas”

Challenges

In urban city like Delhi and other cosmopolitan and metropolitan it has own challenges in maintaining green spaces like shortage of water, high costing on network of irrigation, lack of sustainable landscape conscious, non availability of common duct system, lack of civic sense of public, lack of forethought, visualization, dug of war or ego issues between technocrats and bureaucrats, lack of availability of skilled labour on gardening, lack of fund in maintenance, stereotypic, cryptic tender procedures and rules, non availability of professional, committed contract agencies in greening, taken for granted approach, feeling of thankless job, delayed payments system, lack of political will etc all together surround vicious circles in this urban landscape.










Landscaping Interventions in NDMC

ORBI SEEDS INTERNATIONAL PVT. LTD.

Talent for breeding and innovation

ORBI Seed s International is a company with a difference. We innovate and breed seeds that match the needs of the global farming community. We harness the best talent in vegetable breeding and consistently supply the best quality seeds to the farmers worldwide at affordable prices. Hence our tag line reads, "talent for breeding and innovation".

Dr. Sanjay Dwivedi started ORBI Seeds in the year 2016. Sanjay has been in the seed industry for the last 25 years and has held responsible positions in various companies. ORBI Seeds became a private limited company in the year 2018. It has partnerships with Bhalsar Seed International, Thailand; Nozaki Seeds, Japan; and Dutch Genetics, Netherlands, which has expanded the product range to serve the global market. Today ORBI Seeds can supply vegetable seeds of the highest quality to all the major seed markets of the world. ORBI Seeds is proud to have Dr. Remo Lundergnani as its Chairman and shareholder in Orbi Seeds.

ORBI has a strong R&D base in India, Thailand, and the USA. The stations in India and Thailand cater to breeding vegetable seeds for the Asian markets whereas, the station in the USA focuses on the American and European markets. In USA R&D we do produce and breed organic seeds suitable for the organic producers worldwide. The Bangalore station has a state-of-the-art molecular marker and DH facility. In addition, there are three R&D campuses in Karnataka equipped with the latest breeding facilities. While recognizing the increasing interest in protected cultivation, the company has launched a strong program on protected cultivation that focuses on sweet peppers, other exotic peppers, and melons.

Our products put a smile on every farmer and consumer

India Office: No. 1241, HIG-KHB, 7th B Cross, Yelahanka New Town Bangalore - 560064 INDIA; info@orbiseeds.com; www.orbiseeds.com
USA Office: No. 7600, Fairview Road Hollister, CA-95023, USA; remo@orbiseeds.com

The agro products can be put directly into tote boxes & medical products in corrugated boxes which are taken into the chamber by means of carrier inside the irradiation cell at speed determined by the source strength & dose required each box goes in 2/3 positions on both side of source being shuffled at the product shuffling zone. When it comes out last it is disinfested / sterilized 100% ready for immediate delivery being monitored by the state of art dosimetry laboratory.

WHY PROCESS BY GAMMA RADIATION :

1. It is totally eco-friendly Process, which is safe to workers & public around.
2. This is cold pasteurization process where in freshness like characters i.e. flavor, texture & appearance of foods unvarnished.
3. Foods in packed condition can be processed due to high penetrating power of gamma radiation.
4. Products of any shape & size can be treated for hygienization & shelf life enhancement.
5. It does leave any toxicity in the products processed unlike process like fumigation, ETO treatment.
6. Nutritional value of product is not altered as in case of roasting / heat processed.
7. There is absolutely no residual radioactivity left or induced in the product.
8. Joint expert committee of FAO/WHO/IAEA recommends a dose of 10kGy to be safe as for nutritional, microbial & toxicological aspects.
9. Shelf life of up to 2 years is assured.

GAMMA
AGRO-MEDICAL PROCESSINGS PVT. LTD.

ENSURING FOOD SAFETY AND SECURITY

GAMMA
AGRO-MEDICAL PROCESSINGS PVT. LTD.

