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INDIAN Horticulture

September-October 2026



From Tradition to Innovation – A New Path to Self-Reliant Horticulture

INDIA'S diverse geographical and agro-climatic conditions make it extremely rich in horticultural wealth. From the apples, walnuts and other temperate fruits of the Himalayan regions to the coconuts, spices and tropical fruits of South India, every region of the country has given Indian horticulture its own distinct identity. Whether it is Jammu and Kashmir's apple- and walnut-based horticulture, Himachal Pradesh's successful horticulture model, Uttar Pradesh's mangoes, Maharashtra's oranges, Bihar's litchi and guava, the arid horticulture of Rajasthan and Gujarat, the pineapple and turmeric of Northeast India or Kerala's coconut- and spice-based horticulture – all these reflect India's diversity, richness and potential.

Today, the need of the hour is to link this rich heritage with modern science, technology and innovation. ICAR and its institutes are making significant contributions to the development of improved varieties, quality planting material, production technologies, post harvest management and processing and conservation measures suited to the country's varied agro-climatic conditions. Through germplasm conservation, the genetic wealth of indigenous and rare plant species is being safeguarded for present and future generations.

The Council's endeavour is that scientific achievements should not remain confined to research institutions alone, but should reach farmers' fields and become the basis for increasing their income and improving their standard of living. Through modern production technologies, digital agricultural services, water-conservation-based systems and climate-resilient horticultural practices, farmers are moving towards quality production, efficient use of resources and better market opportunities. At the same time, value addition, processing and marketing are creating new opportunities to further enhance the economic potential of horticultural produce.

Today, India is moving forward towards the goal of self-reliance and becoming a developed nation. In this journey, the role of the horticulture sector is extremely important. It is not merely the foundation of nutritional security and economic prosperity, but also an effective means of rural employment, women's empowerment, entrepreneurship and environmental conservation. Diversification and value addition in horticulture can give new momentum to the rural economy while also providing additional income opportunities for farmers. We believe that the convergence of Indian traditional knowledge, modern science and farmers' experience will play an important role in making Indian horticulture more sustainable, inclusive, profitable and globally competitive.

ICAR is committed to sustainable, inclusive and farmer-centric horticultural development. Let us come together, with respect for nature, faith in science and a spirit of innovation, to contribute towards building a prosperous, sustainable and self-reliant horticultural India.

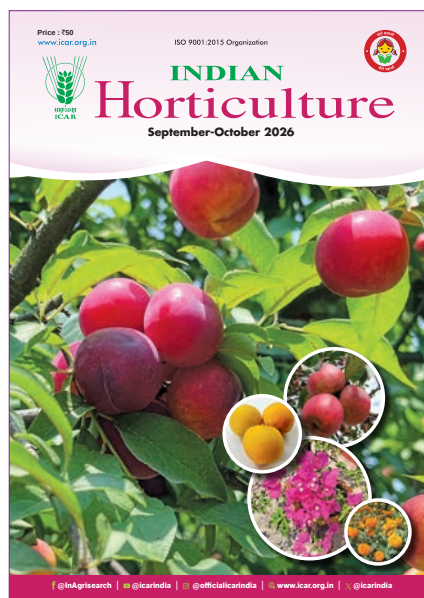


Indian horticulture is not merely a system of agricultural production, but a living confluence of our rich cultural heritage, biodiversity, traditional knowledge and scientific progress. Indian society has always maintained harmony with nature while conserving and utilising fruit-bearing trees, medicinal plants and diverse flora. In the traditional knowledge of Indian society, trees and plants have been regarded as an integral part of life. Our ancient texts also contain detailed references to the utility, medicinal properties and environmental importance of plants. The traditional experiences associated with horticulture embody the selection of plants suited to local climate, soil and biodiversity, the conservation of natural resources, and a spirit of sustainable production. Today, as the world moves towards climate-resilient, resource-conserving and sustainable agriculture, this traditional knowledge of ours has become even more relevant. By linking this rich knowledge to modern science and innovation, India is moving forward on a new path towards self-reliant, sustainable and prosperous horticulture.

A handwritten signature in blue ink, consisting of stylized initials and a long horizontal stroke.

(M. L. Jat)

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Tradition and Innovation: Growing a Self-Reliant Horticultural India

AS India moves steadily towards the twin goals of nutritional security and farmer prosperity and, in a larger sense, toward self-reliance in horticulture, this issue of *Indian Horticulture* affirms a truth that runs through the Council's own vision for the sector: Innovation need not always mean discovering something entirely new. More often, it means looking afresh at what has long been part of our agricultural practices and refining it through modern breeding, agroecology and value addition. This issue opens into a much larger story – one in which colour indicates nutrition, overlooked crops find new purpose and communities uncover pathways to prosperity in the abundance of their own land. At its heart lies a powerful idea that tradition need not stand still. It can evolve, adapt and find new relevance through innovation.

The opening article on Pusa Purple Broccoli-I, the country's first anthocyanin-rich subtropical heading broccoli shows that pigment is not merely aesthetic but a marker of phytochemical wealth and a product of breeding science built on genetic resources that India has long worked to conserve. This theme of 'colour as nutrition' recurs through the issue, most explicitly in the closing article on plant pigments, which explores the science behind the spectrum of hues that vegetables and fruits display, and why breeders are increasingly selecting for pigmentation as a marker for antioxidant richness.

Tubers, long treated as subsistence crops, are being repositioned as vehicles for micronutrients delivery and rural income, provided post-harvest handling and market linkages keep pace with breeding gains. Nutritional security also anchors the articles on biofortified potato and enriching underutilised tuber crops, both of which establish that India's food security strategy cannot rest on staple cereals alone. The same spirit animates in the article on Kales and Collards as 'superfoods' and on Tumba, an underutilised medicinal vegetable of dryland ecosystems. Such crops hold answers to the malnutrition challenge, if only these crops receive the research attention and market visibility.

The story of Thanamir, the apple village of Nagaland, is as much about rural transformation and entrepreneurship as it is about horticulture, a village finding a new economic identity through a single well-adapted crop. The information on wild edible fruits of the Western Ghats shows that horticultural development in India's hill and forest ecosystems must walk a careful line between commercialisation and conservation, ensuring that rural prosperity does not come at the cost of the very biodiversity and environmental balance that make it possible.

The article on combating root-knot nematodes in guava offers a reminder that productivity gains are only as durable as the crop health measures that sustain them, while annual chrysanthemum as a bioremedy for nematode control points to elegant, low-input solutions hiding within our ornamental crops, precisely the kind of climate-resilient and resource-efficient practice horticulture will increasingly need whereas the ToLCNDV-resistant sponge gourd variety Pusa Sponge Gourd-29 underscores the scientific efforts towards ensuring that yield, nutrition and disease resilience must advance together, not as competing priorities, if horticultural science is to serve both the plate and the farmer's income.

The feature on natural farming in Himachal Pradesh and nutri-garden extension model in Malda district illustrates that technology transfer succeeds only when it is embedded in local ecology and community participation. That means reducing chemical dependence in the hills, or, through kitchen gardens largely tended by women, improving household dietary diversity and modest income in the plains of Bengal.

Taken as a whole, this issue makes an implicit but compelling argument, one that echoes the Council's own vision for the sector: India's horticultural future will be built not on any single breakthrough, but on the patient convergence of traditional knowledge, modern breeding science, agroecology, biodiversity conservation and grassroots extension.



(Anuradha Agrawal)

Pusa Purple Broccoli-1: A high-yielding first anthocyanin-rich subtropical heading broccoli

Pusa Purple Broccoli-1, developed by ICAR-IARI, New Delhi, is India's first short-duration, subtropical purple-heading broccoli variety, offering a breakthrough for the National Capital Region. This innovative variety is rich in powerful antioxidants, containing 30.31 mg/100g fresh weight of anthocyanins alongside essential health-beneficial glucoraphanin to combat non-communicable diseases. Unlike the traditional varieties, Pusa Purple Broccoli-1 matures in just 75–85 days after transplanting. This allows it to set seeds abundantly in the North Indian plains and expands market availability from December through March. Yielding compact, intense purple heads with an average weight of 570g, it offers a high potential marketable yield of 20.9 t/ha. Its versatile, medium-stature profile allows high-density planting and presents excellent prospects for premium diversified uses like health-secure sprouts, attractive microgreens, and fresh edible heads.

Keywords: Broccoli, Pusa Purple Broccoli-1, Seed production, Short duration variety

PURPLE heading Broccoli (*Brassica oleracea* var. *italica* Plenck) is an important exotic annual vegetable crop that belongs to cole group. Broccoli, in general, is a rich source of vitamins, minerals and health-beneficial glucoraphanin (2.8–15.43 mg/100 g on dry weight basis), a strong anticancer phytochemical. It has diverse natural variants for head colour, such as green, purple and yellowish green. Green broccoli is commercially grown in India but the purple heading type presents a new option with added value to health. It has higher amount of anthocyanins in addition to other nutrients present in green broccoli. Pusa Purple Broccoli-1, a first-of-its-kind as sub-tropical type has been developed through recurrent breeding at the Division of Vegetable Science, ICAR- Indian Agricultural Research Institute, New Delhi. It is rich in anthocyanins, a powerful antioxidant that takes care of cardiovascular problems. It produces seeds abundantly in North Indian plains during winter season. It has diverse use options such as sprouts, microgreens and edible heads.

Development of Pusa Purple Broccoli-1: 'Pusa Purple Broccoli-1' was developed by recurrent breeding from the segregating exotic material. It is recommended for the National Capital Region of Delhi and similar climatic conditions. During the development process, the major criteria for desirable traits were medium head size, fine to medium-size buds, partial to compact, medium to intense purple heads, early maturity, seed production ability, etc. It is distinct from the purple-heading broccoli 'Palam Vichitra' in India which takes around 120 days after transplanting to marketable maturity and thus able to set

seeds in hills only. The availability of 'Palam Vichitra' in market remains for a short period (February–March) while Pusa Purple Broccoli-1 takes around 85–95 days after transplanting and produces heads in December–January, thus expanding the purple broccoli availability period from December to March, benefiting broccoli growers, traders and consumers. It gets ready for harvesting 35–45 days earlier as compared to 'Palam Vichitra' and grows profusely in North Indian plains during winter season.

MAIN FEATURES

- First anthocyanin rich short duration purple heading broccoli variety.
- Suitable for sowing during mid-August to mid-October.
- Attains marketable head in 75–85 days after transplanting.
- Rich in anthocyanins (30.31mg/100 g fw).
- Average plant height is 52.5 cm and spread is 48.3 cm.
- Average head weight is 570 g with a potential marketable head yield of 20.9 t/ha.
- Produces satisfactory seeds under Delhi condition.
- Suitable for staggered planting from September to October to extend availability.
- Attractive cotyledon and nutritionally rich profile highlighting prospect for microgreens.
- High acceptance by health-conscious consumers, as observed in a limited sample survey.
- Medium-stature variety accommodating more plants per unit area thereby.

Important plant traits and marketable yield are given in Table 1 and 2.

Nutritional and health value: Nutritionally, broccoli (100g edible portion) is a rich source of protein (3.0–3.60 g), dietary fibre (1.40–2.60 g), vitamin A (2,500 IU) and folate (115 µg). It also contains riboflavin (0.23 mg), thiamin (0.10 mg), niacin (0.9 mg) and folate (0.71 mg), against their daily requirements viz., 1.7 mg, 1–2 mg, 19 mg and 1 mg, respectively. It is low in energy (32 Kcal) and fat (0.35%). For every 100g on dry weight basis it also contains micronutrients such as potassium (316 mg), iron (0.7 mg), selenium (3.0 µg), calcium (48 µg) and zinc (0.4 mg), making it an example of ‘low energy – low fat healthy food’.

Today when non-communicable diseases (NCDs) such as cardiovascular diseases, cancers, chronic respiratory diseases and diabetes etc. are emerging as the biggest challenge for public health, proper lifestyle and intake of antioxidant-rich foods are crucial for minimising the incidence of NCDs. Pusa Purple Broccoli-1 contains anthocyanin (30.3 mg/100g fresh weight) in addition to vitamin C, carotenoids and flavonoids present in common green broccoli. Anthocyanins are powerful antioxidants and potential anti-platelet therapeutics reducing thereby the risk of cardiovascular diseases. The high level of anthocyanins makes Pusa Purple Broccoli-1 a nutritionally and functionally better and healthy food option.

Agronomic management: Seeds to be sown in nursery from September to October months for raising the winter season crop @ 400–500 g/ha. Seed treatment with *Trichoderma viridae* 1.0 WP @ 4 g/kg seed or Bavistin 2 g/kg is necessary for healthy nursery raising. One month old seedlings are ready for transplanting at a spacing of 45 cm × 45 cm. Planting on ridges is ideal. It requires 120 kg N, 60 kg P, 60 kg K/hectare. Apply full P and K and half of N as basal dose before ridge making. Remaining half dose of nitrogen should be given during earthing up. Spray urea (1.0%) and boron (0.3%) after 15 and 45 days of transplanting, respectively. Need-based

irrigation should be done.

Harvesting: Heads are ready to harvest when they are compact, buds are medium coarse, attractive and well-grown but still unopened. Keep heads in an upright position in clean trays for markets.

Disease and pest management: Pusa Purple Broccoli-1 has field resistance to downy mildew, black rot and alternaria leaf spot diseases avoiding fungicide spray thereby. Need-based sprays of insecticides such as indoxacarb 14.5 SC @ 1 mL/L to control spodoptera and cabbage



Pusa Purple Broccoli-1:
Head view



Pusa Purple Broccoli-1:
Field view



Pusa Purple Broccoli-1: Fresh harvest



Pusa Purple Broccoli-1: Head internal structure

Table 1. Horticultural traits of Pusa Purple Broccoli-1 alongwith checks in Delhi conditions

Character	Days to harvest after transplanting	Plant height (cm)	Gross plant weight (g)	Seed yield (g/plant)	Head weight (g)	Yield (t/ha)	Yield increase over PKTS-1 (%)
Pusa Purple Broccoli-1	85	52.5	1350	18.0	528.9	20.5	43.3
Pusa KTS-1	83	60.1	1150	11.0	411.5	14.4	
Palam Vichitra	120	63.2	1870	1.5	647.2	23.9	

Table 2. Year-wise mean marketable head yield of Pusa Purple Broccoli-1

Entry	Yield (t/ha)					Avg. yield (t/ha)	Maturity period*
	2019-20	2020-21	2021-22	2022-23	2023-24		
Pusa Purple Broccoli-1	20.3	21.2	19.4	21.2	22.5	20.9	December–January
Pusa KTS-1	12.3	14.4	13.8	13.2	14.1	13.6	January–February
Palam Vichitra	26.5	24.5	-	22.7	23.4	24.3	February–March

*Related to temperature requirements for head development.

fly and cyantraniliprole 10.26% OD @ 60 g a.i. against diamondback moth, jassids and aphids are necessary.

Indigenous seed production in northern plains: Pusa Purple Broccoli-1, is the first tropicalised heading broccoli cultivar and flowers during January–February under Delhi conditions and produces seeds abundantly. An isolation distance of at least 1600 m is needed from other crops and varieties of cole vegetable group.

Suitability in different growing options: Pusa Purple Broccoli-1 has great potential for commercial scale farming due to high yield and remunerative price. Its short duration and stature make it suitable for customised gardens such as kitchen, container and vertical gardens where the nutrient rich pesticide free crop options are major concern. During winter season, it has least incidence of diseases and insect-pests, hence safe from pesticide burden. It has great prospects in school gardens which serve as an instant on-site source to integrate in mid-day meal schemes. It serves as an excellent source for microgreens or super sprouts due to the inherent triple antioxidants ‘vitamin C + glucoraphanin + anthocyanin’.

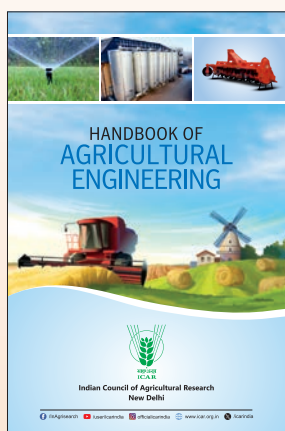
SUMMARY

Pusa Purple Broccoli-1, developed by ICAR-IARI, New Delhi, is India's first short-duration, subtropical purple-heading broccoli variety optimised for the National Capital Region. Rich in anti-cancer glucoraphanin and cardiovascular-protective anthocyanins (30.31 mg/100g fw), this low-fat superfood provides a highly profitable option for farmers and health-conscious consumers. Maturing in 75–85 days, it delivers an average marketable yield of 20.9 t/ha and expands market availability from December to March. Its unique climate adaptation allows abundant winter seed production in the Northern plains, breaking reliance on hilly seed production. Exhibiting excellent field resistance to major diseases like black rot and downy mildew, this medium-stature variety is ideal for high-density farming, microgreens and pesticide-free kitchen gardens.

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TECHNICAL ASPECTS

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Pusa Sponge gourd-29: A high yielding Tomato Leaf Curl New Delhi virus (ToLCNDV) resistant variety of sponge gourd suitable for *kharif* season

Pusa Sponge Gourd-29 (DSG-29), developed by ICAR-IARI, New Delhi, is India's first public-sector-bred sponge gourd variety resistant to the devastating Tomato Leaf Curl New Delhi Virus (ToLCNDV). Notified for the National Capital Territory of Delhi, this early-maturing variety allows farmers to safely cultivate sponge gourd during the *kharif* season- a period traditionally plagued by high whitefly populations and severe viral outbreaks. Ready for harvest in just 45–50 days after sowing, it yields attractive, dark green, 22–24 cm long cylindrical fruits featuring thick skin and tender white flesh, highly prized by consumers. In multi-year open-field trials, DSG-29 achieved an impressive average yield of 17.77 t/ha, outperforming the resistant check and outyielding susceptible checks. Boasting a remarkably low vulnerability index, this landmark variety offers a robust, high-yielding strategy to secure year-round availability and boost farmer income.

Keywords: DSG-29, Pusa Sponge Gourd-29, Resistant variety, Tomato Leaf Curl New Delhi Virus

THE sponge gourd (*Luffa cylindrica* L.), also known as *Chikni tori* in Hindi is a very popular and important vegetable grown in India. It is best adapted to tropical and subtropical regions and easy-to-grow. Its tender fruits are generally consumed immature as vegetable. Tomato Leaf Curl New Delhi Virus (ToLCNDV) is transmitted by whiteflies, causing symptoms like yellowing, leaf curling, chlorosis, mottling, stunting has been reported to be associated with sponge gourd and causing substantial yield loss in north Indian plains during *kharif* season. So far there is no ToLCNDV resistant sponge gourd variety/hybrid developed by any public/private sector. With the release of this variety, sponge gourd can be successfully grown by the farmers during *kharif* season which is conducive for whitefly multiplication and severe spread of the disease. Further, long, dark green and thick skinned fruits with tender flesh will be highly accepted by consumers of north Indian plains. Pusa Sponge Gourd-29 has been notified by the central sub-committee on crop standards, notification and release of varieties of horticultural crops.

Pusa Sponge Gourd-29 (DSG-29): It is the first ToLCNDV resistant sponge gourd variety developed by public sector suitable for *kharif* cultivation under north Indian plains. The fruits become ready for first harvesting in 45–50 days after sowing. Fruits have desirable marketable attributes and are attractive, uniform, dark green, elongated, cylindrical, 22–24 cm long having average fruit weight 105–110g, with superficial ribs, thick skin, smooth texture and white flesh. Presently, north

Indian plain farmers rely only on spring-summer crop and with the release of this variety; long term demand of the farmers can be met as they can successfully grow this crop during *kharif* season. The average fruit yield is 17.77 t/ha under natural field condition during *kharif* season. Pusa Sponge Gourd-29 is highly resistant to ToLCNDV under natural field condition with vulnerability index of 8.9 as compared to 85.3 in susceptible check Pusa Supriya.

Performance of Pusa Sponge Gourd-29 (DSG-29): Pusa Sponge Gourd-29 has been tested in yield trials under open field conditions during *kharif* season at ICAR-IARI, New Delhi from 2022 to 2024 along with DSG-6 and Pusa Supriya as resistant and susceptible checks, respectively. The results indicated that Pusa Sponge Gourd-29 yielded 17.77 t/ha which was 30.76% higher than the resistant check DSG-6 and 259.72% and 303.86% superior than the susceptible checks Pusa Supriya and Kalyanpur Hari Chikni, respectively.

Cultivation: Pusa Sponge Gourd-29 is suitable for cultivation in rainy seasons in NCT of Delhi. As a rainy season crop it is sown in June-end. It can be grown successfully on well-drained loam and sandy loam soils. Application of 20–25 t/ha of well-rotten organic manure before field preparation is beneficial. Seed rate is 2.5–3.0 kg/ha. Seed should be treated with 2g Captan/Thiram/Kg of seed. A spacing of 3.5–4.0 m row to row and 60–75 cm hill to hill is ideal. Fertiliser dose is 100:80:60 kg NPK/ha. Half dose of nitrogen is applied at the time of field preparation and remaining 30 days after sowing

Mean performance of Pusa Sponge Gourd-29 during Kharif season from 2022 to 2024 at ICAR-IARI, New Delhi

Variety	Yield (t/ha)			Average yield (t/ha)	Percentage increase over checks (Resistant and Susceptible)	No. of days to first harvest	Vulnerability Index & Category
	2022	2023	2024				
Pusa Sponge Gourd-29 (DSG-29)	18.53	18.20	16.58	17.77	30.76 (DSG-6), 259.72 (Pusa Supriya), 303.86 (Kalyanpur Hari Chikni)	45–50	8.90
DSG-6 (Resistant Check)	14.95	13.13	12.68	13.59		50–55	4.20
Pusa Supriya (Susceptible Check)	4.55	5.20	5.07	4.94		50–55	85.30
Kalyanpur Hari Chikni (Susceptible Check)	4.03	4.62	4.55	4.40		50–55	89.45

and before flowering. Irrigation is done through channels. Light irrigation, if required, is done depending upon the weather conditions. Earthing up is essential to cover the roots properly in rainy season crop. It requires 2–3 hoeing and weeding.

Pest and disease: for controlling fruit fly, the affected fruits should be plucked and destroyed along with the maggots inside them. Spray the crop with Malathion @ 2 ml/litre of water. Use light traps in night with poison baits. Powdery mildew is controlled by spraying of Bavistin (0.1–0.2%) twice at 10 days interval whereas downy mildew can be controlled by spraying of Ridomil (0.2%) or Dithane M-45 (0.2%) at 8 days interval. Fusarium wilt disease can be checked by drenching the soil and root zone of the crop by Bavistin. Mosaic virus infected plants should be eradicated from the field as soon as they are noticed. Four or five foliar sprays, either of Imidacloprid (0.03%) or Dimethoate (0.05%) or

Metasystox (0.02%) at 10 days interval reduces the spread of mosaic disease.

Harvesting and yield: Fruits are ready for harvesting 45–50 days after sowing. Immature fruits should be harvested at frequent intervals. Average fruit yield is 17.77 t/ha during *kharif* season. The harvested fruits should be kept in plastic crates with fillers instead of gunny bags to avoid bruises and injury.

SUMMARY

Pusa Sponge Gourd-29 is an early maturing variety of sponge gourd for *kharif* season cultivation developed by IARI for NCT of Delhi. It is resistant to Tomato Leaf Curl New Delhi Virus (ToLCNDV). Apart from superior quality characters, it has an average fruit yield of 17.77 t/ha during *kharif* season which is 30.76% and 259.72% superior over resistant check DSG-6 and susceptible check Pusa Supriya, respectively.

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Fruits of 'Pusa Sponge Gourd-29'

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Biofortification in potato to strengthen nutritional security in Indian perspective

Potato (*Solanum tuberosum* L.) plays a major role in food security and livelihoods in India. However, micronutrient deficiencies remain a major public health concern. Biofortification provides sustainable approach to enhance the nutritional quality of potato without altering food habits. Indian efforts, led by ICAR-Central Potato Research Institute, have resulted in biofortified and coloured-flesh varieties such as Kufri Neelakanth, Kufri Manik and Kufri Jamunia, revealing shift towards nutrition-sensitive breeding. Biofortified potatoes provide nutritional, economic and agronomic benefits, contributing towards a promising pathway to strengthen nutritional security in India.