ABOUT US

The Andhra Pradesh first versatile Radiation Processing Plant of One Million Curie Co. 60 Capacity, which is built in collaboration with Board of Radiation & Isotope Technology (A commercial wing of Bhabha Atomic Research Centre, Mumbai has started its commercial operation since In August 2006.

OUR AIM

- To help in minimizing loss of food products in storage by enhancing self life.
- To stabilize the price of seasonal commodity.
- Disease control related to Parasite, Pathogens and Microbes.

APPROVALS

Atomic Energy Regulatory Board

Andhra Pradesh Pollution Control Board

Andhra Pradesh Drug control Authority.

SERVICES

- Disinfestation and microbial decontamination of :

  Spices — Herbal extracts

  Neutraceuticals — Pet Foods

- Disinfestation of :

  Pulses — Cereals and their products

  Dry Fruits (Raisin, Figs and Dry Dates).

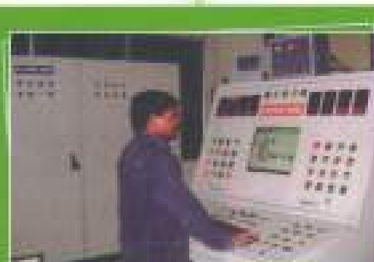
- Sterilization of Lab Animal Diet & Bed.
- Delay in ripening and Phytosanitary purpose

  Mango — Cut Flowers.

- Sterilization of Aseptic baggage for fruit and vegetable pulp packaging.
- Sterilization of health care products.

PRODUCT	PURPOSE OF IRRADIATION
Spices, Atta, Dry Fruits, Nuts Rice Seeds, Pulses, Dried Fish	Control of insect infestation & pathogen in prepackaged products.
Spices, Dried herbs and Vegetables	Hygienization by reducing contaminated micro flora
Potato, Onion, Garlic, Ginger	Inhibition of sprouting to extend shelf life and microbial decontamination to certain extent and reduce the post harvest losses.
Mushrooms	Shelf life extension
Strawberries	Control mold infections
Banana, Mango, Papaya	Delay of ripening to extend shelf life and also quarantine treatment for insect life infection
Sea foods, Meat, Poultry and Meat products	1. Elimination of parasite organisms like tapeworms, round worms & flukes. 2. Shelf-life extension under refrigeration by reducing spoilage bacteria. 3. Control of food born Pathogens like Salmonella, Vibro, Staphylococcus, E.coli etc.

- Gems and jewelries for selective colorization.
- Research in Radiation Processing Technology.
- Any Other Special Purpose Irradiation Services.



PROCESS AND FACILITY

Built to hold 1 Million Curie of Co. 60 Isotope, can be upgraded in stages depending on the volume of products available for processing. The radiation processing facility is versatile meaning, it can process bulky, different shape & size of agro-products in a tote box of 1100mm x 600 mm x 450 mm & medical shippers of 590 mm x 340 mm x 420 mm. It is a dual purpose (food & medical) facility capable of delivering 10kGy & 25kGy of radiation dose to food & medical products respectively.


KRISHIMELA

NITYA®

SINCE 2015

TECHNOLOGY FROM

ICAR-IIHR

100 %
Natural

No
Preservatives

NITYA brand collaborated with IIHR for technology to ensure highest quality of product quality and safety in 2015 and launched a range of natural and healthy products with high protein, vitamin, dietary fiber and essential nutrients for a balanced lifestyle.

Customer Care No.
9980748811
9611470575

Email :
nithyachapati@gmail.com

www.nityachapati.com

Manufactured & Marketed By:
Nidhi Food Products
Mukke, Narimagaru Post,
Puttur Taluk - 574202.
South Kanara District. Karnataka

With Best Compliments From:

Shri Hybrid Seeds

Proprietor : T.M.Venkatesha Gowda

Producers and Co- Ordinator:

Producing High Quality Field Crops & Vegetable Seeds

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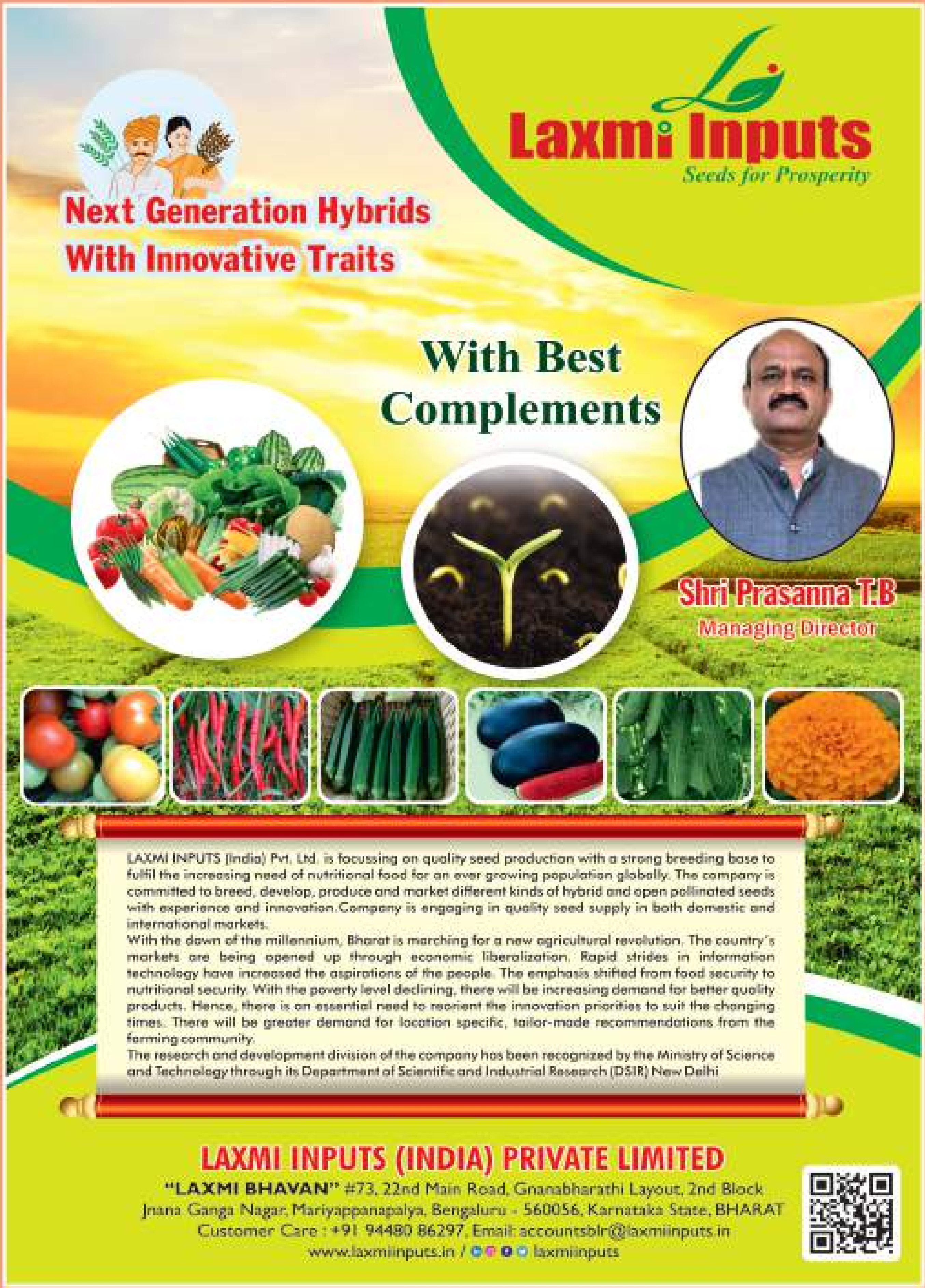
Ph: (O) 268958 (R) 267321, Mobile : 9448922891
Email: venk_tmv@rediiffmail.com