Keywords: Biofortification, Nutritional security, Potato, Potato varieties

POTATO (*Solanum tuberosum* L.) is one of the most important food crops in the world and plays a significant role in ensuring food security due to its high productivity, adaptability and affordability. In India, potato is cultivated across diverse agro-climatic regions and serves as a staple or supplementary food for millions of people. Besides being a rich source of carbohydrates, potato provides vitamins, minerals, dietary fibre and antioxidants, making it an important component of a balanced diet.

Despite considerable progress in agricultural production, micronutrient malnutrition, often referred to as hidden hunger, remains a major public health challenge in India. Deficiencies of iron, zinc, vitamin A and other essential nutrients adversely affects the health, growth and productivity of a large section of the population, particularly women and children. Improving the nutritional quality of commonly consumed food crops has therefore emerged as an important strategy for addressing nutritional deficiencies in a sustainable manner.

Biofortification, a nutritional improvement strategy aimed at increasing the levels and bioavailability of essential micronutrients in food crops through agronomic

practices, plant breeding, genetic engineering and genome editing approaches, has gained increasing attention as a cost-effective and farmer-friendly solution to combat hidden hunger. In potato, biofortification efforts have focused on increasing the levels of micronutrients such as iron, zinc, vitamin C, carotenoids and anthocyanins. The development of nutrient-rich potato varieties offers an opportunity to improve dietary quality without requiring major changes in food habits or additional expenditure by consumers.

The ICAR-Central Potato Research Institute has developed biofortified and coloured potato varieties with enhanced nutritional attributes. These varieties combine desirable agronomic performance with improved nutrient content and have the potential to contribute significantly to food and nutritional security. This article highlights the concept of potato biofortification, important biofortified potato varieties developed in India, their nutritional advantages over conventional cultivars and their potential role in strengthening nutritional security from an Indian perspective.

Biofortification efforts in potato Indian Perspectives: In India, ICAR-CPRI and its regional stations are leading biofortification research. Their efforts focus on:



Pictorial features of Kufri Neelkanth



Pictorial features of Kufri Manik

Biofortified varieties

Kufri Neelakanth: This medium-maturing potato variety produces ovoid tubers with purple skin, yellow flesh and shallow eyes with average tuber yield of 35–38 t/ha and is adapted to the north indian plains. Compared to the white-fleshed cultivars Kufri Jyoti and Kufri Pukhraj and other popular cultivars, it offers enhanced nutritional quality, with higher iron (30–50 ppm), zinc (15–25 ppm), ascorbic acid (25–35 mg/100 g FW), carotenoid (100–350 µg/100 g FW), anthocyanin contents (1–10 mg/100 g FW) and dry matter (18–20%).

Kufri Manik: This medium-maturing potato variety produces round tubers with red skin, yellow flesh and medium-deep eyes with average tuber yield of 23–25 t/ha. Adapted to the eastern plains of Uttar Pradesh, Bihar, Jharkhand, Chhattisgarh and Assam, it is moderately resistant to late blight and possesses enhanced nutritional value. The variety contains higher levels of iron (30–50 ppm), zinc (>25 ppm) and anthocyanins (1–10 mg/100 g FW) and dry matter content (18–19%) as compared to popular white-fleshed cultivars such as Kufri Jyoti and Kufri Pukhraj.

Kufri Jamunia: This medium-maturing potato variety produces oblong tubers with shallow eyes and deep purple skin and flesh with average tuber yield of 32–35 t/ha. Recommended for the north indian plains, it is moderately resistant to late blight. This variety contains iron (30–50 ppm), ascorbic acid (>35 mg/100 g FW), anthocyanins (>10 mg/100 g FW), zinc (15–25 ppm), carotenoids (100–350 µg/100 g FW) and high dry matter content (19–19.5%). It contains substantially higher levels nutrients owing to its attractive purple flesh, enhanced antioxidant content and high dry matter, the variety is suitable for table consumption as well as specialty products such as dalia, suji, ice cream and biscuits.

Red-skinned varieties

Kufri Sindhuri: This late-maturing potato variety produces round tubers with red skin, cream flesh and medium-deep eyes with average tuber yield of 30–35 t/ha. Adapted to the north indian plains, it is moderately resistant to early blight and tolerant to Potato Leaf Roll Virus (PLRV), making it suitable for low-input production systems. The variety contains iron (<30 ppm), zinc (15–25 ppm), ascorbic acid (<25 mg/100 g FW), anthocyanins (<1 mg/100 g FW) and carotenoids (<100 µg/100 g FW), with a dry matter content of 17–18%.

Kufri Kanchan: This medium-maturing potato variety produces ovoid-oblong tubers with red skin, cream flesh

and shallow eyes with average tuber yield of 25–30 t/ha. It is moderately resistant to late blight, immune to wart disease and characterised by a slow rate of seed degeneration, making it suitable for sustained cultivation in the North Bengal Hills and Sikkim. The variety contains iron (<30 ppm), zinc (<15 ppm), ascorbic acid (25–35 mg/100 g FW), anthocyanins (<1 mg/100 g FW) and carotenoids (100–350 µg/100 g FW), with a dry matter content of 19%. Although its micronutrient and antioxidant levels are lower than those of recently released biofortified cultivars, its disease resistance, seed longevity and adaptability make it a valuable cultivar for hill ecosystems.

Kufri Uday: This early to medium maturing potato variety produces ovoid tubers with red skin, shallow eyes, yellow flesh with a mealy texture and an average tuber yield of 36–38 t/ha. It is field-resistant to late blight and recommended for cultivation in the plains of Uttar Pradesh, Punjab, Haryana and Rajasthan. The variety possesses enhanced nutritional quality, containing iron (30–50 ppm), zinc (15–35 ppm), ascorbic acid (25–35 mg/100 g FW) and anthocyanins (1–10 mg/100 g FW), along with a dry matter content of 18–19%. In comparison to popular white-fleshed cultivars such as Kufri Jyoti and Kufri Pukhraj, it offers higher levels of micronutrients and antioxidant compounds while maintaining desirable tuber quality and processing attributes.

Kufri Lohit: This medium maturing potato variety produces medium to large-sized, attractive red-skinned tubers with shallow eyes, cream flesh and a mealy texture with an average tuber yield of 36–38 t/ha. It is field-resistant to late blight and well adapted to the central and eastern north indian plains. The variety contains higher levels of iron (30–50 ppm), zinc (15–25 ppm), anthocyanins (1–10 mg/100 g FW) and carotenoids (100–350 µg/100 g FW) than commonly cultivated white-fleshed varieties such as Kufri Jyoti, while it has dry matter content of 17–19%. These nutritional attributes, together with its attractive tuber appearance and desirable cooking quality, make it a promising cultivar for both table consumption and nutritional security.

Kufri Ratan: This medium-maturing, high-yielding potato variety produces attractive red-skinned tubers with excellent storability and broad adaptation across the north indian plains and plateau regions with average tuber yield of 36–38 t/ha. The variety contains elevated levels of iron (30–50 ppm), zinc (>25 ppm), ascorbic acid (25–35 mg/100 g FW) and anthocyanins (1–10 mg/100 g FW), exceeding those of many widely cultivated white-fleshed



Pictorial features of Kufri Jamunia

cultivars. With a dry matter content of 17–18%, it combines desirable table quality with enhanced nutritional value. Its attractive tuber appearance, good keeping quality and improved micronutrient content makes it a promising option for both farmers and consumers.

White skinned varieties

Kufri Jyoti: This medium-maturing, white-fleshed potato variety is known for its wide adaptability, early bulking ability with an average tuber yield of 25–30 t/ha and slow rate of seed degeneration. The variety contains relatively low levels of iron (<30 ppm), zinc (<15 ppm), ascorbic acid (<25 mg/100 g FW), anthocyanins (<1 mg/100 g FW), carotenoids (<100 µg/100 g FW) and dry matter content of 18–20%, making the variety suitable for general table use.

Kufri Pukhraj: This is a widely cultivated white-fleshed potato variety characterised by early bulking with an average tuber yield of 35–40 t/ha and a slow rate of seed degeneration. The variety contains iron (<30 ppm), zinc (15–25 ppm), ascorbic acid (<25 mg/100 g FW), anthocyanins (<1 mg/100 g FW) and carotenoids (100–350 µg/100 g FW), with a dry matter content of 18–20%. Although its micronutrient and antioxidant levels are lower than those of recently developed biofortified potato cultivars, Kufri Pukhraj remains popular among farmers because of its adaptability, dependable performance and suitability for diverse production environments.

Benefits to Farmers

Biofortified potato varieties provide direct economic and practical advantages to growers while aligning with changing consumer and industry preferences.

Market opportunities: Biofortified potatoes offer opportunities for value addition owing to their enhanced nutritional quality. Their unique nutritional and functional properties may help develop good markets and specialised food products. Wider adoption and market acceptance will depend on increased consumer awareness, efficient marketing and availability of quality planting material.

Greater demand from food and processing industries: Biofortified potato lines possessing high dry matter, desirable texture and attractive flesh colour are well suited for industrial use. These varieties are increasingly demanded for processing into chips, French fries, ready-to-eat foods and functional food products, offering assured markets and contract-farming opportunities to farmers.

Similar cultivation practices: Biofortified potato varieties

do not require special agronomic practices, additional inputs or new technologies. They can be cultivated using standard potato production methods, making adoption easy and risk-free for farmers while delivering added nutritional and economic benefits.

Challenges

Despite the strong potential of biofortified potatoes to improve nutrition and farm income, several challenges need to be addressed for their large-scale adoption.

Limited awareness: Many farmers and consumers are not fully aware of the nutritional advantages of biofortified potatoes over conventional varieties. The absence of clear information and labeling often limits their acceptance and market differentiation.

Need for wider adaptability: For sustained adoption, biofortified potato varieties must show stable yield, disease resistance and quality across diverse agro-climatic regions. Limited regional adaptability can restrict their spread beyond specific zones.

Market linkage: Weak linkages between producers, processors and health-conscious consumers often result in poor price realization. Organised markets, branding and assured procurement mechanisms are required to strengthen demand.

SUMMARY

Biofortification in potato offers a strategic and sustainable solution to strengthen nutritional security in India while maintaining high productivity and farmer profitability. The development of biofortified and coloured-flesh potato varieties marks a paradigm shift from yield-focused breeding to nutrition-sensitive agriculture. Indian efforts have successfully delivered varieties enriched with essential micronutrients and antioxidants without compromising agronomic performance or consumer acceptability. These varieties not only address hidden hunger but also create new opportunities for value addition, specialty markets and enhanced farm income.

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Enriching underutilised tuber crops: Emerging opportunities

India is one of the world's richest centres of diversity for tropical tuber crops, including several minor crop species with significant potential for food, nutrition and industrial applications. Despite this potential, most of these crops remain underutilised and are cultivated only on a limited scale. This article highlights crop improvement efforts including germplasm enrichment, identification of promising genetic stocks and varietal development in Queensland arrowroot, West indian arrowroot, Chinese potato, Yam bean and East indian arrowroot. It also discusses the major production and breeding constraints together with emerging opportunities for their commercial utilization.

Keywords: Germplasm, Underutilised tuber crops, Varieties, Value addition

INDIA is one of the world's richest centres of diversity for tropical tuber crops, which play a vital role in food and nutritional security and livelihood support, particularly in tribal and marginal farming systems. While major root and tuber crops such as Cassava, Sweet potato and Yams dominate commercial cultivation, several minor and underutilised crops remain confined to traditional and subsistence farming despite their considerable potential for value addition and industrial use. Although grouped as minor tuber crops, they are botanically diverse and belong to different families, producing storage roots, tubers or rhizomes rich in starch and essential nutrients. Important examples include Queensland arrowroot, West indian arrowroot, Chinese or coleus potato, Yam bean and East indian arrowroot. These crops produce edible rhizomes, roots or tubers, generally yielding 21–38 t/ha, with fresh-matter starch contents of about 9–27%. Traditionally consumed as foods, they are also valued for dietary and medicinal uses. However, their wider cultivation is constrained by crop-specific production problems and breeding limitations, including vegetative propagation, bulky planting material, long crop duration, narrow genetic diversity and poor or absent seed set (except in Yam bean).

Queensland arrowroot:

Queensland arrowroot is an edible rhizomatous crop of South American origin and is cultivated in Southeast Asia, Southern China, India and Oceania for its starch-rich rhizomes. In India, it is grown in Darjeeling district of



Queensland arrowroot

West Bengal, South Sikkim and as a backyard crop in several regions. It is locally known as '*Seeni kalvazhai*' in Tamil, '*Canna koova*' in malayalam and '*Kanda*' in hindi. No varieties of this crop have been released in India to date. Four major edible canna types are recognised globally: Thai green, Japanese green, Thai purple and Chinese purple. The Chinese purple type produces rhizome yield of 30–38 t/ha and starch yield of 4.1–4.9 t/ha.

At ICAR–CTCRI, green and purple germplasm types have been collected, conserved and evaluated, revealing considerable variation in rhizome yield and starch content. Two promising genetic stocks, Kodalan Green (IC647797) and Manalur Purple (IC647798), have been identified and registered for their desirable agronomic and starch related traits. These genetic resources provide valuable breeding material for future varietal improvement. Commercial cultivation is, however, constrained by tall plants prone to lodging, long crop duration and the requirement for bulky rhizomes as planting material. Crop improvement has remained limited because the crop is cultivated only on a small scale in backyards, receives little breeding attention and is propagated predominantly through rhizomes.

West indian arrowroot: West indian arrowroot belongs to the family Marantaceae and is cultivated primarily for its starch-rich rhizomes, which are used as food and in traditional medicine. In India, the crop is grown mainly in homesteads and backyards under



West Indian arrowroot

partial shade, particularly in Kerala and the North-eastern states, where it fits well into low-input and organic farming systems. It is called 'Koova' in malayalam and 'Koovai' in tamil. Its tolerance to shade and marginal soils makes it suitable for fragile and rainfed ecosystems. The crop has a long duration (9–10 months) and requires bulky rhizome pieces for planting. It is propagated exclusively through clonal rhizomes and does not produce botanical seeds, resulting in very limited genetic recombination and breeding opportunities.

West indian arrowroot produces an average rhizome yield of 25–30 t/ha, with a starch content of 16–24% on a fresh-matter basis. On a dry-matter basis, the rhizome contains about 80–90% starch, 0.2–3.7% protein, less than 1–1.4% fat and 1–4% fibre. Arrowroot starch has oval to spherical granules (about 45 µm long), low lipid and protein contents, high viscosity and excellent swelling power.

Systematic evaluation of germplasm has resulted in the release of the improved varieties Sree Aadya, Sree Nakshathra and Sree Karthi, which are characterised by high starch productivity and improved horticultural performance. These varieties provide greater scope for commercial cultivation than traditional landraces. Future improvement should focus on broadening germplasm base for improvement in starch yield, higher number of tillers and reduced planting-material requirement.

Chinese potato: Chinese potato, also known as coleus potato, is a short-duration (4–5 months) tuber crop of african origin, now cultivated in Southeast Asia including India, Sri Lanka, Malaysia, Indonesia and Thailand. In India, it is cultivated mainly as a smallholder crop in Kerala, Tamil Nadu and Karnataka. Chinese potato is locally known as 'Koorka' in malayalam, 'Sirukizhangu' in Tamil and 'Sambarani gadde' in kannada. It is valued for its pleasant aroma, good cooking quality and nutritious tubers. Four improved varieties, namely Sree Dhara, Suphala, Nidhi and CO-1 have been released in India with desirable traits including high tuber dry weight, photo-insensitivity, superior cooking quality and high starch content. Nevertheless, commercial production is constrained by root-knot nematode susceptibility and photoperiod-sensitive tuberisation, while crop improvement is hampered by reproductive sterility and a narrow genetic base. Future research should focus on overcoming these constraints through mutation breeding and modern biotechnological approaches.

Yam bean: Yam bean is native to Mexico and Central America and has spread to Asia, Africa and parts of India. It is cultivated mainly in Bihar, Odisha, West Bengal and the North-eastern states. This multipurpose leguminous root crop produces nutrient-rich storage roots; its protein-rich seeds,



Chinese potato

however, contain toxic rotenone and must not be consumed. The relatively low root dry matter and the presence of rotenone in the seeds are major production constraints. As a legume, it fixes atmospheric nitrogen and improves soil fertility. The genus *Pachyrhizus* includes three cultivated species, *P. erosus*, *P. ahipa* and *P. tuberosus* among which interspecific hybridisation is feasible. Only *P. erosus* is available in India, and because the crop is predominantly self-pollinated, the available germplasm possesses limited genetic diversity, restricting breeding progress. Introducing the other cultivated species would broaden the genetic base for improvement.

At ICAR–CTCRI, 55 accessions are maintained at the headquarters and 165 at the Regional Centre, Bhubaneswar, in field gene banks. A promising genetic stock, Havelock local (IC635945), has been identified from the NAGS, Thiruvananthapuram. Recently, Bhu Sakarkanda new variety has been released from research centre of CTCRI, Bhubaneswar and recommended for cultivation for Odisha. Several improved varieties, namely RM-1, RM-2 and RM-3 have been developed with desirable traits such as high tuber yield and early maturity from RPCAU, Dholi, Bihar under All India Coordinated Research Project on Tuber Crops (AICRP-TC).

East indian arrowroot: East indian arrowroot is a perennial rhizomatous herb cultivated mainly in Chhattisgarh, Madhya Pradesh, Jharkhand and parts of South India. It is propagated through rhizome pieces, and its rhizomes are valued for edible starch extraction. Commercial cultivation is constrained by the requirement for bulky planting material (approximately 1.8–2.0 t/ha) and long crop duration. Crop improvement has progressed slowly because of vegetative propagation, limited germplasm characterisation and the non-availability of improved varieties in most growing regions. From the minor tuber crops field gene bank maintained at ICAR–CTCRI, a promising genetic stock, TVM Local (IC641835; INGR25038), has been identified and registered with ICAR–NBPGR for its long primary rhizomes and high starch content (16.8%).



East indian arrowroot

Emerging commercial opportunities: Several minor tuber crops have demonstrated considerable commercial value, although their cultivation remains largely subsistence-oriented. Starches from Queensland, West indian and East indian arrowroot are often marketed under the generic name 'Arrowroot powder' despite their different botanical



Yam bean

Promising genetic stocks and released varieties in selected minor tuber crops

Crop	Genetic stocks identified and registered	Varieties released	Distinguishing trait(s) of genetic stock and varieties
Queensland arrowroot	Kodalan green (IC647797) Manalur purple (IC647798)	-	High rhizome starch and vigorous growth
West Indian arrowroot	-	Sree Aadya Sree Nakshathra Sree Karti	High starch yield (5.95 t/ha) High starch yield (8.59 t/ha) High starch yield (5.07 t/ha)
Chinese potato	-	Sree Dhara Suphala Nidhi CO-1	High tuber dry weight Photo insensitive variety Oblong tubers & cooking quality High tuber starch (21.5%)
Yam bean	Havelock local (IC 635945)	RM-1 RM-2 RM-3 Bhu Sakarkanda	High tuber yield (36-40 t/ha) Early tuber maturity (100-110 days) High tuber yield (35-40t/ha) Early tuber maturity (110 days)
East Indian arrowroot	TVM local (IC641835; INGR25038)	-	Long primary rhizome, high rhizome starch (16.8%)

The crop-wise information presented above shows substantial variation in yield, starch content and nutritional composition among collected germplasm and released varieties. These differences, arising from genetic constitution and targeted improvement, influence suitability for specific end uses. Understanding these functional attributes provides a basis for identifying and promoting value-added, market-oriented applications.

origins. Studies have highlighted the exceptional quality of Queensland arrowroot starch for both food and non-food applications. Its rhizomes contain about 73–85% starch on a dry-matter basis, with 25–31% amylose and very large starch granules (40–80 µm). The starch also contains a resistant-starch fraction and has been reported to possess potential for moderating glycaemic response, making it a promising ingredient for functional-food research. Owing to these properties, Queensland arrowroot starch is suitable for the preparation of noodles, vermicelli, gluten-free products and other health-oriented functional foods, and the crop also has potential as animal feed.

West indian arrowroot starch exhibits excellent gelling, pasting, thickening and stabilising properties, making it particularly suitable for biscuits and a wide range of processed food products.

Chinese (coleus) potato starch, characterised by a high amylose content (about 30.44%) and favourable pasting behaviour, has considerable potential for the manufacture of snacks, extruded products and biodegradable films.

Yam bean root starch has potential as an ingredient in functional foods and as a raw material for biodegradable bioplastics. In addition, rotenone containing seed extracts may serve as botanical biopesticides, provided they are used with appropriate safety precautions.

East Indian arrowroot starch possesses desirable hydrocolloid properties and is traditionally used in the preparation of cakes, fruit preserves and biscuits, as well as a binder in sweets and milk puddings

These applications show that minor tuber crops can move beyond subsistence use. Strengthening quality planting-material supply, genetic improvement, varietal development, processing technologies and market linkages is therefore essential for expanding their commercial and industrial utilisation.

SUMMARY

Minor tuber crops possess useful diversity in yield, starch content and nutritional quality. Germplasm evaluation and varietal development have identified variation for important horticultural and quality traits, demonstrating clear scope for targeted improvement and value addition. Wider adoption is nevertheless constrained by a narrow genetic base, vegetative propagation, reproductive sterility, bulky planting material requirements and limited availability of improved varieties. Germplasm enrichment, systematic characterisation and breeding for higher yield, starch quality, early maturity, stress tolerance and market-preferred traits are therefore priorities. Such a coordinated approach can raise farm productivity, create processing opportunities and enable the sustainable commercial exploitation of these underutilized crops.

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Kales and Collards: Superfoods for health and wealth

Kale is a collective term used for various kales and collards that have originated basically from wild cabbage (*Brassica oleracea*) and are the result of evolutionary changes brought about by either natural selections or hybridisations. Kale, in general, demonstrates superior nutritional composition compared to conventional leafy vegetables positioning it as a comprehensive essential source of nutrients. Phytochemical analysis shows that it contains higher total antioxidant activity than other leafy green vegetables, primarily due to the presence of carotenoids, flavonols and glucosinolate-derived isothiocyanates conferring significant protection against various diseases. ICAR-Central Institute of Temperate Horticulture, Srinagar conserves more than 65 genotypes of kale including Kashmiri landraces (*Khanyari*, *Hanz Haak*, *GM Dari*, *Kawdari*) and exotic varieties (*Lacinato*, *Siberian* and *Russian kales*) that acts as an invaluable reservoir for targeted breeding. Furthermore, kale based value-added products developed by the institute offer functional food availability contributing to regional nutritional security and public health goals extendable to national level.

Keywords: Collards, Food Security, Kale, Kashmiri Landraces, Superfood

KALE (*Brassica oleracea* L. group Acephala), widely acclaimed as the 'King of leafy vegetables', is one of the earliest domesticated forms of wild cabbage (*Brassica oleracea* L.), with a long history of cultivation, dating back to more than 2000 years and the characteristic of being non-heading with leafy growth habit, is a member of the *Brassicaceae* family. Unlike cabbage, cauliflower and broccoli – its headed cultivars, the leaves of the kale remain loose, often flat or puckered and are harvested over an extended season. Previously, all types of kales and collards were together put into *Brassica oleracea* gp. Acephala. However, with increasing evolutionary reveals, many of them have been assigned specific botanical names. The exceptional genetic diversity of kale, resulting from its morphological plasticity and high cross-pollination, allows it to thrive in a wide range of agroclimatic environments. The scientific name of kale is, however, restrictive in nature, as with advancing phylogenetic understanding, the group is fast being segregated into different species and varieties. Different kinds of kale that differ as botanical varieties are Collard (*Brassica oleracea* var. *viridis*), Curly/scotch kale (*Brassica oleracea* var. *fimbriata*), Tuscan/Dinosaur kale (*B. oleracea* var. *palmifolia*), Chinese kale/Gai Lan (*Brassica oleracea* var. *alboglabra*) and a separate species *Brassica napus* that consists of siberian and russian kales thought to have originated from Rutabaga. Some lesser known kales like Walking stick kale and Redbor are characterised as *Brassica oleracea*.