Laxmi Inputs
Seeds for Prosperity
Next Generation Hybrids
With Innovative Traits
With Best Complements
Shri Prasanna T.B
Managing Director
LAXMI INPUTS (India) Pvt. Ltd. is focussing on quality seed production with a strong breeding base to fulfil the increasing need of nutritional food for an ever growing population globally. The company is committed to breed, develop, produce and market different kinds of hybrid and open pollinated seeds with experience and innovation.Company is engaging in quality seed supply in both domestic and international markets.
With the dawn of the millennium, Bharat is marching for a new agricultural revolution. The country's markets are being opened up through economic liberalization. Rapid strides in information technology have increased the aspirations of the people. The emphasis shifted from food security to nutritional security. With the poverty level declining, there will be increasing demand for better quality products. Hence, there is an essential need to reorient the innovation priorities to suit the changing times. There will be greater demand for location specific, tailor-made recommendations from the farming community.
The research and development division of the company has been recognized by the Ministry of Science and Technology through its Department of Scientific and Industrial Research (DSIR) New Delhi
LAXMI INPUTS (INDIA) PRIVATE LIMITED
"LAXMI BHAVAN" #73, 22nd Main Road, Gnanabharathi Layout, 2nd Block
Jnana Ganga Nagar, Mariyappanapalya, Bengaluru - 560056, Karnataka State, BHARAT
Customer Care : +91 94480 86297, Email: accountsblr@laxmiinputs.in
www.laxmiinputs.in / laxmiinputs

ಭಾ.ಕೃ.ಅನು.ಪ.-ಭಾರತೀಯ ತೋಟಗಾರಿಕೆ ಸಂಶೋಧನಾ ಸಂಸ್ಥೆ भा.कृ.अनु.प.- भारतीय बागवानी अनुसंधान संस्थान

ICAR-Indian Institute of Horticultural Research

Hesaraghatta Lake Post, Bengaluru - 560 089

ISO 9001: 2015 INSTITUTE

BESST - HORT

(Business Entrepreneurship and Start-up Support through Technology in Horticulture)

A Technology Business Incubator of
ICAR-Indian Institute of Horticultural Research
Catalysed & Supported by NSTEDB Division,
Department of Science & Technology
Hessarghatta Lake Post,Bangalore - 560089

Entrepreneurship Development Programs

- Horticulture based Entrepreneurship Opportunities Awareness Programmes
- Hands-on training programmes of un-protected technologies
- Entrepreneurship Development Programme through incubation of licensed technologies of ICAR-IIHR.

Incubation

BESST-HORT facilitates entrepreneurs in the incubation & promotion of start-ups.

Technology	*Incubation*
Tech Licensing	On-Site
Tech Development	Off-Site
Tech Improvisation	Mentorship
Open Lab of Ideation	Proof of Concept

Commercialization	*Advise on*
Business Mentorship	Intellectual property
Investment	Financing
ScalingUp	Marketing etc.
Marketing	Strategy

On-site Incubation

- Should be an ICAR-IIHR Technology licensee.
- 10,000/- is the annual membership fee. The member will be provided manufacturing facility & office space for 6 months to start-up their venture.
- The scientific guidance for scaling up will be provided for the licensee.
- Members can avail mentorship from any of the business/technology mentors accessible to BESST-HORT to remove bottlenecks if any. The charges for mentorship will be decided on a case-to-case basis, based on time of mentor involved.
- Women-owned enterprises are eligible for 50% discount on the membership fees of BESST-HORT.

Off-site Incubation

- Any start-up organization venture/ enterprise working in the field related to horticulture is eligible to apply. The technology could be from ICAR-IIHR or any other institute or their own innovation.

For more information on EDPs, technology licensing, incubation, mentorship and marketing support please contact

Dr. M. V. Dhananjaya,
Principal Scientist & Chief Executive Officer, BESST-HORT (a NIDHI-TBI, GoI)
ICAR-IIHR, Bengaluru-89
Mobile No. 9141704357, 93790749274

Ph : 080 - 2308 6100 (Extn 514) , 080- 2846 6202 Mob: +91 77608 83948
Email : bessthort@gmail.com / bessthort.iihr@icar.gov.in
Web : https://www.bessthort.in
ICAR - Indian Institute of Horticultural Research
Campus, Hessarghatta lake post, Bengaluru - 560089