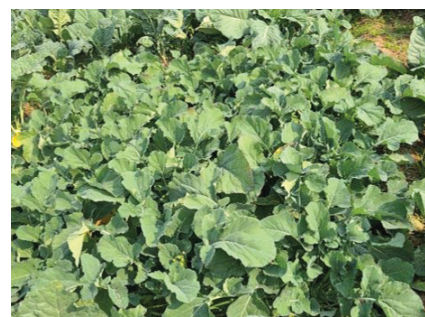
In the Indian subcontinent, kale has a unique cultural significance. Although it remains underexploited in the plains, the crop holds pride of place in the Union Territory of Jammu and Kashmir, particularly in the Kashmir Valley under the name '*Haak*'. The term '*Haak*' is derived from sanskrit word '*Shaak*', meaning edible greens. kashmiri cuisine is incomplete without '*Haak*'. Kale has been perfectly woven into the local food system for generations, unlike exotic vegetables that require careful adaptation. It is grown in kitchen gardens, home gardens and commercial farmlands in all districts of the valley.

Economically, kale has immense potential to diversify the vegetable basket of India. In an advancing urbanisation wherein, dietary habits change and demand for health-oriented foods increases, there exists a specific market potential for nutrient-rich traditional crops. The adaptability of kale to temperate and sub-temperate climates makes it suitable for hilly areas like Himachal Pradesh, Uttarakhand, Sikkim, and the North-eastern states, where vegetable cultivation often remains challenging during winters. Its high biomass production, multiple harvests, and resistance to pest and diseases further add to its advantages as a climate resilient crop.

Germplasm, landraces, improved indian varieties and exotic varieties: The Kashmir Valley located in biodiverse Indian Himalayan region probably has the most diverse kale gene pool in the country. This diversity due to genomic plasticity in response to different micro-climates has largely been captured through seed saving and folk

taxonomy traditions of indigenous farmers and is now being generated through formal breeding and selection. For generations, Kashmiri farmers have identified, preserved and traded landraces based on traits such as leaf texture, frost resistance, plant height and palatability. Recognising the significance of this genetic wealth, ICAR-Central Institute of Temperate Horticulture (CITH), Srinagar has actively characterised and conserved more than 65 accessions of kale germplasm including indigenous

landraces, single plant collections and exotic introductions alongside developing breeding lines for agronomic and biochemical traits. The germplasm generated by the institute (breeding lines) have unique traits such as purple colour, leaf blade puckering or plant main stem branching. It also possesses remarkable variability for plant height, leaf shape, leaf length, leaf colour, petiole length, branching habit and plant stature. These traits have been well characterised and associated with *Brassica*



True siberian kale



Improved dwarf siberian



Red russian



Tuscan kale



Khanyari



GM dari



Hanz haak



Kawdari

Diverse varieties and species of kale at ICAR-CITH, Srinagar

based SSR markers for facilitating marker assisted breeding. Two microsatellites have highly been associated with seed yield and plant architecture. The germplasm has great potential for successful breeding programmes aimed at biofortification, adaptation to climatic changes and higher productivity as well as novel product development.

The landraces reflect adaptation to local environmental conditions and centuries of farmer-driven selection. Several of them stand out for their agronomic and culinary value, for example, Khanyari is characterised by its succulent, puckered leaves, indeterminate, scantily branched, columnar growth habit and its adaptability to warmer temperatures, making it suitable for a wide range of environments. GM Dari bears large, flat leaves with high adaptability to cool-season cultivation resulting in enormous yields. Hanz Haak is a highly branched plant with rosette appearance of tightly arranged leaves on top of each branch that continue appearing indefinitely, ensuring multiple harvests over an extended period. In addition to these, other traditional varieties like Kawdari and Anchar Haak, each with unique characteristics suited to specific growing conditions and local preferences exist.

Likewise, ICAR-CITH has evaluated several exotic introductions for their performance under Kashmir conditions. True siberian kale, Improved dwarf siberian kale, and red and green russian kales have shown exceptional tolerance to frost. The dark green, blistered leaves of Lacinato/Dinosaur/Tuscan kale offers a distinctive earthy taste. These kales are all known for their high nutritional value and diverse culinary applications. In 2025, ICAR-CITH developed distinctiveness, uniformity and stability guidelines for testing new kale varieties for the purpose of registration. These guidelines were notified by PPV&FRA in 2026.

Climatic requirements and agronomic practices: Kale thrives in cool climate, tolerating temperatures as low as -10°C to -15°C , but optimum growth occurs between 15°C to 21°C .

Sowing, land preparation and transplanting: Seeds are sown in a well-prepared nursery bed. Kale prefers well-drained, organically rich loamy soil having pH between 5.5 and 6.5. The final field should be enriched with 15-20 tonne well-decomposed FYM or 7.5 to 10 tonne vermicompost per hectare well before transplanting. Seedlings with 4-5 true leaves are ready for transplanting 4-5 weeks after sowing. Seedlings are transplanted at a spacing of 60-45 cm between rows and 45-30 cm between plants depending on species/variety.

Fertilisation: As per the package of practices by State Agricultural University, apply fertilisers at 60 kg N, 40 kg P₂O₅ and 40 kg K₂O per hectare as basal dose at transplanting. Apply an additional 30-40 kg of nitrogen/hectare 3-4 weeks after transplanting to enhance leafy growth.

Irrigation: Kale requires consistent moisture for tender leaves. Regular watering is crucial, especially during dry spells. Drip irrigation is highly recommended to conserve water and prevent moisture borne diseases.

Weeding: Intercultural operations such as weeding should be done especially within the first month after transplanting to reduce competition for nutrients, water, and light.

Growing Seasons in Kashmir: It can be grown in two main seasons in the Valley:

Spring-Summer Crop:

- **Nursery Sowing:** Mid-February to Mid-March (under protected cover if frost is expected)
- **Transplanting:** Late March to April
- **Harvesting:** May to July

Autumn-Winter Crop (Main Season):

- **Nursery Sowing:** July
- **Transplanting:** August
- **Harvesting:** October onwards
- **Harvest:** Harvesting begins 45-60 days after transplanting. Multiple pickings ensure steady supply over an extended period.

Nutritional and Medicinal Value: Kale has achieved international recognition as a superfood because of its nutritional profile and high concentration of health-promoting compounds. Comparative nutrient profiling of most popular leafy greens clearly indicates kale's superiority in nutritional content (Table 1). Kale contains 4.3 g protein/100 g fresh weight, far higher than in other leafy greens, thereby, ensuring a high satiety index and plant predominant eating habits. The dietary fiber content in kale is 3.6 g/100 g, ensuring glucose metabolism and colonic health. The micronutrient content in kale is particularly noteworthy. Its calcium content is 150 mg/100 g, nearly four times higher than in cabbage and three times higher than in broccoli. Although kale contains less iron

Table 1. Comprehensive nutrient comparison per 100 g of fresh weight

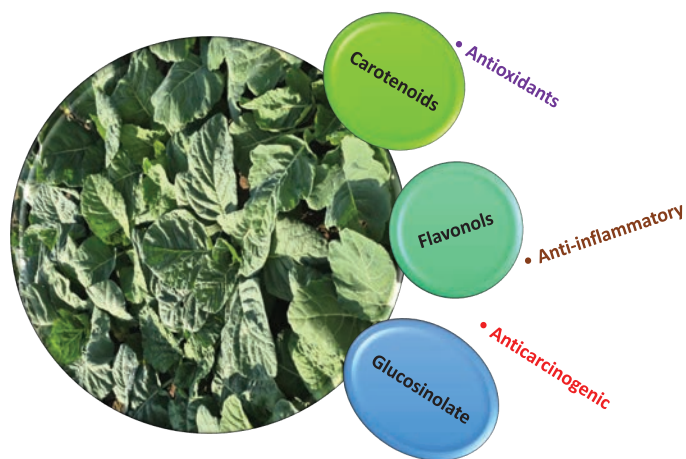
Nutrient/100g	Kale	Spinach	Amaranth	Cabbage	Broccoli	Lettuce	Rocket
Energy (kcal)	49	23	230	25	34	14	25
Protein (g)	4.30	2.90	2.50	1.30	2.80	1.40	2.60
Fat (g)	0.90	0.40	0.30	0.10	0.40	0.20	0.70
Carbohydrate (g)	8.80	3.60	4.00	5.80	7.00	2.90	3.70
Sugar (g)	2.30	0.40	0.50	3.30	1.70	1.20	2.10
Fibre(g)	3.60	2.20	2.50	2.50	2.60	1.20	1.60
Calcium (mg)	150	99	215	40	47	36	160
Iron (mg)	1.50	2.70	2.30	0.50	0.70	0.90	1.50
Magnesium (mg)	47	79	55	12	21	13	47
Phosphorous (mg)	92	49	50	26	66	20	52
Potassium (mg)	491	558	611	170	316	194	369
Sodium (mg)	38	79	20	18	33	28	27
Zinc (mg)	0.60	0.50	0.70	0.20	0.40	0.15	0.50
Vitamin C (mg)	120.00	28.00	43.00	36.00	89.00	9.20	15.00
Thiamine (mg)	0.11	0.08	0.03	0.06	0.07	0.04	0.04
Riboflavin (mg)	0.13	0.19	0.16	0.04	0.12	0.08	0.09
Niacin (mg)	1.00	0.72	0.9	0.23	0.64	0.38	1.00
Vitamin B ₆ (mg)	0.27	0.20	0.18	0.12	0.19	0.09	0.07
Folate (µg)	141	194	85	43	63	38	97
Vitamin B12 (µg)	0	0	0	0	0	0	0
Vitamin A (IU)	9990	9377	2910	98	623	745	2373
Vitamin E (mg)	1.50	2.00	1.50	0.15	0.78	0.20	0.40
Vitamin K (µg)	705	482	1140	76	126	24	108

than spinach and amaranth, it contains more iron than meat products. Kale contains 491 mg/100 g potassium, ensuring cardiovascular health, while magnesium content is 47 mg/100 g, ensuring neuromuscular functions and glucose metabolism. Vitamin K content in kale is 705µg/100g, which plays vital role in coagulation/hemostasis, while high folate content which is 141 µg facilitates DNA replication and fetal growth.

Phytochemically, kale is notable for its exceptionally high total antioxidant capacity, frequently placing it among the top-ranking vegetables in terms of ORAC (Oxygen Radical Absorbance Capacity) value. Its key bioactive compounds include:

Carotenoids (*lutein and zeaxanthin 12–20 mg/100 g*): These xanthophylls are deposited in the macula lutea of the human retina, acting to absorb phototoxic blue light and to quench singlet oxygen. They have also been epidemiologically linked to a decreased risk of age-related muscular degeneration.

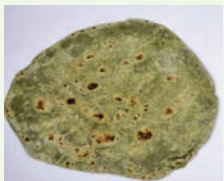
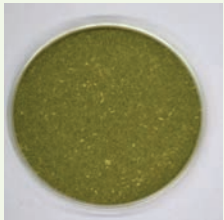
Flavonols (*quercetin and kaempferol glycosides 50–80 mg/100 g*): These polyphenols have potent anti-



Biactive compounds in kale

inflammatory, antiplatelet and vasodilatory properties and have been shown to inhibit histamine release and to stabilise mast cells.

Table 2. Major kale value-added products developed at ICAR-CITH, Srinagar

Product	Key ingredients	Processing	Nutritional enhancement	Images
Kale chapatti	5% kale powder + wheat flour	Dough rest 20 min, hot plate	Protein and fiber	
Soup premix	7% kale powder + flours/spices	Dry blending	Minerals, glucosinolates	
Seasoning mix	Kale powder + chili/turmeric	Fine grinding	Antioxidants	
Kale pickle	Blanched kale + spice oil	Brining 24-48h, anaerobic	Probiotics, phenolics	
Savory crackers	Shredded kale + starch/fat	Sheet 0.3mm, bake 150°C/20 min	Crunchy protein snack	
Sugar-free muffins	Kale powder + polyols/maida	Bake 160°C/25 min	Zero sugar, green hue	

Product	Key ingredients	Processing	Nutritional enhancement	Images
Savory muffins	Kale powder + polyols/ maida	Bake 160°C/ 25 min	Savory, green hue	
Instant noodles	Kale powder + wheat flour	Oven dry 40°C/36h	Increased phytochemicals	
Papads	Shredded kale + rice flour	Sun dry, hot oil fry	Traditional papad into functional food	
Kale powder	Kale leaf (veins removed)	NaHCO ₃ dip (20 g/L), blanch 85-90°C/30-40 sec, tray dry 50°C/2-3% moisture	ORAC >10 mmol TE/g	
Kale shreds	Kale leaf lamina	Cut 3-5 mm shred, blanch 90 °C/30-40 sec, centrifuge, air dry, airtight PE pouches	Value ingredient in bakery products	
Brined kale	Kale shreds + 20% brine	Blanch 90 °C/2 min, 85:15 leaf: brine ratio	Probiotics + phenolics preserved	
Kale pakoras	Kale stems + rice flour batter	Clean stems, steam for 15 min, dip in batter, deep fry	Zero-waste, green hue	

Glucosinolates and isothiocyanates (20–40 µmol/100 g FW): Glucosinolates are hydrolysed to form isothiocyanates, including sulphoraphane and iberin, in the presence of myrosinase enzyme. These electrophiles facilitate carcinogen elimination by inducing phase II detoxification enzymes e.g., quinone reductase, glutathione S-transferase.

Medicinal uses: Kale has been utilised globally in traditional medicine practices for preventing and treating chronic and degenerative disorders. Its therapeutic roles encompass gastric ulcers, hypercholesterolemia, hyperglycemia, rheumatism and hepatic diseases. These health- protective effects stem from bioactive constituents, including glucosinolates, carotenoids and polyphenols. Consequently, pharmaceutical and nutraceutical industries worldwide are formulating kale based-dietary supplements and functional foods.

Value added products from kale: Despite its exceptional nutritional profile, fresh kale faces significant marketability barriers: Bulky volume, high moisture content (84–87 %), rapid post-harvest deterioration and limited refrigerated shelf life (5–7 days.) These constraints restrict market reach beyond production areas and cause substantial losses during peak harvest. To address these challenges, ICAR-CITH has pioneered innovative nutrient-preserving processing technologies, transforming traditional kashmiri *haak* into stable value-added products (Table 2).

Recently celebrated ‘Kale Carnival’ at CITH showcased the diverse germplasm and the products arising out of it, confirming consumer acceptance ratings >8/10 across diverse demographics. These breakthrough innovations strategically position kale as India’s response to global superfood demand, seamlessly bridging himalayan culinary heritage with modern nutraceutical science.



Glimpses of Kale Carnival at ICAR-CITH, Srinagar

SUMMARY

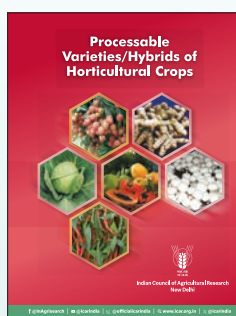
Kale represents an outstanding model of nutritional density, phytochemical diversity and genetic variability, reiterating its position as a key component in the development of dietary and food security. This article confirms kale's nutritional superiority over traditional leafy vegetables, particularly in protein content, dietary fibre, vitamins A, C and K and essential minerals. The Kashmir valley preserves rich genetic diversity where landraces like *Khanyari*, *Kawdari*, *Hanz haak*, and *GM dari* showcase

emerges not just as a superfood, but as a strategic asset for nutritional security, genetic conservation and agri-entrepreneurship.

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Processable Varieties/Hybrids of Horticultural Crops



This book will be useful for the processing industry as it provides information on the recent varieties /hybrids of horticultural crops and their availability. The information provided in this document will help the Indian farmers and Food Processing Industry in identifying suitable crops and varieties/hybrids based on their processing qualities for strengthening entrepreneurship.

TECHNICAL ASPECTS

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Tumba: An Underutilised Medicinal Vegetable of Dryland Ecosystems

***Tumba (Citrullus colocynthis)* is an underutilised medicinal vegetable species indigenous to arid and semi-arid ecosystems. The crop exhibits remarkable tolerance to drought and extreme temperatures and is capable of growing in marginal soils with low fertility. Traditionally, it has been widely used in ayurvedic and indigenous medicinal systems due to the presence of diverse bioactive compounds. Its extracts possess antidiabetic, laxative, anti-inflammatory and antimicrobial properties. Owing to its resilience and therapeutic potential, the cultivation and utilisation of this species may contribute to sustainable agriculture, value addition in medicinal plant resources, and improved livelihood opportunities in dryland regions.**

Keywords: Cultivation, Economic potential, Tumba, Underutilised medicinal vegetable

TUMBA (*Citrullus colocynthis*), a member of the family Cucurbitaceae, is a hardy wild herbaceous vine widely adapted to arid and desert environments. In India, it is commonly known as Bitter cucumber, Wild gourd, *Tumba* and *Indrayan*. The species is believed to have originated in the tropical regions of Asia and Africa and is now widely distributed across the Mediterranean and North African regions. It was the progenitor of present cultivated watermelon. In India, the plant commonly occurs in wild habitats, particularly in sandy areas of Punjab, north western regions, southern India and along the Coromandel Coast. It is naturally adapted to desert ecosystems such as those found in Arabia, the Sahara and parts of South Asia including India and Pakistan.

Composition and uses: India is recognised as an important centre of diversity for many wild medicinal plants. In traditional medical systems such as Ayurveda, Siddha

and Unani, a large number of therapeutic preparations are derived from plant species, a practice that has been followed since ancient times and continues to be widely used and commercially exploited today. The different plant parts including roots, fruits, seeds and leaves are valued for their medicinal and nutraceutical properties. The plant holds an important place in traditional medicine and can be propagated both vegetatively and through seeds, particularly during the summer season. In addition to these nutrients, fruits and seeds contain several essential bioactive compounds such as alkaloids, essential oils, flavonoids, cucurbitacins (A, B, C, D, E, K and L) and colocynthosides (A and B) and minerals, which contribute to their dietary significance.

Furthermore, seed oil is considered valuable due to the presence of beneficial fatty acids and bioactive constituents. The powder prepared from the dried fruits and seeds are also used in traditional medicine for various therapeutic purposes. Because of these nutritional and pharmacological properties, it has significant potential for use in functional foods, nutraceuticals and herbal formulations.



Vining habit of *tumba* plant

Table 1. Nutritional profile of *Tumba*

Particulars	Flesh contents/ 100 g	Seeds contents/ 100 g
Moisture %	85–90	3–6
Protein %	2–4	13–26
Carbohydrates %	7–10	20–30
Ash %	–	2.4
Fat %	0.5–1	14–24



Mature fruits of *Tumba*



Fruit flesh with mature seeds

Botany: Botanically, it is an important herbaceous vine adapted to arid and semi-arid environments. The plant is usually perennial in nature and develops long creeping or trailing vines that may reach up to about 3 m in length. The stems bear rough, angular tendrils covered with coarse hairs, which help the plant spread over the ground. The leaves are alternately arranged, deeply lobed, and typically measure 5–10 cm in length, with petioles attached to the vine. The plant produces monoecious flowers, meaning that separate male and female flowers occur on the same plant. The flowers are pale yellow in colour and possess a five-lobed corolla and a five-parted calyx, which are characteristic features of cucurbitaceous crops. Each plant can produce approximately 15–30 globose fruits. The fruits are about 5–7.5 cm in diameter, pepo-type with a smooth outer surface. They are green when immature and gradually turn yellow at maturity and ripening.



Drying of mature fruits



Naturally dried fruits

Anticancer activity: The anticancer potential is due to the presence of diverse bioactive compounds. Extracts prepared from the seeds using solvents such as methanol, chloroform and hexane have been evaluated against different cancer cell lines, including hepatic (HepG2), prostate (DU145), cervical (HeLa) and lung (A549). The most extracts exhibit inhibitory effects on cancer cell proliferation, although the chloroform extract showed comparatively lower activity. Among the extracts, the hexane seed extract demonstrate the strongest antiproliferative effect, particularly against the DU145 prostate cancer cell line.

Anti-inflammatory and immunomodulatory properties:

gastritis and psoriasis, often through increased levels of inflammatory mediators including TNF- α , COX-2 and IL-6. By modulating these inflammatory pathways, it helps alleviate inflammation and improve overall health.

Antimicrobial activity: It possesses notable antimicrobial properties against a wide range of microorganisms, including bacteria, fungi, and viruses. The presence of bioactive compounds enables the plant extracts to inhibit the growth of pathogenic microbes. Considering the increasing global challenge of antimicrobial resistance, it may serve as a valuable source for developing alternative therapeutic agents. The silver nanoparticles derived from aqueous extract exhibited antibacterial, antiviral, fungicidal and larvicidal properties.

Antioxidant Properties: It contains several antioxidant compounds capable of neutralising free radicals and reducing oxidative stress in biological systems. These antioxidants help protect cells from oxidative damage, which is often associated with the development of chronic diseases such as cardiovascular disorders, cancer, and neurodegenerative conditions. Therefore, the antioxidant potential contributes to its therapeutic importance in promoting overall health.

Cardioprotective benefits: The nutritional composition of its fruits may contribute to cardiovascular health. Potassium present in the fruits plays a key role in maintaining normal blood pressure, while dietary fibre helps reduce cholesterol levels. Calcium also supports proper muscle and cardiac function. Regular consumption of such nutrient-rich plant products may help lower the risk of cardiovascular disorders such as hypertension and coronary artery disease. by decreasing C-reactive protein (CRP), alanine aminotransferase (ALT), ALP, AST, and lactate dehydrogenase (LDH) levels.

Antidiabetic Potential: It has promising antidiabetic activity in various experimental studies. Bioactive constituents present in the fruit and seed extracts help regulate blood glucose levels and improve insulin sensitivity. These compounds influence glucose metabolism and support better glycaemic control. It may serve as a

potential natural supplement for managing diabetes and improving metabolic health. It has more blood sugar-lowering potential (58%) than ethanol (36%) and chloroform extract (34%).

Cultivation practices

Soil and climate: It is a typical xerophytic plant adapted to arid and semi-arid climates. It grows well in areas with a mean annual temperature of about 23–27 °C and annual rainfall ranging from 25–37 cm. The plant can be found up to 1500 m above sea level and thrives in sandy or sandy-loam soils with a pH range of 5.0–7.8, including sub-desert soils and coastal sandy habitats.

Field preparation: Sandy soils does not require but field should be free from weeds/grasses at the time of sowing.

Seed selection and treatments: There is no specific superior variety of *tumba*, mostly farmers grow desert local cultivars. After selection of healthy and disease-free seeds they are dipped in 5% NACL solution, for quick germination.

Sowing: Early sowing is done at the onset of monsoon and late sowing up to mid-August. The treated seeds may be sown in two ways;

- Drilled in the field by opening the furrows
- **Pit sowing:** (best method for high yield) 2,3 seeds are sown in each pit which are 120 cm × 120 cm distance. Before seed sowing filled 2 t/ha FYM and 5 kg/ha BHC dust to reduce soil borne problem and enhances seeding growth. The seed should be thinned at 10-15 days after germination to maintain proper plant spacing.

Manure and fertilizers: 2 t/ha FYM is incorporated in field before sowing. Crops are grown under rainfed condition, application of 80 kg/ha nitrogen should be done as top dressing while phosphorus and potassium are not necessary.

Weeding and intercultural operations: These practices are done in early stages when plant attains 20–30 cm height

and another 45 days after sowing for better growth of vine.

Plant protection: Basically tumba is not affected by any serious diseases or pests, at vegetative stage tumba beetles attacks have been noticed, for controlling beetles damage spray 0.2% carbaryl at 10–15 days interval.

Harvesting and yield: The mature yellow fruits are picked dried and threshed for seed purpose whereas the green fruits are fed to animals. It yields 120-150 q/ha dried fruits and 450 kg/ha seed.

SUMMARY

Tumba is a drought- and heat-tolerant cucurbit well suited to arid and semi-arid regions because of its low water and input requirements. Its seeds and fruits possess nutritional, medicinal and industrial importance with potential applications in nutraceutical, pharmaceutical and biofuel industries. Cultivation on marginal lands can enhance farmer, income and support climate-resilient dryland agriculture. In addition to its economic value, it serves as an important genetic resource for improving biotic and abiotic stress tolerance in cucurbit crops. Future research should emphasise phytochemical characterisation, genetic improvement and development of safe therapeutic products. Value addition through seed oil, powders and nutraceutical formulations along with improved cultivation and commercialisation strategies, can further enhance its economic viability and livelihood opportunities in arid regions.

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TECHNICAL ASPECTS

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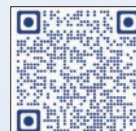
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Thanamir – The apple village of Nagaland: A promising beacon of rural prosperity

Apple cultivation in Thanamir, a picturesque village in the foothills of Nagaland, is both unusual and inspiring. Traditionally, apples are associated with cooler Himalayan regions such as Kashmir or Himachal Pradesh, where altitude and climate naturally favour the crop. In contrast, growing apples in Nagaland once seemed improbable. However, the residents of Thanamir discovered that their village's unique microclimate, marked by cooler temperatures due to elevation, fertile soils and mist-laden mornings, was favourable, making it a suitable apple-growing niche. The story of Thanamir apples is not merely about fruit cultivation; it is a narrative of community initiative, resilience and rural transformation. What began with a few experimental saplings gradually became a collective effort, as farmers recognised the potential of their environment and worked together to develop orchards. Looking ahead, an integrated networking approach involving research institutes and non-governmental organisations can play a crucial role in strengthening apple cultivation in the region.

Keywords: Apple genotypes, Challenges, Nutrient composition, Prospects

NESTLED in the remote hills of North-eastern India, Thanamir village in Nagaland's Kiphire district has gained recognition for its success in apple cultivation. What began as a small initiative has grown into a symbol of resilience and ingenuity, showing how innovation and perseverance can transform a rural community as the 'Apple Village of Nagaland' and has reshaped the local economy, diversified agriculture and instilled pride among villagers. Situated in the foothills of Mount Saramati at an altitude about 2,071 meters above mean sea level, near the India-Myanmar border, the village enjoys a unique climate. The village's cool temperatures between 2 °C and 20 °C, moderate rainfall of about 19 inches annually and well drained soils provide ideal conditions for temperate horticulture producing the distinctive Saramati or Thanamir apple that has become a regional emblem. To build on this progress, Department of Horticulture, Government of Nagaland has distributed more than 10,000 apple graft to the farmers since 2009–10 and their performance and yields accounts to 57.31 tonnes of apples annually from Thanamir. The growing importance of apple farming was celebrated with the first 'Apple Festival' on 29 September 2010, initiated by Tangit Longkumer. Today, the orchards surrounding the village stand as a testament to agricultural innovation and community determination, making the village one of Northeast India's most inspiring horticultural success stories.

The origin of apple cultivation and the apple village of Nagaland: The origin of apple cultivation in Thanamir village, dates back to 1975 when village guard (Lance

Niak) T. Ningtsemong first encountered apples at the Penkim army outpost. Preserving the seeds given to him by the quarter master, he planted them experimentally in his backyard, three of the four germinated successfully. By 1977, the saplings were transplanted into his kitchen garden and after years of careful nurturing, they flowered in 1984. In 1985, the trees bore fruit with distinct taste, shape and colour, confirming the region's suitability for apple cultivation. Ningtsemong also discovered that apple plants could be propagated through root cuttings, which facilitated wider distribution of saplings, encouraged by this success, villagers expanded orchards across the slopes, transforming the local landscape and economy.

Agricultural practices: Apple cultivation in the village follows systematic orchard management supported by a sound understanding of horticultural practices. The production is largely based on organic methods, with zero use of synthetic fertilisers or chemical pesticides and orchard tasks typically include clearing forested areas, levelling the ground, digging pits, planting nursery crops, weeding and harvesting. This organic approach not only reflects the community's ecological ethics but also aligns with the growing market demand for sustainably produced fruits. Propagation is primarily carried out through seeds and root cuttings, with saplings generally planted during the early spring months of March-April at a spacing of 5 × 5 meters. The plants start flowering from the 1st week of March till 1st week of May and are ready for harvest from the month of July to late September depending on different cultivars.



Orchard view



View of apple fruiting plant



Glimpse of different apple genotypes grown in Thanamir, Nagaland

the area.

Economically, apple cultivation provides a significant seasonal source of income for the villagers, with a benefit-cost ratio of 1.95 indicating that apple-based farming is profitable in Thanamir. Apples are sold both as fresh fruits and as value added products such as dried slices and juice, marketed in nearby towns, neighbouring states and directly to visitors. This diversification has reduced dependence on traditional shifting cultivation (Jhum), and offers a more stable and sustainable livelihood option for the uphill farmers.

Challenges faced by apple farmers: While the village climate supports apple cultivation but despite its resounding success, apple cultivation in Thanamir still faces a mix of logistical, technical and environmental challenges. Some of them are discussed here:

- **Transportation and Infrastructure:** One of the major challenges faced by Thanamir's apple growers is poor infrastructure, particularly inadequate road connectivity. The villagers struggle with costly and time consuming transport of apples to district centers and state markets, often leading to postharvest losses as fruit spoils before reaching buyers. The absence of cold storage and processing facilities further compounds the issue, forcing farmers to sell produce quickly, often before full maturity at lower prices, rather than storing, processing or marketing strategically for better returns.
- **Market access and marketing channels:** Growers face significant market access challenges, as their organically grown produce is available only in relatively small quantities and reaching larger markets outside Nagaland remains difficult. In the absence of marketing cooperatives and proper branding or packaging facilities, Thanamir farmers often sell to middlemen at low prices, reducing profit margins and limiting competitiveness.
- **Technical knowledge and training gaps:** Since apple cultivation in the village began as a community driven experiment, many scientific orchard management practices have not yet been fully adopted. Farmers often lack formal training in essential techniques such as pruning, resulting in overgrown canopies with dense, tangled branches that restrict sunlight and air circulation, leading to poor tree health and low quality fruit. Key practices such as grafting, soil and nutrient management and integrated pest management (IPM) remain underutilised.
- **Environmental and climatic constraints:** Thanamir's high altitude climate favours apple cultivation, but farmers face growing environmental challenges. Rising temperatures, erratic rainfall and persistent humidity encourage fungal diseases, reducing orchard health and yields. Climate change adds uncertainty, as apples are highly sensitive to temperature fluctuations, making production unstable. Soil erosion from

Nutritional composition of Thanamir apples: Most of the apples grown are traditional local varieties and the fruits vary in shape, size (round, conical, oblong, ovate) and fruit surface colour (ruby red, purple red, yellowish green) but are appreciated for their unique crisp texture, balanced sweetness and a subtle tartness that makes them refreshing and versatile which are ideal for eating fresh, juicing or drying.

Cultural and economic impact of apple farming: Apple cultivation has become a defining socio-economic and cultural feature of Thanamir village; beyond its agricultural importance, it symbolises resilience, adaptation and collective progress. Most households maintain apple trees in homesteads or orchards, making the fruit central to the village's identity and the fruits are commonly offered to visitors as fresh juice or dried slices, reflecting traditions of hospitality. The orchards, set against Mount Saramati, enhance both the aesthetic and ecological character of

Physical and nutritional content range of the different apple genotypes of Thanamir apple

Physico-chemical attributes	Range
Fruit weight (g)	82.60 – 207.3
Fruit length (cm)	5.46 – 7.76
Fruit diameter (cm)	6.20 – 8.40
Fruit firmness (kg/cm ²)	6.90 – 10.20
Fruit juice (ml/100gm)	37.33 – 54.33
Total soluble solutes (°Brix)	9.53 – 12.90
Total sugar (%)	5.32 – 7.43
Reducing sugar (%)	3.36 – 4.20
Titrateable acidity (%)	0.33 – 0.77
Vitamin C (mg/100gm)	5.65 – 12.57
Crude fiber (%)	3.13 – 5.25
Crude protein (%)	5.40 – 8.69

steep terrains and limited irrigation further weakens sustainability. Orchards are also prone to pests like woolly apple aphids, stem borers and leaf miners, along with diseases such as apple scab, powdery mildew and fire blight. Managed mainly through organic methods, these pressures reduce tree vigour, fruit quality and longterm productivity.

Future prospects: Thanamir's apple cultivation holds strong promise, especially as production is organic by default, with farmers relying on traditional practices that preserve soil health and biodiversity. This natural advantage positions the apples well for premium organic markets and support from government schemes such as the Mission for Integrated Development of Horticulture (MIDH) and the Rashtriya Krishi Vikas Yojana (RKVY) can further strengthen the sector by providing improved saplings, modern techniques, training and infrastructure such as cold storage, packaging and processing units. These measures would enhance productivity, reduce postharvest losses and help establish Thanamir apples as a recognised regional brand.

Expanding cultivation of apples neighbouring villages would also create a wider apple belt, while agro-tourism linked to the scenic orchards and Mount Saramati could diversify income and reinforce cultural identity. In addition, generating valueadded and processed products can help transforming largely perishable, high volume

harvests into low volume, high value exports such as dried slices, juice or specialty apple products that would improve profitability and market reach. Together with its organic strength, government support, extension works, diversification and product innovation will offer a sustainable pathway for Thanamir's apple farming to grow into a regional specialty with wider recognition.

SUMMARY

Nagaland, identified as a hub for organic farming, offers limitless potential for niche horticulture and Thanamir's apples embody this promise. With orchards expanding, better techniques adopted and stronger marketing channels built, production and income can rise. Valueadded processing can transform perishable harvests into high value products and Thanamir apples can stand as a promising beacon of rural prosperity, thrive as a premium organic product and cultural emblem when cultivation is farmer driven, research supported and linked with tourism, while ecological care ensures sustainability and longterm prosperity.

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SUSTAINABLE DEVELOPMENT GOALS RELATED TO FRUITS AND VEGETABLES



SDGs 2 3

Health benefits of fruit and vegetables
Harness the goodness

Fruit and vegetables have multiple health benefits. They strengthen the immune system, combat malnutrition and help prevent non-communicable diseases.



SDGs 2 3

Diversified diet and a healthy lifestyle
Live by it, a diverse diet

Adequate amounts of fruit and vegetables should be consumed daily as part of a diversified and healthy diet.



SDGs 2 8 12 13 14 15

Food loss and waste
Respect food from farm to table

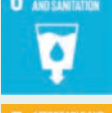
Fruit and vegetables are worth more than their price. Maintaining their quality and assuring their safety across the supply chain, from production to consumption, reduces losses and waste and increases their availability for consumption.



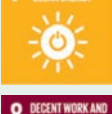
SDGs 1 2 3 4 5 8 11 12 15

Highlighting the role of family farmers
Growing prosperity

Cultivating fruit and vegetables contributes to a better quality of life for family farmers and their communities. It generates income, creates livelihoods, improves food security and nutrition, and enhances resilience through sustainably managed local resources and increased agrobiodiversity.



Source: *Fruit and vegetables – your dietary essentials, FAO background paper, FAO, Rome*




efficiency and productivity within fruit and vegetable supply chains to reduce loss and waste.

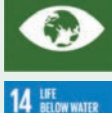
SDGs 1 2 12 15

Sustainable value chains
Foster sustainability

Sustainable and inclusive value chains can help increase production, and help to enhance the availability, safety, affordability and equitable access to fruit and vegetables to foster economic, social, and environmental sustainability.









Enhancing Productivity and Income through Improved Orchard Management in GI-Tagged Kachai Lemon: A Success Story from Manipur

Kachai Lemon (*Citrus jambhiri* Lush.), a unique citrus species from Manipur, is not only a cultural and economic pillar for the tribal communities of Ukhrul district but also a powerhouse of nutrition. Rich in flavonoids and ascorbic acid, it offers significant health benefits. Despite its Geographical Indication (GI) tag, its potential was constrained by traditional, low-yielding practices. This article chronicles the transformative journey of Shri Humao, a progressive farmer from Kachai village, who adopted scientific orchard and nursery management interventions from KVK, Ukhrul. His integrated approach of combining soil conservation, pest management, canopy architecture improvement and apiculture led to a staggering 297% increase in his annual income over five years (from ₹2.15 lakh to ₹8.54 lakh). More importantly, it ensured the production of high-quality, nutrient-dense fruits, reinforcing the link between scientific farming, income enhancement and community health. His success has ignited a rural entrepreneurship movement, inspiring fellow farmers to adopt commercial cultivation and diversify into nursery enterprises, thereby strengthening the local bio-economy and food system.

Keywords: *Citrus jambhiri*, GI tag, Kachai lemon, Orchard management

THE North-eastern region of India, a treasure trove of biodiversity, harbours a vast array of indigenous crops with immense nutritional and medicinal value. Among these is the Kachai Lemon (*Citrus jambhiri* Lush.), locally known as 'Kachai champpra'. Endemic to Kachai village in the Ukhrul district of Manipur, this unique fruit is a natural hybrid of mandarin orange (*Citrus reticulata*) and citron (*Citrus medica*). Its recent conferment of a Geographical Indication (GI) tag has rightfully acknowledged its distinctiveness, driven by its bold flavour, aroma and superior nutritional profile. It is exceptionally rich in ascorbic acid (vitamin C), a potent antioxidant that bolsters immunity, aids in collagen synthesis and protects against cellular damage.

However, for years, the cultivation of this nutritional goldmine was hampered by traditional, low-input practices. Farmers faced challenges like improper spacing, severe pest infestations (trunk borer, leaf miner, fruit fly), nutrient deficiencies and a lack of scientific post-harvest management. This resulted in low productivity and significant post-harvest losses, which limited both the income of farmers and the accessibility of this healthy fruit.

Technological interventions for a healthier orchard

Shri Humao, a forward-thinking farmer owning 4.5 hectares of land in Kachai village, experienced these challenges firsthand, with his initial annual income

stagnating at ₹2,15,000. In collaboration with the Krishi Vigyan Kendra, Ukhrul, he implemented a series of scientific interventions designed to rejuvenate his orchard and boost productivity. These practices not only improved fruit yield but also enhanced its quality and nutritional value.



Orchard view of Kachai Lemon

Key interventions adopted by Shri Humao:

Soil and water conservation: Given the hilly terrain, soil erosion was a major concern. The adoption of half-moon terraces prevented nutrient-rich topsoil loss, improved moisture retention and promoted healthier root systems. Healthy soil is the foundation for nutrient-dense crops.

Integrated pest management (IPM): To combat pests without resorting to harmful chemical pesticides, yellow sticky traps and pheromone traps were introduced for managing fruit flies, leaf miners and trunk borers. This

approach ensured the production of clean, residue-free fruits, preserving their natural nutritional quality and safety.

Scientific canopy and shoot management:

- Regular pruning of dried, diseased and undesirable shoots improved air circulation and sunlight penetration, which is crucial for reducing fungal diseases and enhancing the photosynthetic process that builds nutrients.
- Removal of unwanted shoots (up to 30–45 cm from ground level) directed the plant's energy into productive branches, leading to better fruit setting and larger, juicier fruits.

Disease prevention: Application of bordeaux paste on the trunk during winter acted as a powerful prophylactic measure, protecting trees from fungal infections and trunk borers, thereby ensuring the orchard's longevity and sustained production of healthy fruits.

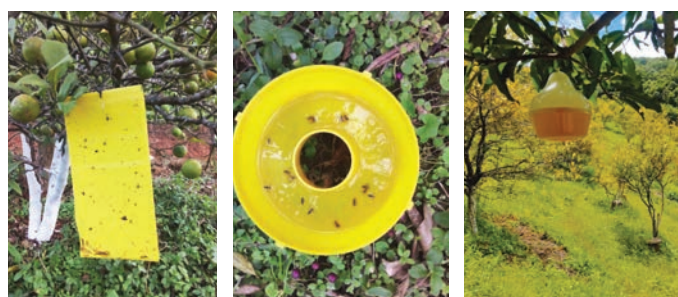
Integration of apiculture (honeybees): Introducing honeybee colonies in the orchard served a dual purpose. It enhanced pollination efficiency, leading to a higher fruit set and more uniformly developed fruits. It also provided an additional income stream from honey, which itself is a health product.



Training and pruning of lemon plant



Application of bordeaux paste

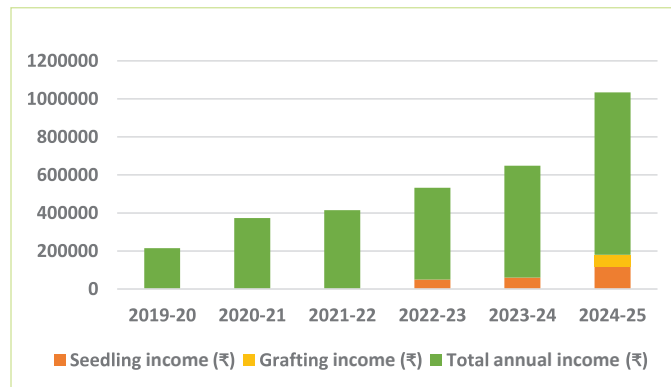


Sticky trap and pheromone trap

From subsistence to prosperity: The economic impact

The cumulative effect of these interventions was a dramatic transformation in both yield and income, as detailed below:

A. Diversification and income growth: Shri Humao diversified from only fruit sales to include nursery activities, creating multiple revenue streams.

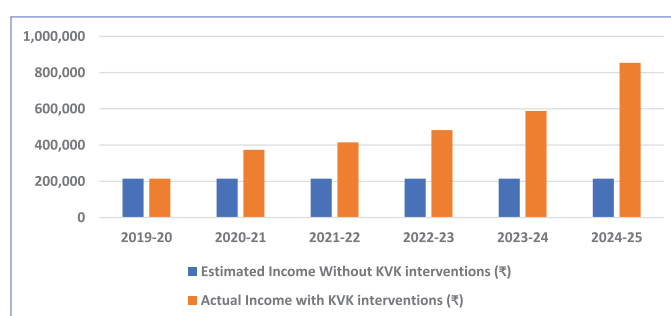


Year-wise income from Kachai lemon and nursery activities

B. Quantifying the impact of KVK interventions: The direct comparison highlights the power of scientific adoption. The price per kilogram of lemon also increased from ₹40 to ₹60, reflecting the better quality and possibly the GI tag's growing influence.



Fruit harvesting for marketing



Comparison of income with and without KVK interventions

The results are undeniable. By adopting scientific practices, Shri Humao didn't just increase his income; he ensured the production of healthier and chemical-free fruits. While the estimated annual income without intervention remained at the baseline level of ₹2.15 lakh, the actual income increased steadily over the years, reaching ₹8.54 lakh in 2024–25. This represents a 297.2% increase over the baseline, indicating the effectiveness of scientific orchard management, enterprise diversification and market-oriented interventions introduced by KVK.



Nursery preparation under low-cost polyhouse

The establishment of polyhouses for nursery production also ensures the availability of high-quality, disease-free planting material for the community, further promoting the cultivation of this health-promoting crop.

A ripple effect: From individual success to community strength: Shri Humao's success has catalysed a positive change throughout the region. His farm became a living demonstration of the benefits of scientific horticulture.

- Inspiring 15 fellow farmers to take up scientific Kachai lemon cultivation across 20 hectares, multiplying the production of this nutritious fruit in the district.
- Motivating 10 farmers to start their own seedling and grafting businesses, creating a local source of healthy planting material and generating additional income.
- Strengthening the local economy by creating employment opportunities in orchard management, nursery operations and potentially in future value-addition units.

This collective shift towards commercial scientific farming ensures a greater supply of high-quality and nutrient-rich Kachai lemons for local and regional markets. It directly contributes to the nutritional security of the community and beyond.

Way forward: This success model holds immense potential for replication across the North-eastern region to unlock the value of its unique biodiversity. To scale up

such initiatives, a concerted effort is needed:

- Strengthening KVK outreach to provide need-based, hands-on training to more farmers.
- Promoting value addition by establishing small-scale processing units for juice, squash, pickles and dried rinds, which can reduce post-harvest losses and create nutritious, shelf-stable products.
- Leveraging the GI tag for robust branding and marketing, connecting consumers who value health and unique food origins with premium products.
- Encouraging Farmer Producer Organizations (FPOs) to collectively invest in infrastructure, quality certification and stronger market linkages.

Shri Humao's story is a microcosm of a larger truth: Investing in the farmer and equipping them with scientific knowledge yields a rich dividend - prosperous farms, thriving communities and a healthier nation.

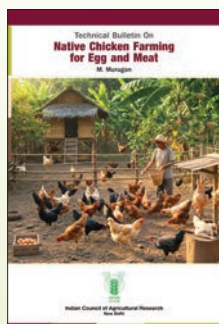
SUMMARY

The journey of Shri Humao is a powerful testament to the transformative potential of science-led and entrepreneurially-driven agriculture. It demonstrates that improving orchard management is not just about increasing yield and income; it is intrinsically linked to enhancing the nutritional quality of the produce and the health of the community. By adopting IPM and soil health practices, he has become a producer of safe and functional food.

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Technical Bulletin on Native Chicken Farming for Egg and Meat



This publication provides a comprehensive understanding of native chicken farming, including its production and marketing systems. The subject matter is sequentially presented, covering the introduction, native chicken stocks concept, stock selection, rearing systems and housing models, feeding basics meat and egg production, biosecurity principles, health management, economics and capacity building.

TECHNICAL ASPECTS

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Wild Edible Fruits of Western Ghats for Future Nutritional Security

The Western Ghats is recognised as one of the biodiversity hotspots in the world and has abundance of underutilised wild fruit species, with great nutritional, medicinal and cultural value. These species are high in vitamins, minerals, dietary fibre and bioactive antioxidants, which can also provide food security and livelihoods for indigenous peoples of rainforests. These native species which are widely adaptable, pest-resistant and provide benefits for sustainable agriculture practices are being rapidly lost due to habitat loss, climate change, exotic species introduction and socio-economic shifts. In this article 38 wild fruit species represented by 23 families have been documented from various locations of Western Ghats in which Rhamnaceae, Rosaceae, Rutaceae family represent the highest with 3 species. The common and vernacular name, flowering and fruiting period have also been given. The article will also provide information on the timing of availability of wild edible fruit species.

Keywords: Food security, Nutritional security, Underutilised wild fruits, Western ghats

INDIA is one of the world's most biodiverse countries, rich in flora and fauna due to its diverse variety of climates, geographies and ecosystems. It is also home to four biodiversity hotspots, one of which is the Western Ghats. The Western Ghats, a UNESCO World Heritage site that lies on the East Coast of the Arabian Sea and stretches along the western coast of India and renowned for its rich biodiversity, many of which are endemic to this region. This mountain range spans more than 1,600 km across several Indian states, including Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. This region is home to 7,402 species of flowering plants, of which 5,588 are native or indigenous and over 500 species of medicinal plants, including wild edible fruit plants, growing wild in the forest, road side and in almost every backyard. It has been reported that the wild edible fruits belong to 25 families, 38 genera and 50 species, although many more are yet to be identified. The agro-climatic conditions, soil health and rainfall pattern create a congenial environment that makes it a genetic reservoir that contributes to ecological conservation and agricultural sustainability.

Wild fruits are those which are less known, often edible, underutilised or neglected species. These fruit species are indigenous and regarded for their cultural, medicinal and nutritional value. They play a crucial role in maintaining the ecological stability of the region and serve as vital resources for local communities. The wild underutilised fruit crops hold significant potential in improving livelihood, nutrition, health, income generation, biodiversity conservation and combat hidden hunger

caused by micronutrient deficiencies. The wild fruits play an important role in food and nutrient security as they have better nutritive value than the cultivated fruits. They are typically consumed fresh/raw or processed and helps to fulfill daily caloric needs. These fruits are a source of carbohydrates, proteins, vitamins (C, A, B1, B3, B6, B9, E), minerals like sodium, potassium, magnesium, iron, calcium and phosphorus, dietary fiber and possess significant medicinal properties which are essential for overall well being and maintaining good health. Wild edible fruits act as staple food for many tribal communities during food deficit. Recent studies of the phytochemical composition of fruits have attracted much interest in terms of their antiproliferative and antioxidant properties which can help to combat malnutrition. They are also hardy in nature, widely adaptable, resistant to pest and diseases and can be utilised in crop improvement programs.

The wild fruits are consumed only in smaller amounts due to less availability, being less palatable and have lesser demand in the market since they are found to a limited extent. The fruiting season as well as the shelf life of these wild fruits are limited to a very short span. In the Western Ghats of India, the underutilised wild fruits are an integral part of the traditional diet of several communities. The introduction of exotic fruit varieties has led to a gradual decline in the reliance on wild fruits in urban areas. However, many tribal communities continue to use them as a dietary supplement. Indigenous people of these areas play a major role in identifying the nutritional and medicinal value of wild fruit species and still have knowledge on almost all the wild fruit species as a source

of food, fodder, medicine and timber. The fruits are often preserved for consumption during dry seasons or sold in rural markets.

Consumption of wild fruits is reported from ancient times to the present era. These fruits have historically been used as a medicinal agent, as these are rich in biologically active compounds, along with essential vitamins, minerals and other nutrients, but they are greeted with skepticism. There are records mentioning the use of the wild fruits, nuts, seeds, leaves and roots. Many of the wild underutilised edible fruit species are not known to present society but mostly known to local folks and tribes as they are found only in their natural habitat. Some of the wild fruit species have promising ornamental properties that can be used in beautification of gardens and avenues. Some of such species are *Flacourtia montana*, *Garcinia morella* and *G. indica*. These species also contribute to biocultural diversity and traditional festivals; one such species is *Artocarpus hirsutus*, used as an offering to god in the southern part of the Western Ghats.

Although the Western Ghats region is rich in wild fruits, there is a high risk of biodiversity loss due to climate change, cultivation of exotic fruits, deforestation, low rainfall, elephant damage, encroachment, poverty, migration of tribes and as their use is lesser-known, local communities sometimes clear wild areas to make way for cultivation. In such conditions, the knowledge on such fruits and their uses are lost. There is a lack of organised efforts in prospecting, exploration, collection, evaluation, characterisation, conservation, documentation and improvement to identify superior genotypes for developing agro-techniques. Therefore, greater emphasis is needed to explore and create awareness and to manage the genetic resource efficiently which will encourage cultivation on

a large scale, along with research into nutritional and antioxidant properties, product development, marketing and documenting the knowledge, all of which will help to improve their economic standing in the near future. The first step for this process can be done by integrating wild fruit plants as intercrops with commercial crops. This may help to combat food scarcity, support economic development in tribal regions and aid in restoring degraded lands.

To preserve and enhance this resource, greater focus should be placed on promoting these underutilised fruits. Despite being frequently disregarded, they hold immense potential in addressing nutritional deficiencies and enhancing food security for an immensely growing population. They are perfect for sustainable agriculture because of their low cultivation requirements, resistance to pests and diseases and ability to adapt to local conditions. Moreover, their natural abundance in forested and tribal regions makes them accessible and affordable for marginalised communities. The information on flowering and fruiting period of these wild fruit species were not documented as compared to major fruits, which has led to a lack of knowledge and awareness about the availability of the fruits. The time of flowering, fruiting and maturity varies depending on the region, season and other environmental factors like soil, temperature, photoperiod, rainfall and various other endogenous genetic components. In this article, the diversification of underutilised wild fruits of the Western Ghats of India was documented.

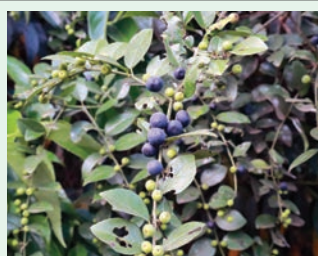
A total of 38 wild fruit species were collected, their common name, vernacular name, the time of flowering and fruiting period of each species along with their photographs are given below in the table.

List of wild fruits in Western Ghats region

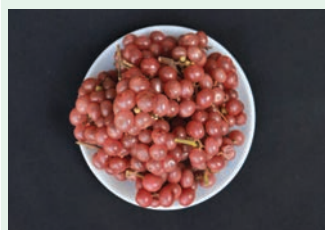
Image of the fruit	Name of fruit species	Image of the fruit	Name of fruit species
	<i>Uvaria narum</i> Common name: South Indian Uvaria Family: Annonaceae Vernacular name: Kodambale hannu (Kannada) Time of Flowering: June–July Time of fruit availability: September–October		<i>Rourea minor</i> Common name: Big-leaved Rourea Family: Connaraceae Vernacular name: Huli hannu (Kannada) Time of Flowering: January–February Time of fruit availability: May–June
	<i>Alangium salviifolium</i> Common name: Sage leaved alangium Family: Cornaceae Vernacular name: Ankole hannu Time of Flowering: April–May Time of fruit availability: July–August		<i>Elaeagnus conferta</i> Common name: Silverberry Family: Elaeagnaceae Vernacular name: Beeruguli hannu Time of Flowering: October–November Time of fruit availability: February–March
	<i>Syzygium caryophyllatum</i> Common name: South Indian Plum Family: Myrtaceae Vernacular name: Kunta Nerale Time of Flowering: May–June Time of fruit availability: June–September		<i>Securinega leucopyrus</i> Common name: Indian Snowberry Family: Phyllanthaceae Vernacular name: Bili Sooli gida (Kannada), More pann (Kodava) Time of Flowering: April–July Time of fruit availability: September–October.



Ziziphus rugosa
Common name: Wild Jujube
Family: Rhamnaceae
Vernacular name: Kotte hannu (Kannada), Kotte Pann (Kodava)
Time of Flowering: December-January
Time of fruit availability: February-March



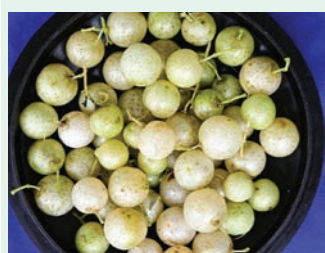
Scutia myrtina
Common name: Cat Thorn
Family: Rhamnaceae
Vernacular name: Kurudi hannu (Kannada)
Time of Flowering: March-April
Time of fruit availability: June-August



Glycosmis mauritiana
Common name: Ash Sheora
Family: Rutaceae
Vernacular name: Somari hannu (Kannada), Kurmana pann (Kodava)
Time of Flowering: October-December
Time of fruit availability: March-April



Toddalia asiatica
Common name: Orange Climber
Family: Rutaceae
Vernacular name: Gonne hannu (Kannada)
Time of Flowering: July-October
Time of fruit availability: August-September



Clausena indica
Common name: Indian Wampi
Family: Rutaceae
Vernacular name: Majjige hannu (Kannada)
Time of Flowering: February-April
Time of fruit availability: May-July



Zizipus oenopolia
Common name: Jackal jujube
Family: Rhamnaceae
Vernacular name: Choori hannu (Kannada)
Time of Flowering: Sep-Oct
Time of fruit availability: December-February



Rubus niveus (BLACK)
Common name: Mysore Rapberry
Family: Rosaceae
Vernacular name: Nuchate hannu
Time of Flowering: February-March
Time of fruit availability: June-July



Rubus elepticus
Common name: Golden Himalayan Raspberry
Family: Rosaceae
Vernacular name: Nuchate hannu
Time of Flowering: February-March
Time of fruit availability: June-July



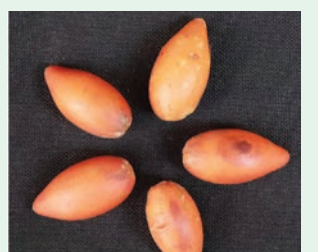
Canthium coromandelicum
Common name: Coromandel Canthium
Family: Rubiaceae
Vernacular name: Kare hannu, Karemullu (Kannada)
Time of Flowering: May-June
Time of fruit availability: July-August



Flacourtia indica
Common name: Governor's plum
Family: Salicaceae
Vernacular name: Kakkade hannu (Kannada), Kothri pann (Kodava)
Time of Flowering: December-January
Time of fruit availability: March-April



Chrysophyllum lanceolatum/Chrysophyllum roxburghii
Common name: Indian Star Apple
Family: Sapotaceae
Vernacular name: Pale hannu (Kannada)
Time of Flowering: January-February
Time of fruit availability: April-May



Mimosa elengi
Common name: Bullet Wood Tree
Family: Sapotaceae
Vernacular name: Ranjala hannu (Kannada)
Time of Flowering: November-February
Time of fruit availability: March-May



Debregeasia longifolia
Common name: Orange Wild Rhea
Family: Urticaceae
Vernacular name: Keppasi, Kurigele (Kannada)
Time of Flowering: December-January
Time of fruit availability: March-April



Aporosa lindleyana
Common name: Lindley's Aporosa
Family: Euphorbiaceae
Vernacular name: Yechi pann (Kodava)
Time of Flowering: September-December
Time of fruit availability: February-April



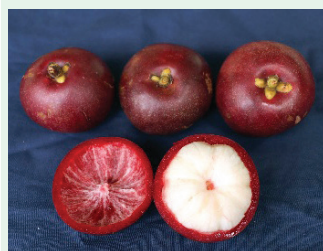
Carissa gangetica /
Carissa carandas
Common name: Karonda
Family: Apocynaceae
Vernacular name: Karmanji
pann (Kodava)
Time of Flowering: January–
March
Time of fruit availability:
April–July



Margaritaria indica
Common name: Airy Shaw
Family: Euphorbiaceae
Vernacular name: Uppalli pann
(Kodava)
Time of Flowering: April–June
Time of fruit availability:
September–November



Elaeocarpus munronii
Common name: Nilgiri Marble
Tree
Family: Elaeocarpaceae
Vernacular name: Edanji pann
(Kodava)
Time of Flowering: November–
January
Time of fruit availability:
March–April



Garcinia indica
Common name: Kokum
Family: Clusiaceae
Vernacular name: Punarpuli
(Kokum)
Time of Flowering: December–
January
Time of fruit availability:
April–May



Garcinia xanthochymus
Common name: Yellow
Mangosteen
Family: Clusiaceae
Vernacular name: Benakepuli
(Kodava)
Time of Flowering: April–June
Time of fruit availability:
August–October



Artocarpus hirsutus
Common name: Wild Jack Tree
Family: Moraceae
Vernacular name: Hebbalasuv,
Aajin chekke (Kodava)
Time of Flowering: January–
March
Time of fruit availability:
May–June



Bridelia stipularis
Common name: Climbing
Bridelia
Family: Phyllanthaceae
Vernacular name: Akshathe
balli (Kannnda)
Time of Flowering: November–
February
Time of fruit availability:
December–April



Grewia tillifolia
Common name: Dhaman
Family: Tiliaceae
Vernacular name: Thadachi
pann (Kodava)
Time of Flowering: February–
April
Time of fruit availability:
May–June



Elaeocarpus tuberculatus
Common name: Warty Marble
Tree
Family: Elaeocarpaceae
Vernacular name: Koome Pann
(Kodava)
Time of Flowering: February–
March
Time of fruit availability:
July–August



Physalis peruviana
Common name: Cape
Gooseberry
Family: Solanaceae
Vernacular name: Goomatte
pann (Kodava)
Time of Flowering: May–July
Time of fruit availability:
July–September



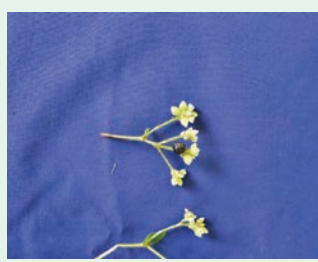
Garcinia gummigatta
Common name: Malabar
tamarind
Family: Clusiaceae
Vernacular name: Kachampuli
(Kodava)
Time of Flowering: February–
April
Time of fruit availability:
June–August



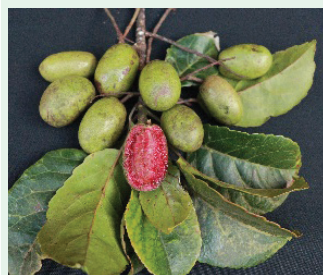
Canthium diocuum
Common name: Ceylon
Boxwood
Family: Rubiaceae
Vernacular name: Amme pann
(Kodava)
Time of Flowering: December–
February
Time of fruit availability:
March–May



Solanum nigrum
Common name: Black Night
Shade
Family: Solanaceae
Vernacular name: Ganike
hannu, Kake pann (Kodava)
Time of Flowering: March–
April
Time of fruit availability:
May–July



Persicaria chinensis
Common name: Chinese
Knotweed
Family: Polygonaceae
Vernacular name: Sorale hannu
(Kannnda)
Time of Flowering: year-round
Time of fruit availability:
throughout year



Eleocarpus variabilis
Common name: South Indian Marble Tree
Family: Elaeocarpaceae
Vernacular name: Kume hannu (Kannada)
Time of Flowering: May–June
Time of fruit availability: September–October



Cordia dichotoma
Common name: Lasoda
Family: Boraginaceae
Vernacular name: Challe hannu (Kannada)
Time of Flowering: December–February
Time of fruit availability: March–May



Rubus rugosa
Common name: Wild Raspberry
Family: Rosaceae
Vernacular name: Nuchate hannu
Time of Flowering: February–March
Time of fruit availability: May–June



Salacia wayanadica
Common name: Wayanad Salacia
Family: Celastraceae
Vernacular name: Madike hannu
Time of Flowering: February–April
Time of fruit availability: May–July

SUMMARY

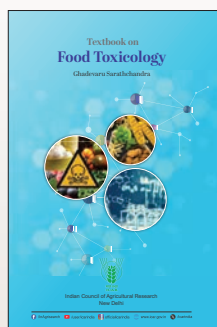
Documenting indigenous knowledge about their use, cultivation and preservation is crucial to maximising their value. By developing agro-techniques specific to these species, along with proper post-harvest handling and value addition strategies, can boost their market appeal. Promoting awareness through community involvement, educational initiatives and inclusion in public nutrition policies will encourage wider acceptance. In summary, the conservation and scientific exploration of wild fruits should be prioritised, not only to safeguard biodiversity but also to offer viable solutions for nutritional

improvement, economic upliftment and ecological sustainability.

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Textbook on Food Toxicology



This textbook encompasses various aspects of fundamentals of toxicology, including basic toxicology toxicants and their fates in foods and the human body. This textbook also provides the basic principles of food toxicology to help the general public to understand better the real problems of toxic materials in different foods. Additionally, this book covers fundamental aspects of laboratory analytical skills which is a prerequisite for successful toxicologist.

TECHNICAL ASPECTS

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Combating Root-Knot Nematodes: Boosting Guava Health and Productivity

Guava (*Psidium guajava* L.) is the 4th most commercially important fruit crop in India and is indigenous to tropical America. India leads in global guava production, but the area of expansion is declining due to biotic stresses. Among the major constraints in its commercial cultivation is the root-knot nematodes (*Meloidogyne* spp.), which significantly hampers productivity. Recently, *Meloidogyne enterolobii* was reported from Tamil Nadu, which is considered a serious threat to guava cultivation. This nematode causes substantial yield loss across various crops, resulting in considerable economic damage to growers. RKNs can cause yield loss of 60 to 80% in guava. *M. enterolobii* possesses a wide host range, enabling its survival and spread across cropping systems. Effective management strategies include the use of bio-agents, bio-pesticides and chemical nematicides such as Carbofuran.

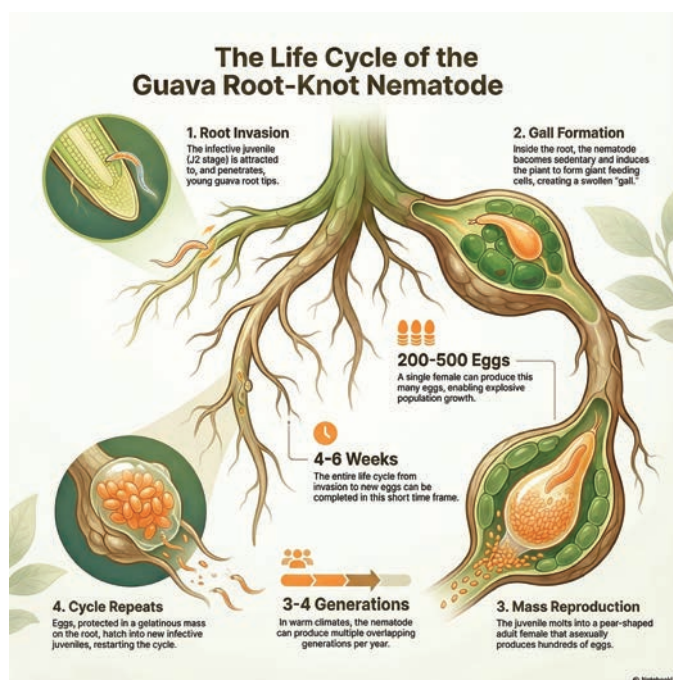
Keyword: Bio-pesticides, Guava, Management, Root-knot nematode

GUAVA (*P. guajava* L.) is the 4th most important fruit crop of India, which is globally spread from tropical to subtropical regions. Southern Mexico or Central America is the native place of the guava. It is popularly referred to as the 'apple of the tropics'. Guava can be cultivated across a wide range of soils and climatic conditions and is relatively tolerant to extremes of temperature, hot winds, scanty rainfall, saline soils and waterlogging. India is the largest producer of guava, with an area of 287 thousand hectares and a production volume of 4,304 thousand metric tonnes, followed by China, Thailand, Indonesia, Mexico and Brazil. Within India, Uttar Pradesh leads in guava production with 983.59 thousand metric tonnes, followed by Madhya Pradesh (776.75 thousand MT) and Bihar (434.41 thousand MT).

Guava roots were primarily affected by root knot nematodes and once infected, the roots are more vulnerable to the wilt fungus, a common pathogen that causes wilt disease in guava. The severity of the disease was increased because of this synergetic interaction

between RKNs and wilt pathogen. *Fusarium oxysporum* and *Meloidogyne* spp. together cause more damage to guava than the nematode alone. In India, *M. enterolobii* was found to be associated with wilted guava orchards. The root-knot nematodes, *Meloidogyne* spp., have been reported on some species of tropical fruit trees grown in the region over the last two decades. The RKN, *M. enterolobii*, was isolated in China for the first time. Later, it was isolated from guava orchards in different parts of China. The first report of *M. enterolobii* on guava came in 2016 from the Ayakudi region of Tamil Nadu. It has been added to the EPPO A2 list due to the risk of introduction and spread throughout the country. *M. enterolobii* is a serious threat to guava cultivation due to its rapid spread, and it makes guava cultivation impossible in highly infested areas. *M. enterolobii* is found in poly-specific communities and interacts dynamically with the host plant, the environment and other organisms in the rhizosphere.

Distribution: The root-knot nematodes (*Meloidogyne* spp.) of guava have become



Infographic illustration of the life cycle and mode of infestation of root-knot nematodes (RKNs) in guava plants.

one of the world's most dangerous pathogenic nematodes due to their widespread geographical distribution and wide host range. The RKNs occur in tropical to subtropical parts of the world, including Asian countries, African countries and Central and South America. Recently, *M. enterolobii* has emerged as the most prevalent pathogenic nematode species that infests various crop species such as fruit crops, vegetables and ornamentals as well as weeds. It has previously been reported from Florida, North Carolina and most recently from South Carolina and India. Currently, this species is considered the most destructive and aggressive among the *Meloidogyne* genus due to its high rate of reproduction and the difficulty in controlling it.

In India, *M. enterolobii* was first reported from Tamil Nadu during 2016 and later reported from different parts of the country such as Uttar Pradesh, Uttarakhand, Madhya Pradesh, Rajasthan, Haryana and other parts of country; and it can cause a yield loss of 60–80%.

Mode of infestation: A single female nematode can lay up to 400–600 eggs in warm weather conditions (27°C), and the life cycle can be completed within one month. Many creamy or whitish egg masses can be observed on

Table 1. The reactions of host plants to the root-knot nematode (*Meloidogyne* spp.) of guava

Susceptible plants			Resistant plants		
Cotton	Bell pepper	Brinjal	Millet	Rye	Cabbage
Peanut	Broccoli	Okra	Corn	Sorghum	(S-R)
Peanut	(S-MR)	Squash	Oats	Wheat	Cauliflower
Sugarcane	Celery	Tomato	Radishes	Carrot	Garlic
(S-R)	Cabbage	Cucumber	Rice	Broccoli	Lettuce
Sun Hemp	(S-R)	Beetroot		(S-MR)	Parsley
(S-R)	Chilli				
Sweet	Cowpea				
potato	(S-R)				
Tobacco	Common				
	bean				

Note: S= Susceptible, R= Resistant, MR= Moderately resistant

the roots of the plant. However, the nematode is unable to move quite far in the soil and it can spread easily through any form of soil movement viz., farm implements, irrigation and heavy rainfall.

The guava root-knot nematode behaves similarly to other species of root-knot nematodes in that it produces young juveniles that migrate towards the root tips of susceptible plants after hatching from eggs in the soil. These juveniles (J2) penetrate roots, establishing a permanent

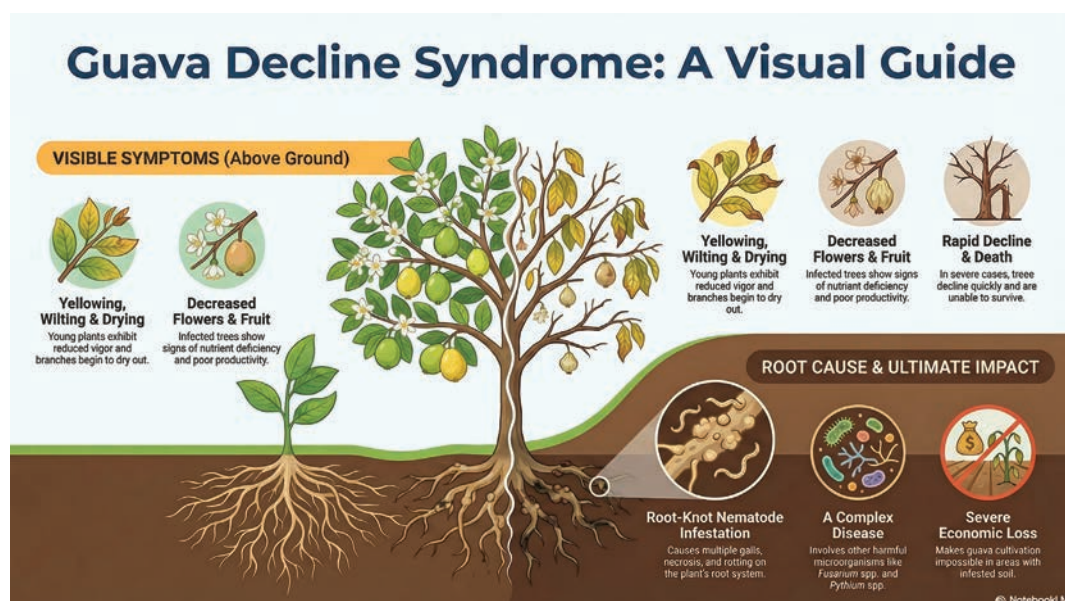
Table 2. Losses in other fruit crops due to nematodes in India

Fruit crops	Nematode species	Annual Loss (%)
Banana	<i>Radopholus similis</i> & <i>Meloidogyne</i> spp.	19–40, can up to 100%
Strawberry	<i>Meloidogyne</i> spp., <i>Pratylenchus</i> spp. & <i>Aphelenchoides</i> spp.	10–41
Grape	<i>Meloidogyne incognita</i>	30
Citrus	<i>Tylenchulus semipenetrans</i>	10–30
Papaya	<i>Meloidogyne incognita</i> & <i>Rotylenchulus reniformis</i>	30–40
Pomegranate	<i>Meloidogyne</i> spp.	40

feeding site and begins to mature into females. The formation of large galls or swellings of root tissues may happen in association with the developing females during this process.

Symptoms: The symptoms caused by the guava root-knot nematodes (RKNs) are similar to those caused by other species of RKNs; however, the symptoms of guava root-knot nematode infection are generally more severe. Young plants exhibit yellowing, wilting, branch drying, reduced vigour and decreased productivity.

Trees that are severely infected decline rapidly, eventually dying. Moderately infested plants show symptoms of general chlorosis and deficiency of nutrients, and they have decreased flowering and fruiting. Infected tree roots have multiple galls and root necrosis, resulting in a significant reduction of fine roots. The RKNs affect the entire root system of the plant, which may show distorted and swollen symptoms and heavily infested roots may rot. The death and decline of guava plants infested by *M. enterolobii* is a complex disease that involves other microorganisms such as *Fusarium* spp., *Trichoderma* spp., *Verticillium* spp. and *Pythium aphanidermatum*. This syndrome makes guava cultivation in infested areas



Infographic illustrating characteristic symptoms of root-knot nematodes (RKNs) infestation in guava plants.



Infested guava plant with RKN in field

Infested guava saplings showing chlorosis and stunting symptoms

Root distortion, rotting and decaying symptoms

Overview of infested guava saplings

Many galls and egg masses are showing on the infested guava root

impossible, causing serious economic problems for growers.

Management

Nematode management in nursery: Soil mixture treatment is a good method which is used to raise guava rootstocks to produce nematode-free planting material. A tonne of soil mixture needs to be blended using 50–100 kg of neem cake or pongamia cake that has been supplemented with some bio-pesticides like '*Paecilomyces lilacinus*', '*Pseudomonas fluorescens*' and '*Trichoderma harzianum*'. Additionally, 5 kg of carbofuran or phorate may be incorporated into 1 tonne of the soil mixture for more effective results.

Nematode management in orchards

Before planting

A) Prevention: The soil for establishing a new orchard should be free of nematodes and the planting material used for new planting should not be infected with nematodes. The saplings that will be used for rootstock or transplanting purposes should be grown in sterilised soil. All farm implements should be sterilised before use.

B) Deep summer ploughing: Deep ploughing of the soil is recommended during the hot summer months before planting new guava plants. At intervals of 15 days, it should be done twice or three times.

C) Soil application: The soil needs to be thoroughly ploughed and well pulverised before the planting of guava saplings. Afterwards, the recommended fertiliser dose needs to be incorporated for better growth and development of the plants, as vigorous plants may avoid the attack of nematodes. Add 20–25 kg carbofuran or phorate + 200 g of neem or pongamia or mahua cake per acre for the reduction of the initial population of nematodes. The beds must be kept at the optimal moisture level for better decomposition of organic matter.

Two tonnes of FYM/500 kg of neem or pongamia cake or one tonne of vermicompost enhanced with three bio-pesticides like *P. fluorescens*, *Trichoderma harzianum* and *Paecilomyces lilacinus* should be applied during the land preparation phase in organic farming.

After planting

A) Biological control: Several bacterial and fungal bio-agents are employed in the management. *P. lilacinus* and

Verticillium clamydosporium have been identified to be the most potent fungal parasites for controlling the root-knot nematodes on several crop species. Another fungal bio-agent i.e., *Trichoderma harzianum* also effectively reduce the RKNs in both soil as well as roots.

a) Preparation of Bio-pesticide: Apply 3–4 kg of compost or FYM or vermicompost enhanced with bio-pesticide per plant every three to four months. A mixture of 20 kg of neem/pongamia cake that is enriched with bio-pesticides should be soaked in 200 L of water for 2 days. This suspension can be used for drenching purposes @2–3 L/plant, or it can be thoroughly filtered and used for drip irrigation once every 15–20 days. This filtered suspension can also be used to spray the crop or as a spray fluid for spraying micronutrient mixtures.

b) Procedure for enrichment of different cakes with bio-pesticides: Mix 3–4 kg of each of '*Paecilomyces lilacinus*' or '*Pochonia chlamydosporia*', '*Pseudomonas fluorescens*' and '*Trichoderma harzianum*' or '*T. viride*' in 1 tonne of neem/pongamia cake and leave it in shade for 20 days at 25–30% moisture for multiplication of beneficial microbes.

B) Use of non-host and antagonistic crops: Sunn hemp, sorghum and mungbean were reported to be poor or non-hosts for RKNs. However, onion, garlic and marigold were found to be antagonistic crops to *M. enterolobii* and these crops can be grown as intercrops with guava. Brassicas and certain green manures also offer resistance. Avoid susceptible crops like sunflower, cowpea and pulses.

C) Chemical control: Carbofuran is a pesticide that belongs to the carbamate family and is commonly used for nematode control in many crops. The application of Carbofuran 3G @60 g/plant is recommended when symptoms such as yellowing, bronzing and stunting are observed. In India, two novel chemical compounds, namely fluensulfone and fluopyram, were registered as nematicides in 2018. These new compounds differ in chemistry and mode of action from commonly used chemicals and they are relatively safe for the environment.

Way forward: Due to the hazardous nature of chemical nematicides, we should encourage the application of such efficient bio-control combinations in the management of plant-parasitic nematodes in guava orchards. Bio-pesticides don't harm the soil environment and are less expensive to formulate than chemical substances. It effectively controls a variety of other soil-borne pathogens and has been shown to induce disease resistance and encourage more adventitious root growth in plants. Research should be

emphasised to develop resistant rootstock and/or cultivars with wide adaptability.

SUMMARY

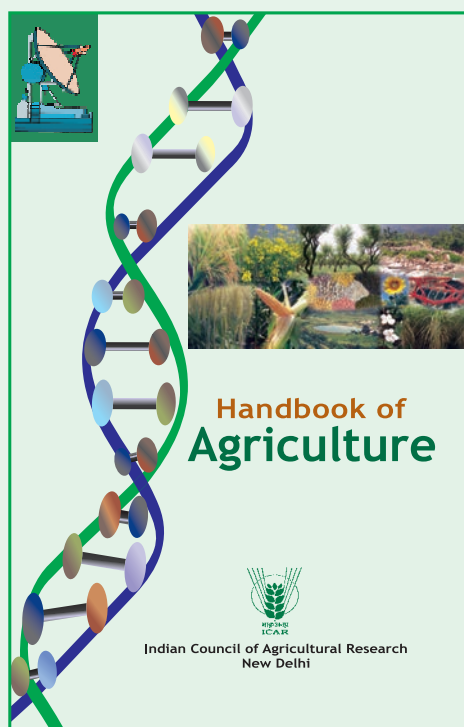
Meloidogyne enterolobii, a highly aggressive root-knot nematode (RKN), poses a severe threat to guava production in India, causing 60% to 80% yield loss through severe root galling. These parasites facilitate the guava wilt complex alongside *Fusarium oxysporum*, leading to rapid orchard decline. Effective management necessitates an integrated approach, utilising nursery sanitation, non-host

crop rotation, bio-agents and the application of chemical nematicides.

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Handbook of Agriculture



The Handbook of Agriculture is one of the most popular publication of the ICAR with a wider readership. The present edition presents science-led developments in Indian agriculture, the ongoing research efforts at the national level and with some ideas on the shape of future agriculture. While information in some chapters such as Soil and water, Land utilization, field and forage crops has been updated with latest developments, many new topics such as the Environment, agrobiodiversity, Resource conservation technologies, IPM, Pesticides residues, Seed production technologies, Energy in agriculture, informatics, Biotechnology, Intellectual Property Rights, Agricultural marketing and trading and Indigenous Technical Knowledge have been included in the present edition. For those who take intelligent interest in agriculture – and their number is increasing fast – the present edition would serve as a useful book.

TECHNICAL SPECIFICATIONS

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Advancing Sustainable Agroecological Systems through Natural Farming in Himachal Pradesh

Himachal Pradesh's Natural Farming (NF) movement has engaged over 2.5 lakh certified NF farmers. Additionally, 10 dedicated natural farming Farmer Producer Companies (FPCs) have been established, along with a certification system based on natural farming principles. The first ever state to announce MSP for NF maize (₹40), wheat (₹60) and turmeric (₹90) to ensure market security for farmers. In Shimla district, NF achieved 7% higher kharif yield and 147% higher rabi yields compared to chemical farming, alongside 18% to 42% lower kharif costs due to reduced labour and materials. Additionally, Dr. Yashwant Singh Parmar University of Horticulture and Forestry has launched Bachelor's degree program in Natural Farming, marking a milestone in academic support for sustainable agriculture.

Keywords: Agroecology, Certified Evaluation Tool for Agricultural Resource Analysis (CETARA), Natural Farming, Sustainable Food Systems

THE agricultural landscape of Himachal Pradesh has undergone a significant transformation, marked by a shift from chemical-intensive farming towards natural farming systems. Since 2018, Natural Farming (NF), introduced as a state programme under the '*Prakritik Kheti Khushhal Kisan Yojna*' has evolved into a statewide movement and a national and global model of sustainable food systems. This progress reflects the growing recognition among farmers of the long-term ecological, economic and social benefits of sustainable agriculture.

To support this transition, the Government of Himachal Pradesh (GoHP) has launched a self-certification system called the 'Certified Evaluation Tool for Agricultural Resource Analysis – Natural Farming (CETARA-NF)' to certify NF farmers. At present, more than 2.5 lakh farmers have been certified, covering 3,584 panchayats (99.14%) across all 12 districts of the state. This transition reflects a philosophy that prioritises soil health, biodiversity, climate resilience and farmer well-being.

In recent years, declining farming returns has raised concerns about income security of farmers. Introducing chemical input intensive practices during green revolution to make the nation food secured have led to several long-term adverse effects, including deterioration of soil fertility, contamination of water, human health and

greenhouses gas emission. NF provides a sustainable farming way forward, according to Niti Aayog, this practice offers both on-farm and off-farm benefits by supporting long-term soil fertility, eliminating reliance on external synthetic inputs and emphasising the use of on-farm resources.

Natural farming is based on four fundamental pillars: *Beejamrit*, *Jeevamrit*, *Accaddan* (Mulching) and *Whapasa*. *Beejamrit* is used for seed treatment that enhances germination and protect seeds from seed borne diseases. *Jeevamrit* is a fermented microbial formulation applied to soil to stimulate biological activity and improve nutrient availability. *Accaddan* involves covering the soil with organic residues to conserve moisture, regulate soil temperature and reduce erosion. *Whapasa* refers to the maintenance of an ideal balance of air and moisture in the soil, which improves water use efficiency, promotes root development and enhances crop resilience under drought conditions.

NF system discourages the use of synthetic fertilisers, pesticides and chemical growth regulators, advocating instead for the utilisation of locally available resources such as indigenous cow dung, cow urine, crop residues, and plant-based extracts. Preparations like *jeevamrit* and *beejamrit* form the backbone of this system, acting as microbial inoculants and seed



On-farm demonstration of natural-farming inputs for farmers

treatments, enhance soil biological activity and nutrient cycles. By strengthening the natural soil processes, natural farming aims to create a self-sustaining ecosystem that reduces external input dependency while improving crop resilience and sustainability.

Recognising the impact of the '*Prakritik Kheti Khushhal Kisan Yojana* (PK3Y),' farmers have reported that Natural Farming (NF) helps to reduce cultivation costs and enhance farm incomes by promoting sustainable farming practices. Under the PK3Y, farmers receive two days of on-field training at farmers' fields and seven days of training at recognised institutions, such as State Agricultural Universities. In addition, subsidies are provided for the purchase of indigenous cows, construction of livestock sheds and procurement of drums for preparing natural farming inputs such as *Jeevamrit*, *Beejamrit*, *Brahmastra*, and *Agniasta* etc. On-farm and off farm demonstrations, exposure visits and awareness programmes are regularly organised to build confidence among farmers transitioning from chemical systems.



Acchadan practice in an apple orchard under natural farming

A pioneering step taken by Himachal Pradesh has been the introduction of Minimum Support Prices (MSP) for selected crops grown under natural farming methods, such as maize and wheat. By ensuring remunerative prices, the government has addressed one of the primary concerns of farmers-market security. This policy not only incentivises adoption but also signals institutional recognition of natural produce as a distinct and valuable commodity. Additionally, natural farming initiatives have been integrated with cluster-based programmes like *Him-unnati* and aligned with central schemes such as the *Paramparagat Krishi Vikas Yojana* (PKVY), further expanding outreach and technical support.

The impact of natural farming is particularly visible in districts like Shimla, where apple cultivation dominates the horticultural economy. Traditionally, apple orchards relied heavily on chemical fertilisers and pesticides, leading to concerns about soil degradation and rising input costs. Under Subhash Palekar Natural Farming (SPNF), farmers are adopting diversified cropping models that combine apple orchards with multiple intercrops. On the same land, growers cultivate between 3 to 18 crops, ensuring nearly 100% soil cover throughout the year. Common cropping combinations include apple with beans, pulses and vegetables during the *kharif* season, and apple with peas and vegetables during the *rabi* season. This diversification enhances soil organic matter, improves nutrient cycling and provides multiple income streams, reducing dependence on a single crop.

Comparative studies between Natural Farming (NF) and chemical Farming (CF) systems in Shimla district demonstrate the economic viability of the natural approach. A study was conducted in Shimla district in 2022 which highlights the effectiveness of Natural Farming (NF) under the Subhash Palekar Natural Farming (SPNF) system in apple-based cropping systems. Thirty farmers from two blocks namely Jubbil, Kotkhai and Choupal were selected randomly. The sample of 60 farmers was taken for this study. The integration of multiple crops ensured complete soil cover and better resource utilisation. Natural farming recorded higher yields compared to Conventional farming (CF), with a 7.01% increase in *kharif* and a significant 147.62% increase in *rabi* season. These improvements are likely due to enhanced soil health, moisture retention and biological activity. Additionally, diversified cropping reduced input costs and increased profitability. Overall, Natural Farming proves to be a sustainable and economically viable alternative for hill agriculture and long-term farming resilience. The increase in *rabi* productivity is particularly significant due to diversified intercrops cultivated under natural systems. In terms of costs, chemical farming incurred substantially higher labour, material and total costs during *kharif* which were 18%, 42% and 20% higher, respectively, than natural farming. Although *rabi* costs were slightly higher under natural farming due to the cultivation of multiple intercrops in the absence of a major apple harvest, the diversified output compensated for these expenses through enhanced overall returns.

Beyond statistical comparisons, the field-level experiences of farmers highlight the transformative potential of natural farming. Progressive farmers across Himachal Pradesh have demonstrated that sustainable agriculture can be both ecologically sound and economically rewarding. For instance, Mohan Singh significantly improved his financial condition after adopting natural farming practices. By reducing chemical input costs and focusing on soil health management, he now earns an annual profit of approximately ₹15 lakh. His success story has inspired neighbouring farmers to reconsider their dependence on chemical-based agriculture and explore



Crop diversification with nine crops under a natural farming system

natural alternatives.

Similarly, in Solan district, natural farming has shown promising results in commercial vegetable cultivation, particularly in coloured capsicum grown under protected conditions. In villages such as Dyarag Bukhar and Jaunaji, farmers observed severe thrips infestation in chemically managed polyhouses. However, growers practicing natural farming reported comparatively lower pest intensity and healthier plant growth. The use of botanical extracts, mulching, *jeevamrit* applications and improved soil microbial activity appear to create a balanced ecosystem within the polyhouses. Healthier plants exhibited better tolerance to pest attacks, reducing the need for repeated chemical sprays. These experiences reinforced the understanding that ecological balance plays a crucial role in integrated pest management.

To further institutionalise this transition, academic support has also been strengthened. Dr Yashwant Singh Parmar University of Horticulture and Forestry, a leading State Agricultural University, has initiated formal academic training by introducing a bachelor's degree programme in natural farming. This represents a critical shift from extension driven promotion to structured capacity building through higher education.

One of the defining strengths of natural farming in Himachal Pradesh is its emphasis on indigenous knowledge and locally available resources. The reliance on native cow dung and urine reduces external input dependency and keeps production costs manageable. Farmers are encouraged to prepare their own inputs, fostering self-reliance and strengthening community networks. Training sessions conducted at village levels not only disseminate technical knowledge but also build a sense of collective ownership over the movement. Women farmers, in particular, have actively participated in preparing natural formulations and managing diversified cropping systems, contributing to household income and empowerment.

Environmental benefits are equally noteworthy. Natural farming enhances soil structure, increases organic carbon content, and improves moisture retention capacity—An essential factor in hill agriculture where water availability can be irregular. By avoiding chemical residues, the system protects groundwater quality and promotes biodiversity in agricultural landscapes. Pollinators, earthworms and beneficial microorganisms thrive under reduced chemical



Indigenous cattle as the backbone of natural farming system

stress, contributing to long-term ecosystem stability. As climate variability intensifies, natural farming's emphasis on diversified cropping and soil health strengthens resilience against erratic rainfall and temperature fluctuations.

The declaration of specific areas as natural farming zones further reflects institutional support. For example, the Pangi sub-division in Chamba district has been recognised for its efforts to transition toward chemical-free

cultivation. Such initiatives demonstrate the state's intent to create model regions that can serve as learning centres for others. Through continuous monitoring, capacity building and policy backing, Himachal Pradesh aims to consolidate its position as a leader in sustainable mountain agriculture.

Despite its progress, the transition to natural farming is not without challenges. Initial yield fluctuations during the conversion phase, limited market awareness about premium pricing and the need for robust certification mechanisms require ongoing attention. However, the steady increase in farmer participation and government backing indicates strong momentum. With assured MSP for selected crops, financial allocations and integration with broader agricultural development programmes, the state is systematically addressing these constraints.

SUMMARY

Overall, natural farming in Himachal Pradesh represents a holistic shift toward ecological balance, economic sustainability and social well-being. It has moved beyond isolated experiments to become a statewide movement supported by policy, research and grassroots participation. By reducing cultivation costs, enhancing yields in diversified systems, improving soil health and promoting market incentives, the state is demonstrating that sustainable agriculture is both practical and profitable. As more farmers share their success stories and adopt climate-resilient practices, Himachal Pradesh continues to strengthen its identity as a pioneer in natural and chemical-free farming in India.

For further correspondence, contact:

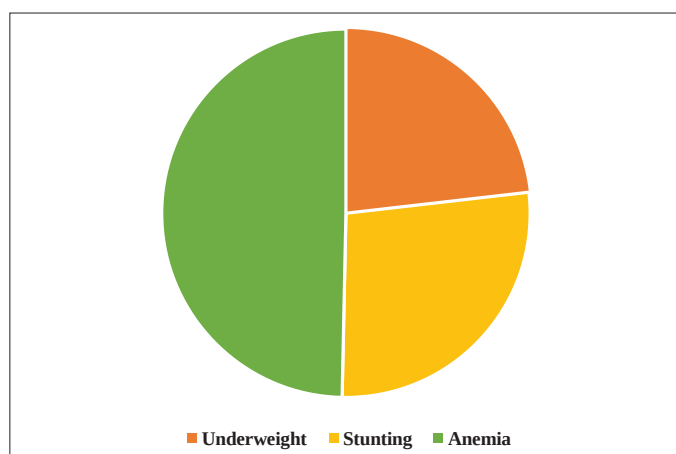
²Shraddha, Assistant Professor, University School of Agriculture Sciences, Rayat Bahra University, Punjab 140 104, India. Email: shraddhapundeer@gmail.com; ¹ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India; ³Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh 173 230, India.

Nutri-Garden as an Extension Model for Enhancing Household Nutritional Security in Malda District

Malda district is presently facing a complex nutrition challenge marked by the co-existence of undernutrition and rising lifestyle-related diseases. High levels of anemia, child stunting and underweight persists among women and young children, while overweight, diabetes and hypertension are increasingly observed among adult women. Although calorie intake may be adequate in many households, poor dietary diversity and limited intake of nutrient-rich foods contribute to hidden hunger. Field-level assessments by ICAR-CISH KVK indicated inadequate diversity in household diets, particularly among women. In response, structured nutri-garden models were promoted to enhance year-round availability of vegetables, fruits, legumes and herbs within homesteads. The circular and rectangular models, supported by season-wise crop planning, align with ICMR-NIN dietary guidelines and offer a practical, affordable and locally adaptable strategy to improve diet quality and strengthen household nutritional security in Malda district.

Keywords: Dietary diversity, Hidden hunger, MDD-W, ICMR-NIN, Nutri-garden, Nutritional security

ACCORDING to the District Nutrition Profile of Malda (2020), malnutrition remains a major public health challenge affecting both women and young children. Nearly 70–75% of women (15–49 years) and children under five are reported to be anemic, indicating widespread micronutrient deficiencies, particularly iron deficiency. In addition, around 41% of children are stunted and 35% are underweight, reflecting chronic undernutrition, poor dietary diversity, recurrent infections and inadequate infant and young child feeding practices. Such nutritional deprivation during the critical first 1,000 days of life adversely affects growth, immunity, cognitive development and long-term productivity.



Nutrition status of Malda district
(District Nutrition Profile of Malda, 2020)

At the same time, Malda is witnessing a nutrition transition, with rising levels of overweight, obesity, diabetes and hypertension among women. This co-existence of undernutrition and overnutrition clearly reflects the double burden of malnutrition in the district. While calorie intake may be sufficient for many households, diet quality remains poor, characterised by low consumption of fruits, vegetables, pulses and other micronutrient-rich foods. Addressing this dual challenge requires both nutrition-specific interventions and nutrition-sensitive approaches that promote dietary diversity, women's empowerment and sustainable local food systems.

Understanding local dietary patterns in Malda: Field observations and household-level interactions carried out by ICAR-CISH KVK in Malda district indicated limited dietary diversity among many families. A 24-hour dietary recall survey was conducted among 60 households selected using simple random sampling, which revealed that meals were largely cereal-based, with comparatively lower inclusion of fruits, green leafy vegetables, milk, eggs and other nutrient-rich foods. Dietary diversity was assessed using standard indicators by grouping foods into broad categories. The mean Dietary Diversity Score (DDS) was 3.4 ± 1.2 , indicating low diversity. Only 28% of households consumed fruits, while 22% consumed milk or milk products and 18% included eggs in their daily diet. Among women of reproductive age, 76% exhibited low dietary diversity, consuming fewer than five food groups per day.

Despite access to staple foods, diets remained

imbalanced and deficient in protective foods. Women particularly consumed limited food groups, mainly cereals and pulses, increasing the risk of micronutrient deficiencies, especially iron and essential vitamins. The National Family Health Survey (NFHS-5, 2019–21), reports a high prevalence of anemia in West Bengal. Similar concerns of 'hidden hunger' have been emphasised by the Food and Agriculture Organization and the World Health Organization, linking poor dietary diversity with micronutrient deficiencies. Previous studies have demonstrated that home or nutri-gardens improve dietary diversity and nutritional outcomes by increasing access to micronutrient-rich foods. Recent evidence also shows that nutri-garden interventions enhance vegetable consumption and reduce micronutrient deficiencies and anemia.

This situation reflects the presence of 'hidden hunger,' where energy needs may be met but diet quality remains poor. At the same time, increasing cases of overweight and lifestyle-related diseases suggest an ongoing nutrition transition marked by imbalanced food habits. In this context, promoting household nutri-gardens emerges as a practical and sustainable nutrition-sensitive approach to diversify diets, increase intake of micronutrient-rich foods and strengthen long-term nutritional security.

Role of nutri-garden in addressing micronutrient deficiencies: A well-designed nutri-garden serves as a practical and sustainable household-level approach to improving dietary diversity and reducing micronutrient deficiencies. By cultivating a range of seasonal vegetables, perennial crops, fruits and herbs within the homestead, families gain year-round access to fresh, safe and nutrient-rich foods. This diversity increases the number of food groups consumed at the household level and enhances the likelihood of meeting minimum dietary diversity standards for women and children.

Nutri-gardens are especially valuable for rural households, where limited market access and financial constraints often restrict the regular consumption of protective foods such as green leafy vegetables and fruits. By producing these foods at home, families reduce their dependence on market purchases and shield themselves from price fluctuations, while simultaneously improving diet quality. Regular intake of green leafy vegetables, vitamin A-rich produce, fruits, pulses and herbs improve the consumption of key micronutrients such as iron, calcium, folate, vitamin C and β -carotene, nutrients essential for preventing anemia, strengthening immunity and supporting child growth and development.

Beyond nutrition, nutri-gardens promote self-reliance, food and nutritional security and greater involvement of women in household food production. When thoughtfully planned in alignment with ICMR–NIN dietary guidelines, nutri-gardens can help to transform cereal-dominated diets into more balanced, diversified and micronutrient-rich eating patterns at the household level.

Nutri-garden models for household nutritional security: Nutri-gardens can be developed using two simple and adaptable models depending on available household space, both designed to ensure year-round availability of diverse, nutrient-rich foods. The circular model ($\approx 65 \text{ m}^2$ or 700 sq. ft) is ideal for small homesteads. In this layout,

taller fruit crops such as drumstick, papaya, banana or guava are placed at the outer corners to avoid shading, while protective border crops like onion, marigold and maize act as natural pest repellents and wind barriers. The circular area is divided into seven outer plots for major seasonal crops including cruciferous vegetables, cucurbits, solanaceous crops and legumes, with trellises used for climbers to optimise vertical space. The middle ring accommodates green leafy vegetables and seasonal root crops, while the inner circle is reserved for medicinal and culinary herbs. A central compost pit enables recycling of kitchen waste, making the system sustainable and self-reliant.



Rectangular Nutri Garden Layout (Pre-establishment stage)



Rectangular layout (after crop establishment)

The rectangular model ($100\text{--}200 \text{ m}^2$) is suitable for households with larger backyards. The space is divided into organised beds that allow systematic crop rotation and seasonal planning. Fruit trees are planted along the boundaries and internal plots are allocated for leafy vegetables, other vegetables, roots and tubers, legumes and climbers. This arrangement ensures continuous harvest across seasons while maintaining soil health and reducing pest incidence. With greater area and flexibility, the rectangular model supports higher crop diversity and productivity, aligning well with ICMR–NIN dietary recommendations. Both models enhance household dietary diversity, improve micronutrient intake and contribute to long-term nutritional and food security.

Season-wise crop planning for year-round nutrition: Season-wise crop guidance for the nutri-garden, as presented in Table 1 below, highlights major crop categories and their key nutritional contributions, enabling systematic year-round planning aligned with household dietary requirements. This structured crop planning framework can be effectively adopted in both the circular and rectangular nutri-garden models. By reducing seasonal nutrient gaps and ensuring continuous availability of



Circular Nutri Garden Layout (Pre-establishment stage)



Circular layout (after crop establishment)

Table 1. Seasonal Crops in nutri-garden

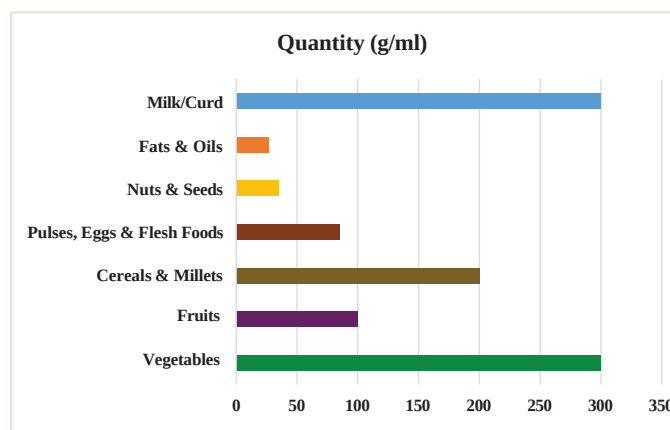
Season	Time period	Crop category	Crops included	Key nutritional contribution
Kharif	June to October	Green Leafy Vegetables	Amaranthus (green & red), Colocasia leaves, Tender pumpkin leaves	Iron, β -carotene, folate, dietary fibre
		Vegetables	Okra, Tomato, Brinjal, Chilli, Cucurbits	Vitamin C, potassium, antioxidants
		Legumes	Cowpea, Cluster beans, Yard long beans	Plant protein, iron, fibre
		Roots & Tubers	Colocasia, Tapioca, Elephant foot yam, Sweet potato	Energy (carbohydrates), β -carotene, potassium
Rabi	October to March	Green Leafy Vegetables	Spinach, Methi, Mustard, Bathua, Green sorrel, Radish leaves, Beet greens, Garden cress	Iron, calcium, folate (B9), β -carotene
		Vegetables	Tomato, Brinjal, Chilli, Capsicum, Cruciferous vegetables	Vitamin C, antioxidants
		Legumes	Peas, Broad beans, French beans	Protein, iron, fibre
		Roots & Tubers	Potato, Beetroot, Radish, Carrot, Jicama, Onion, Garlic	Carbohydrates, β -carotene, vitamin C
Zaid	March to June	Green Leafy Vegetables	Amaranthus (green & red)	Iron, β -carotene
		Vegetables	Okra, Brinjal, Chilli, Cucurbits	Vitamin C, potassium
		Legumes	Cowpea, Cluster beans	Protein, fibre
		Roots & Tubers	Colocasia	Energy, minerals

diverse food groups, the nutri-garden model strengthens household food security and builds long-term nutritional resilience.

Perennials, fruits & herbs for continuous nutrient supply: Perennial leafy plants, fruits and herbs in the nutri-garden ensure continuous nutrient availability throughout the year without seasonal gaps. As highlighted in Table 2, these crops are rich sources of iron, calcium, vitamin C, β -carotene, antioxidants and dietary fibre, thereby supporting micronutrient adequacy and overall family health.

Daily nutritional contribution of selected nutri-garden crops: As presented in Table 3, the recommended daily intake of green leafy vegetables, other vegetables, roots, tubers and fruits as per ICMR–NIN guidelines can be effectively met through a well-planned nutri-garden. Regular consumption of these food groups supplies essential micronutrients and helps prevent deficiencies, thereby supporting balanced

nutrition and improved family health.



Recommended daily intake of food groups (g/ml) based on ICMR–NIN guidelines (2020)

Table 2. Perennial crops in nutri-garden

Category	Crops included	Key nutritional benefits
Leafy & medicinal Plants	Malabar spinach, Drumstick, Gogu leaves, Ponnaganni, Agathi leaves	Iron, calcium, β -carotene, antioxidants
Fruits	Banana, Lemon, Papaya, Guava, Ber, Amla, Pomegranate, Custard apple	Vitamin C, potassium, fibre, β -carotene
Herbs	Curry leaves, Mint, Lemongrass, Ajwain leaves, Betel leaves	Micronutrients, digestive benefits, antioxidants

Table 3. Recommended daily intake and nutritional contribution of nutri-garden food groups

Food group	Recommended intake/day (g)	Key nutrients
Green leafy vegetables (GLVs)	150 g	Iron, calcium, vitamin A (β -carotene), folate (B9), dietary fibre
Other vegetables	100 g	Vitamin C, B6, folate (B9), potassium, magnesium, dietary fibre
Roots and tubers	100 g	Carbohydrates (energy), β -carotene, potassium, dietary fibre
Fruits	150 g	Vitamin C, potassium, β -carotene, dietary fibre

(Based on ICMR–NIN Dietary Guidelines, 2020)

The ICMR–NIN dietary guidelines recommend a balanced plate with half comprising vegetables and fruits, adequate pulses and protein sources, inclusion of milk and milk products and moderate cereal intake; however, diets in Malda remain largely cereal-dominant with limited diversity. A well-planned nutri-garden offers a practical household-level solution by ensuring regular availability of 300-350 g of vegetables and 100-150 g of fruits/person/day, helping bridge the gap between recommended and actual intake. Inclusion of legumes enhances plant-based protein intake, while combining iron-rich leafy vegetables with vitamin C-rich fruits improve iron absorption. Beyond improving daily diet quality, nutri-gardens support maternal nutrition, better complementary feeding for young children and reduced risks of stunting and anemia during the critical first 1,000 days. They also reduce market dependence, improve affordability of nutrient-dense foods and strengthen women's participation in household food decision-making, thereby promoting long-term food and nutritional security.

SUMMARY

Low dietary diversity and cereal-dominated food

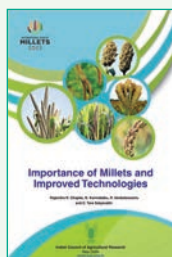
patterns in Malda contribute significantly to hidden hunger and the double burden of malnutrition, particularly among women and children. In this context, nutri-gardens offer a practical and sustainable nutrition-sensitive extension model by ensuring year-round availability of diverse, locally grown, micronutrient-rich foods at the household level. By reducing dependence on market purchases, improving access to protective foods and enhancing diet quality, they directly address micronutrient deficiencies in a cost-effective and scalable manner. Their adaptability to different household conditions and suitability for KVK-led interventions make them a viable strategy for strengthening household nutritional security and promoting long-term health and resilience in rural communities.

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Annual Chrysanthemum: A potential bio-remedy for nematode control

Annual chrysanthemum has emerged as a valuable horticultural crop with expanding significance beyond ornamental cultivation. The species offers considerable potential for promoting environmentally sustainable crop production owing to its wider adaptability, multifunctional utility and compatibility with low-input farming systems. The availability of genetically diverse genotypes possessing attractive floral traits and stress tolerance further enhances its suitability for commercial floriculture, landscape horticulture and sustainable agricultural practices. Moreover, its utility in biologically based pest management highlights the increasing shift toward safer, plant-derived alternatives in horticulture. The crop also offers significant opportunities for developing eco-friendly production systems that effectively integrate aesthetic appeal with agricultural sustainability. With growing emphasis on climate-resilient agriculture and reduced dependence on synthetic chemicals, annual chrysanthemum is likely to become an important component of future sustainable horticultural systems and green agricultural technologies in India.

Keywords: Annual Chrysanthemum, Bio-Nematicide, Botanical extracts, Pyrethrin, Root-knot nematodes, Sustainability

INDIA'S horticulture sector has witnessed remarkable growth in recent decades; however, the productivity of horticultural crops continues to be severely constrained by various biotic stresses. Among these, soil-borne pests, particularly root-knot nematodes (*Meloidogyne incognita*) are highly destructive. These microscopic plant parasite nematodes infect plant root systems and induce gall formation, thereby disrupting water and nutrient uptake. As a result, infected plants exhibit stunted growth, chlorosis, poor flowering, reduced fruiting and substantial yield loss. Since nematode infestations are often detected only at advanced stages of crop growth, significant economic damage frequently occurs before effective management interventions are implemented. Although synthetic nematicides are commonly used for nematode control, their prolonged and indiscriminate application leads to environmental pollution, health hazards, destruction of beneficial soil microorganisms and the development of resistance in target pest populations. Consequently, increasing emphasis is being placed on sustainable and eco-friendly alternatives. In this context, plant-based approaches involving annual

chrysanthemum (*Chrysanthemum coronarium* L.) have gained considerable importance due to their nematicidal and nematode suppressive properties. Such approaches offer an environmentally safe and sustainable alternative that is comparatively safer for both human health and ecological systems.

Annual chrysanthemum as a bio-nematicide: In the search for sustainable alternatives to synthetic nematicides, annual chrysanthemum (*Chrysanthemum coronarium* L.), a member of Asteraceae family, commonly known as Crown daisy, has emerged as a promising ornamental crop with additional potential as a bio-nematicidal plant. The species contains several bioactive compounds that exhibit significant activity against root-knot nematodes (*Meloidogyne incognita*), highlighting its potential role in sustainable nematode management strategies. The crop is

highly valued for its profuse flowering, attractive blooms, extended flowering duration and suitability for loose flower production as well as landscape beautification. Its adaptability to marginal lands, low water requirement and compatibility with low-input cultivation practices further enhances its suitability for commercial



Pusa Swarna



Pusa Dhaval



Pusa Ivory

cultivation and home gardening. Generally, the crop is raised through transplanting of approximately one-month-old seedlings at a spacing of 30 × 30 cm.

Bioactive compounds of annual chrysanthemum with strong nematicidal potential, includes: pyrethrins, cinerins, jasmolins, flavonoids and phenolic compounds. These constituents interfere with nematode metabolism and nervous system activity, ultimately leading to paralysis and mortality. Among these, pyrethrins are regarded as the most potent compounds, rapidly disrupting nervous system function and inducing paralysis in nematodes. Cinerins and jasmolins further enhance and prolong this nematicidal action, while flavonoids contribute by interfering with nematode growth, metabolism and infectivity. Advanced phytochemical analyses have additionally identified compounds such as luteolin, quercetin, myricetin and pyrethrin derivatives, which possess well known pesticidal, antioxidant and protective properties. Collectively, these bioactive constituents act through multiple mechanisms, thereby increasing the effectiveness of annual chrysanthemum against nematodes while reducing the likelihood of resistance development.

Improved annual chrysanthemum genotypes developed by ICAR-IARI, New Delhi

Promising genotypes identified at institute level: Indian Agricultural Research Institute, New Delhi has developed improved annual chrysanthemum genotypes through purification, sib mating and rigorous selection from heterogeneous populations. The breeding programme was primarily focused on developing hardy genotypes with attractive flower colours, higher flower yield and suitability for loose flower production as well as garden display.

- Pusa Dhaval is a white- double flowered annual chrysanthemum genotype characterised by profuse flowering, hardiness and excellent ornamental value. The plants produces approximately 162 flowers/plant and well suited for loose flower use and garden decoration. This genotype performs satisfactorily under low-management practices and is comparatively less prone to major pests and diseases.
- Pusa Ivory is a cream-coloured genotype possessing attractive double flowers with compact plant growth habit. It produces about 137 flowers/plant and performs well under minimal crop management practices. Its elegant blooms and profuse branching habit make it highly suitable for ornamental gardening and landscape planting.
- Pusa Swarna is a vigorous yellow-flowered genotype with high flower production potential. It produces

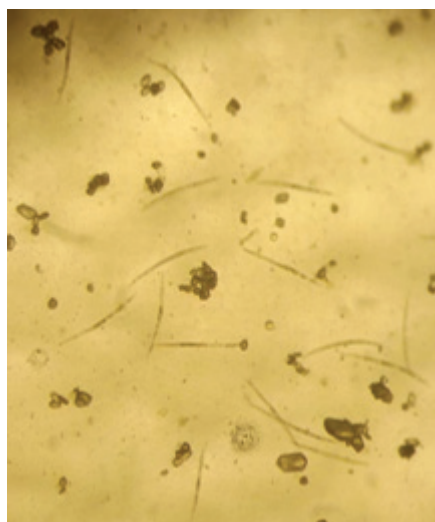
nearly 190–195 attractive flowers/plant, making the genotype highly suitable for loose flower markets and landscape purposes. Its high flower yield coupled with bright, attractive blooms makes it a promising genotype for commercial cultivation.

Factors influencing nematicidal activity of plant extracts: The novelty of this approach lies in the integration of ornamental horticulture with eco-friendly crop protection strategies. Biomass and plant extracts of annual chrysanthemum can be effectively utilised as components of integrated nematode management programmes. The nematicidal potential varies among these annual chrysanthemum genotypes. Amongst them, the white-flowered genotype, Pusa Dhaval, exhibits comparatively higher nematicidal activity against root-knot nematodes followed by the Pusa Ivory and Pusa Swarna. This indicates that fresh leaf extracts, particularly from white-flowered genotypes, possess strong nematicidal potential and may serve as an effective plant-based alternative for sustainable nematode management.

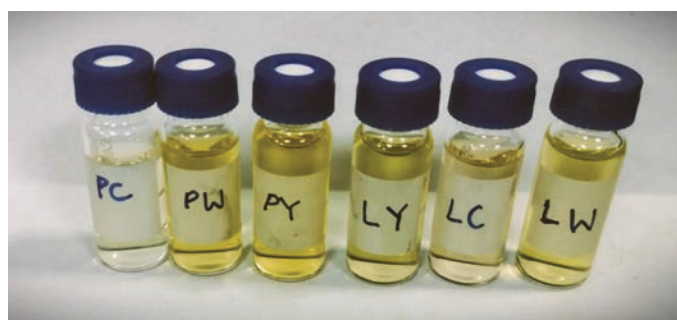
- All parts of the plant are not equally effective. Fresh leaves show the strongest nematicidal activity, followed by fresh flowers and dried leaves. Whereas, dried flowers are the least effective. The greater efficacy of fresh plant material may be attributed to the higher concentration of active volatile compounds.
- The nematicidal efficacy of annual chrysanthemum extracts increases with increasing extract concentration. At lower concentrations, the extracts cause only temporary immobilisation of nematodes, and many individuals recover after transfer to fresh water, indicating a nematostatic effect. In contrast, higher concentrations, particularly full-strength extracts, cause irreversible damage and result in complete nematode mortality.
- The effectiveness of the extracts increases with longer exposure duration. Nematode mortality progressively increases over time, with the maximum effect after 96 hours of exposure. This indicates that the bioactive compounds requires sufficient contact time to penetrate the nematodes and disrupt their metabolic and physiological functions, ultimately leading to mortality.
- Although botanical extracts may require comparatively longer exposure periods than synthetic nematicides to achieve maximum effectiveness, their eco-friendly nature, lower environmental risk and compatibility with sustainable farming systems makes them highly valuable components of integrated nematode management strategies.



Galls and egg masses induced by *Meloidogyne incognita* infected roots of tomato cv. Pusa Ruby.



Plant extracts showing nematicidal effect under *in-vitro*



LC-MS/UPLC-ToF-MS-based extraction of chemical constituents from annual chrysanthemum for nematicidal activity

Advantages of annual chrysanthemum-based management: Annual chrysanthemum offers considerable potential as an eco-friendly alternative to synthetic nematicides, as plant-based extracts help to reduce dependence on hazardous chemicals and minimise environmental contamination. The crop performs well under low fertility and minimal management conditions, thereby lowering cultivation costs

and making it suitable for low-input farming systems. In addition to its ornamental value, annual chrysanthemum possesses multi-purpose utility by providing attractive flowers along with bioactive compounds that contribute to pest suppression. Furthermore, the presence of multiple bioactive constituents acting through different mechanisms reduces the likelihood of nematode resistance development, enhancing its potential as a sustainable component of integrated nematode management strategies.

Sustainable utilisation: Annual chrysanthemum can be effectively integrated into sustainable agricultural systems through practices such as intercropping, crop rotation, green manuring and the application of botanical extracts. Its cultivation not only provides ornamental and economic benefits but also contributes to the natural suppression of root-knot nematode populations. Incorporation of annual chrysanthemum herbage into the soil through ploughing and mixing of fresh biomass helps to suppress plant-parasitic nematodes due to the release of bioactive compounds during decomposition, while simultaneously improving soil health and organic matter. In addition, extracts derived from different plant parts offer an eco-friendly alternative to synthetic nematicides. Thus, annual chrysanthemum serves as a multifunctional crop that supports sustainable pest management, soil health improvement and eco-friendly horticultural production systems.

The future prospects of annual chrysanthemum appear highly promising. With the increasing emphasis on sustainable horticulture, eco-friendly pest management and ornamental landscaping, the crop has the potential to play multiple roles in Indian agriculture. Integration of annual chrysanthemum-based management practices with other environmentally safe approaches may further enhance its effectiveness in sustainable crop protection systems. Moreover, further refinement and standardisation of extraction techniques under diverse field conditions could strengthen the commercial viability of bio-nematicidal formulations derived from this crop.

The newly developed genotypes from ICAR- Indian Agricultural Research Institute, New Delhi, namely Pusa Dhaval, Pusa Ivory and Pusa Swarna, possess varied flower colours, profuse blooming habit and adaptability to marginal lands, making them highly suitable for commercial cultivation as well as public and home gardens. Simultaneously, the bioactive potential of these genotypes provides significant opportunities for the development of plant-based nematicidal formulations, thereby contributing to sustainable and environmentally resilient horticultural systems.

SUMMARY

Annual chrysanthemum is no longer an ornamental flower crop, it is gradually emerging as a multifunctional species with aesthetic, ecological and agricultural importance. The improved genotypes combine attractive flower colours, profuse flowering, hardiness and adaptability under low-input cultivation conditions. Simultaneously, the presence of naturally occurring bioactive compounds makes the crop a promising eco-friendly alternative for the management of root-

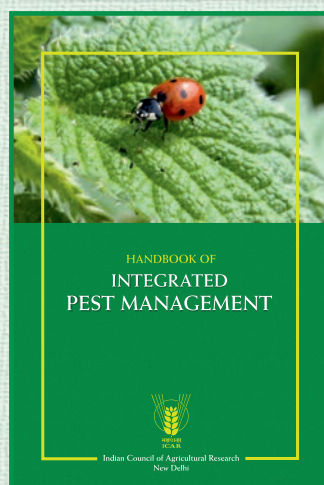
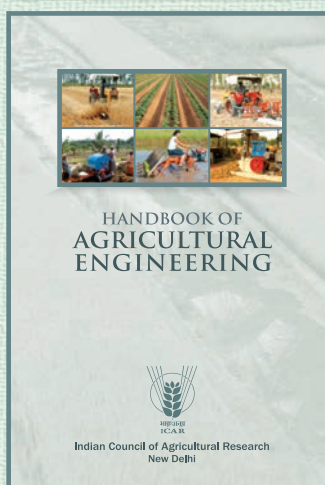
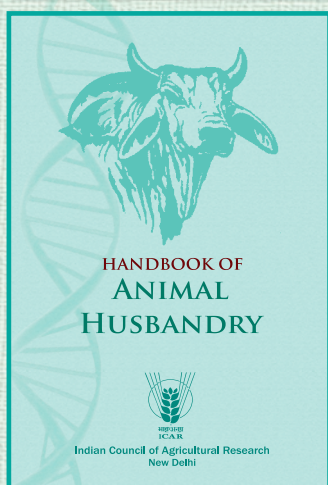
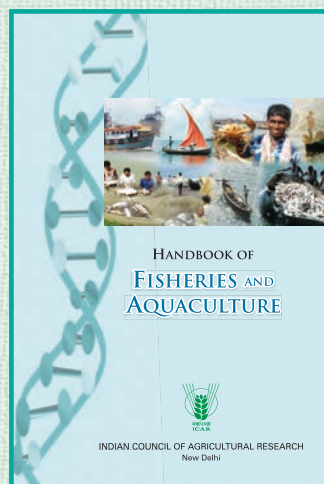
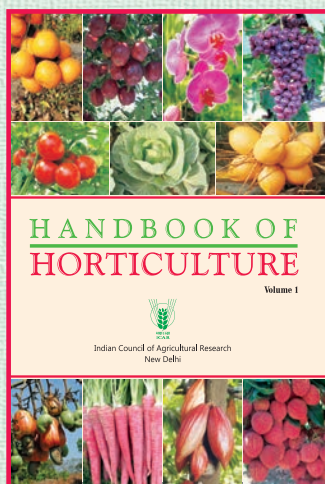
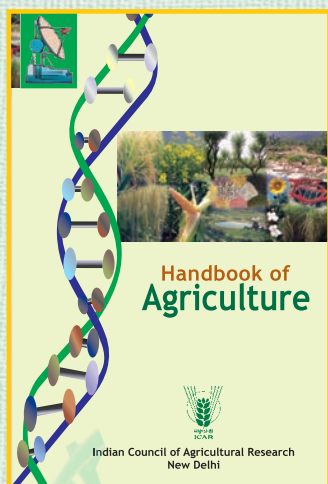
knot nematodes. Therefore, the integration of annual chrysanthemum into sustainable farming systems through ornamental cultivation, intercropping, crop rotation and the use of botanical extracts may help to reduce the dependence on synthetic chemicals while improving environmental health and agricultural sustainability. With further research, refinement and field-level validation, annual chrysanthemum has the potential to become an

important component of climate-resilient and sustainable horticultural systems in India.

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Plant Pigments: Science of Exploring the Spectrum

Plant pigments are vital molecules, responsible for the various colours in the plant kingdom, mainly chlorophyll, carotenoids, anthocyanins and betalains. Chlorophyll, being green in colour, is a principal pigment, as it is directly involved in photosynthesis by capturing light energy, whereas carotenoids, ranging from yellow to red in colour, are considered accessory pigments and also aid in light harvesting and energy transfer; thus, both are crucial for photosynthesis. Anthocyanins contribute to red, purple and blue colour, which depend on pH, molecular structure and presence of metal ions. These vibrant colours attract pollinators, important for the reproduction and dispersal of plant seeds and are beneficial in scavenging reactive oxygen species (ROS). Pigments are not only vital for plants, but also for humans, as they possess anti-inflammatory, anti-obesity, anti-allergic and anti-cancerous properties and reduce skin pigmentation. Also, they are precursor for vitamin synthesis; thus, pigments are very important. Moreover, plant pigments are also gaining interest in technological aspects, predominantly in dye-sensitised solar cells, where they offer an environment friendly alternative to conventional solar cells. Diverse applications of plant pigments highlight their enormous potential to boost creativity and environmental responsibility across multiple sectors, including agriculture, food, nutraceuticals, textiles, animal feeds and technology.

Keywords: Anthocyanins, Betalains, Carotenoids, Plant Pigments

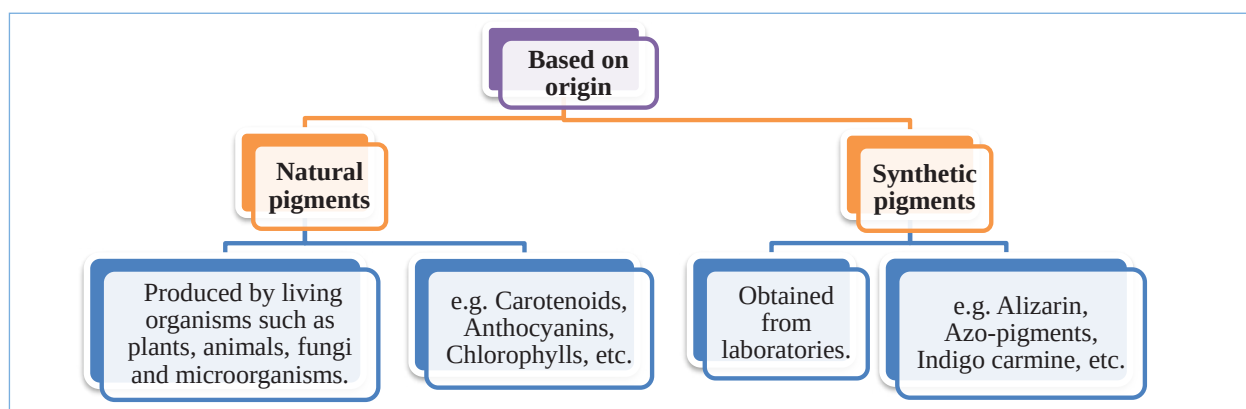
FLOWERS captivate the human mind with vibrant colours and make the world more magnificent. These colour depicting compounds are known as pigments. These pigments are not only restricted to flowers, they are also present in leaves, vegetables, fruits, etc. Fundamentally, pigments are chemical compounds that selectively absorb or reflect light in the visible range of wavelength (380–730 nm) and are crucial for the biological functioning of flowering plants. When visible light strikes the pigment molecule (chromophores)

at a particular wavelength, it absorbs the energy, which causes the excitation of electrons to a higher energy state, that is dissipated and utilised inside the plant in various ways, however, non-absorbed energy is reflected back and depicts the colour.

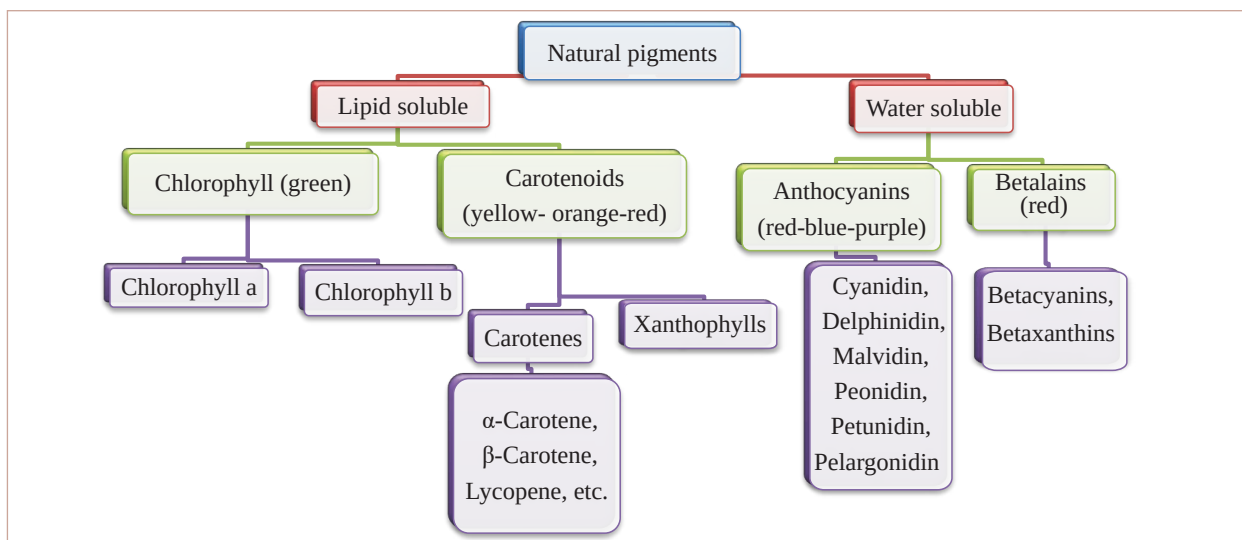
CLASSIFICATION OF PIGMENTS

Pigments are classified on several basis

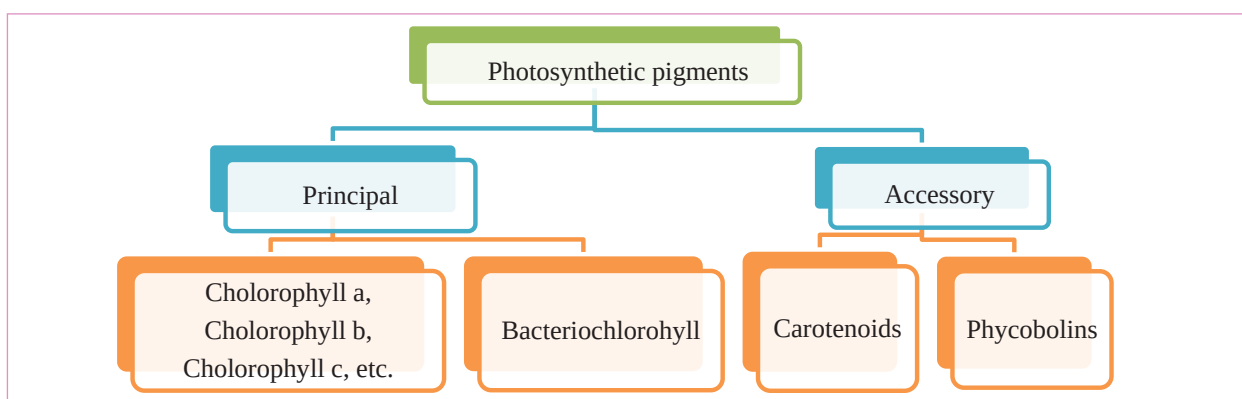
- *Based on origin:* Pigments can be naturally originated



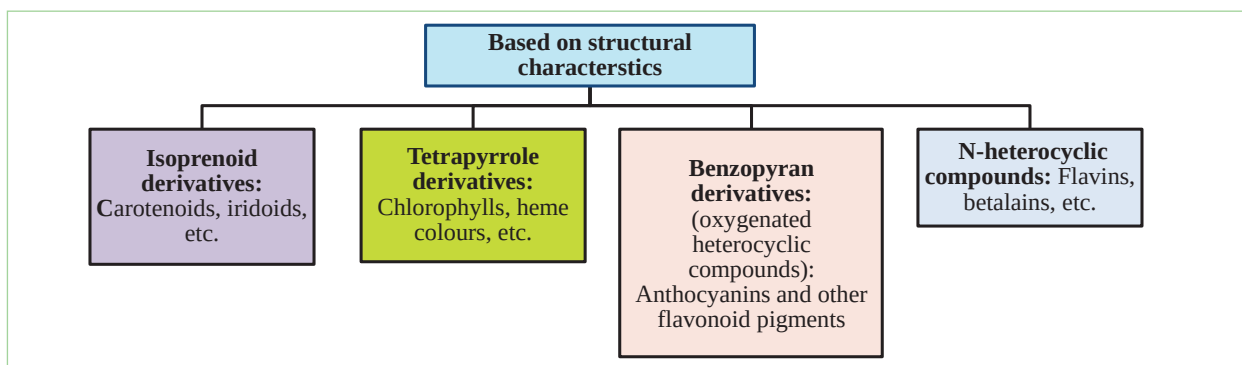
Classification of pigments based on origin



Classification of natural pigments based on solubility



Classification of pigments based on structural characteristics



Classification of photosynthetic pigments

inside living organisms as inside plants, fungi, animals, etc. On the other hand, they can also be synthesised artificially in lab.

- Further, natural pigments are classified on the basis of solubility.
- *Based on structural characteristics:* Pigments can also be classified on the basis of their structural characteristic.
- *Photosynthetic pigments:* The process of photosynthesis is a biochemical process through which light energy is converted into chemical and crucial for existence of life on the earth and it is impossible without pigments, as pigments are required for light harvesting for photosynthesis.

Photosynthetic pigments can be further elaborated under the following heads

A. *Chlorophyll:* The life on earth directly or indirectly depends on a vital plant pigment known as chlorophyll which is predominantly green in colour. Chemically, chlorophyll is comprised of tetra pyrrole ring with a central magnesium ion. It is hydrophobic in nature and strongly absorbs blue and red light of electromagnetic spectrum, however, poor absorber of green to near-green, thus depicts green colour. It is located in chloroplast of mesophyll cells and is directly involved in photosynthesis, thus known as principal pigment.

Function of chlorophyll: The main function of chlorophyll is photosynthesis, where the molecules of chlorophyll

absorb light energy in blue to red region of electromagnetic spectrum and cause excitation of electrons. Further, the excited electrons flow through a series of electron carriers and participate in light-dependent reactions that help in production of chemical energy in the form of ATP.

B. *Carotenoids*: Carotenoids are also hydrophobic and fat-soluble compounds made up from condensation of eight isoprene unit-terpenoid. They are found in plants, algae, bacteria and fungi and colours range from yellow to red. However, they are also present in non-photosynthetic organisms. They are accessory pigments and important for photosynthesis. Carotenoids are further classified into:

(i) *Carotene*: Unsaturated hydrocarbon consists of carbon and hydrogen atoms and colour ranges from orange to red. e.g. β -carotene in orange, carrots, etc.

(ii) *Xanthophyll*: Consists of carbon, hydrogen and one

or more additional oxygen atoms, colour ranges from yellow to orange. e.g. lutein in marigold, etc.

Functions of carotenoids

- They provide colours to fruits, flowers, vegetables and seeds; thus, attract pollinators and are important for reproduction.
- They are considered as accessory pigments and aid in light harvesting process of photosynthesis.
- They also protect photosynthetic system by dissipating the excess energy and prevent the formation of reactive oxygen species and control photo-oxidative damage.
- Carotenoids, such as β -carotene are precursors of vitamin A.

Different kinds of carotenoids and their origin from horticultural crops are given in Table 1.

Table 1. Different kinds of carotenoids and their origin from horticultural crops

S.No.	Carotenoids	Colour	Examples
1.	Lycopene	Red	 Tomatoes 0.88-4.20 mg/100 g Papaya 2.00-5.30 mg/100 g Water melon 2.30-7.20 mg/100 g
2.	Lutein	Yellow	 Spinach 7.043 mg/100 g Kale 39.55 mg/100 g Marigold 17-570 mg/100 g
3.	α -Carotene	Yellow	 Orange capsicum 0.89 mg/100 g Pumpkin 0.83-4.2 mg/100 g Carrot 2.5-4.9 mg/100g
4.	β -Carotene	Orange	 Carrot 8.29 mg/100g Apricot 1.09 mg/100 g Rose hips 2.984 mg/100 g

5.	β -Cryptoxanthin	Orange			
			Pumpkin 0.589 mg/100 g	Butternut squash 3.471 mg/100 g	Persimmon 1.447 mg/100 g
6.	Zeaxanthin	Yellow-orange			
			Broccoli 1.73628mg/100 g	Orange 0.24497 mg/100 g	Brussels sprouts 1.0062 mg/100 g
7.	Violaxanthin	Yellow			
			Lettuce 2.7 mg/100 g	Fenugreek leaves 4.62 mg/100 g	Moringa leaves 3.7 mg/100 g

C. Anthocyanin: Anthocyanin is a Greek word where, *anthos* means flower and *kyanos* means blue. It is a water-soluble phenolic compound which belongs to flavonoids, synthesised in the cytosol and stored in vacuoles. The structure consists of two aromatic rings linked by three carbon atoms forming an oxygenated heterocyclic ring. The precise colour of anthocyanins depends on numerous factors such as *pH*, molecular structure and presence of metal ions. If numerous OH groups are present, the colour shifts toward blue, however, more OCH₃ groups lead to red colour.

- *pH*: Anthocyanins are highly affected by *pH*, as it changes the ionisation state of the compounds and its ability to absorb light differently. In general:
- Acidic conditions: colour appears red.

- Neutral *pH* to slight alkaline: colour shifts towards purple and blue.
- Metal ions: Presence of different metal ions i.e., magnesium, aluminum and iron form complexes with anthocyanins, thus change the colour. For instance, presence of aluminum ions can shift the colour red, whereas magnesium ions can intensify blue colour.
- Anthocyanins are further classified as cyanidin, delphinidin, malvidin, peonidin, petunidin and pelargonidin based on the specific anthocyanidin molecule. Different kinds of anthocyanins and their origin from horticultural crops are given in Table 2.

Functions of anthocyanins

- Attract pollinators by making flowers more appealing

Table 2. Different kinds of anthocyanins and their origin from horticultural crops

S.No.	Anthocyanin	Colour	Examples
1.	Cyanidin	Red (acidic) purple (neutral) blue (alkaline)	  
			Sweet cherries 18.73 mg/100 Strawberries 2.88 mg/100 Plum 8.63 mg/100 g

2.	Delphinidin	Blue (acidic) violet (neutral) purple (alkaline)			
			Blackcurrant 86.68 mg/100	Blueberries 8.08 mg/100 g	Black grapes 16.61 mg/100 g
3.	Malvidin	Red (acidic) purple (neutral) blue (alkaline)			
			Blueberries 11.18 mg/100	Black grapes 39.23 mg/100 g	Raspberry 0.62 mg/100 g
4.	Peonidin	Red to purple			
			Plum 0.46 mg/100 g	Cranberries 4.16 mg/100 g	Grapes 5.80 mg/100 g
5.	Petunidin	Purple to blue			
			Blueberries 11.20 mg/100 g	Grapes 2.76 mg/100 g	Blackcurrant 3.87 mg/100 g
6.	Pelargonidin	Red (acidic) orange to pink (slightly alkaline)			
			Strawberries 47.14 mg/100 g	Raspberries 1.65 mg/100 g	Pomegranate 0.46 mg/100 mL

and vibrant, thus vital for reproduction and seed production.

- When co-occurred with other pigments i.e. chlorophyll, carotenoids, etc. leads to petal pigmentation.
- They screen harmful UV radiations and protect plant tissues from damage.
- They are source of antioxidants, which neutralise free radicals scavenge reactive oxygen species and reduce oxidative stress.
- They are produced in response to various biotic and abiotic stresses i.e. excess light intensity, low temperature, nutrient deficiencies and certain infections.

D. **Betalains:** Betalains are nitrogen containing, indole-derived compounds, synthesised by tyrosine with the condensation of betalamic acid. They are water soluble pigments, present in vacuole of cells and present in various parts of plants i.e. dragon fruit, roots of beetroot, flowers of celosia, bougainvillea, portulaca, etc. They are mainly

present in species of order Caryophyllales. They are independent of pH, more stable than anthocyanins and commercially used as source of dye in food.

Functions of betalain

- They are strong antioxidants, possess free radical scavenging properties and protect cells from oxidative stress.
- They can absorb excess UV radiations, protecting tissues from damage.
- Bright colour attracts pollinators and aids in the plant reproduction.

Pigments are not only meant for metabolic activities of plants, but also essential for human body due to several reasons such as:

- Possess antioxidants properties that shield the cells from damage by free radicals and lower the chances of chronic diseases.
- Some pigments such as beta-carotene are precursors

Table 3. Examples of betalains containing plant parts

Beetroot (root)	Dragon fruit (fruit)	Prickly pear (fruit)
Betacyanin = 30–60 mg/100 g Betaxanthin = 16.3 mg/100 g	Betacyanins = 73 mg/100 g	Betacyanins = 13.4 mg/100 g Betaxanthin = 24.3 mg/100 g
		
Amaranth (leaves)	Portulaca (flower)	Bougainvillea (bracts)
Betacyanins = 237 mg/100 g	Betalain = 26.6 mg/100 g	Betaxanthin = 249.5 mg/100 g Betacyanins = 145 mg/100 g
		

Table 4. Versatile applications of plants pigments in various fields

Health and nutrition	<i>Chlorophyll:</i> Detoxification properties and source of magnesium. <i>Carotenoids:</i> Vital for vision and immune function, reduce the risk of cancer and heart diseases. <i>Flavonoids:</i> Possess antioxidants and anti-inflammatory properties. <i>Betalains:</i> Contains detoxification, antioxidants and anti-inflammatory properties.
Pharmaceutical	<i>Chlorophyll:</i> Antioxidant, wound healing, detoxification, anti-inflammatory, etc. <i>Carotenoids:</i> It can lower the danger of breast, ovarian, gastrointestinal, pancreatic, cervical and colorectal cancers, prevent cardio-vascular disease and treat certain eye diseases. <i>Anthocyanins:</i> Anti-inflammatory, cardiovascular protection, prevent cancer by inhibiting cancer cell growth, lower cholesterol and combat oxidative stress. <i>Betalains:</i> Prevent hypertension, dyslipidemia and vascular stenosis, promotes liver health.

Cosmetics	Makeup products: Eye-shadows, lipsticks, nail polish, blushes, etc. Skin care: Pigments possess UV protection, anti-aging and moisturising properties, thus are added into certain skin care products. Hair care: Natural hair dye with the use of henna (<i>Lawsonia inermis</i>) and indigo, also used in conditioning of hairs.
Animal feed	<i>Carotenoids</i> : Improves the colour of egg yolks, chicken and fish flesh, thus enhance marketability. Also, improve milk quality in mammals. <i>Anthocyanins and xanthophylls</i> : Improve colour in fish i.e. trout and salmon.
Textiles	Plant based natural dyes are used for colouring the fabrics. Most used plants for dyeing fabrics are: (i) Indigo (<i>Indigo feratinctoria</i>): Blue tone. (ii) Henna (<i>Lawsonia inermis</i>): Orange and red tones. (iii) Madder (<i>Rubia tinctorum</i>): Red hues. (iv) Turmeric (<i>Curcuma longa</i>): Yellow shades. (v) Chlorophyll: Green tone, etc.
Technology	Plant based natural pigments are also incorporated into the solar cell structure to absorb sunlight and facilitate in the production of low cost 'Dye-sensitised solar cells' Plants used for production of dye-sensitised solar cells are: (i) <i>Cochlospermum religiosum</i> (ii) <i>Rhododendron arboretum</i> (iii) <i>Perilla frutescens</i> , etc.

- of vitamins A, thus are vital for vision and immunity.
- Possess anti-inflammatory properties that can reduce the risk of cardiovascular conditions.
- Possess anti-obesity, anti-allergic and anti-cancerous properties, also encounters reactive oxygen species in human body and also used as anti-aging supplements.
- Enhances oxygen intake inside human body and helps in recovering deficiencies.
- Reduce skin pigmentation and help in detoxifying body.

SUMMARY

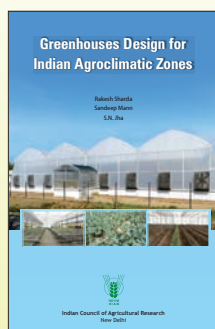
The diverse plant pigments are not only responsible for aesthetic vibrant colours, but are also crucial for bio-chemical functioning of plants. From harvesting of light for photosynthesis to protecting cells from excess light and oxidative stress, they are essential for growth, development and reproduction of plants. The proportion of these pigments inside plants are determined by

developmental stages, genetic factors and environmental circumstances, thus serving as valuable markers of stress responses and plant health. Further, the versatile nature of pigments has far-reaching applications beyond their aesthetic beauty, playing an imperative role in influencing advancements across a variety of industries including agriculture, food and nutraceuticals. Furthermore, plant pigments are employed in dye-sensitised solar cells, providing a sustainable energy source. Overall, the diverse applications of plant pigments illustrate their expanding influence on innovation and sustainability, necessitating renewed scientific research.

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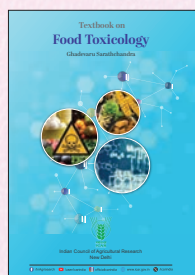
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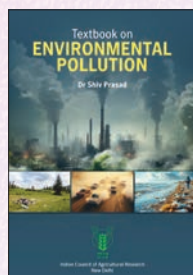


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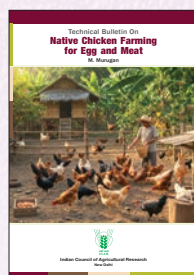
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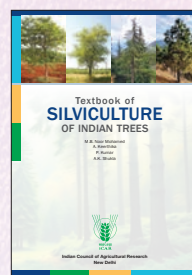
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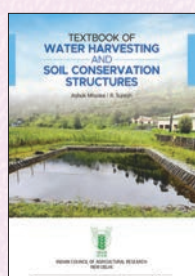
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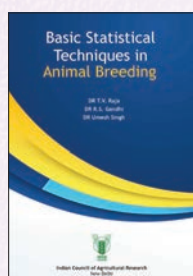
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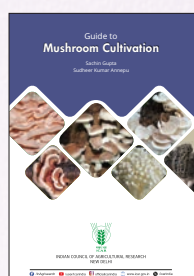
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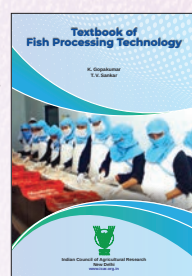
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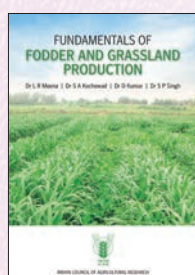
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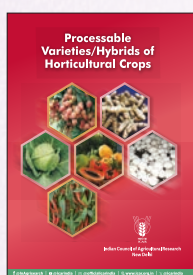
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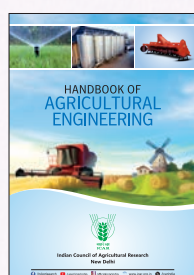
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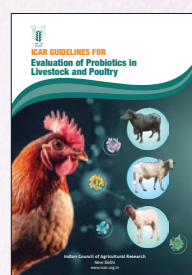
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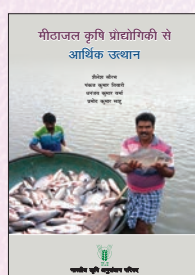
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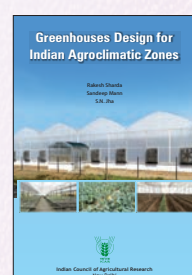
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