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INDIAN Horticulture

May-June 2026

R K Yadav*, B S Tomar[1], H Chaudhary[1], Suman Lata[2], Gograj Singh Jat[1] and Nirankar[2]

Pusa Red Cherry Tomato-3 : A new promising variety for cultivation under protected and open conditions

Pusa Red Cherry Tomato-3 is a newly developed high-yielding cherry tomato variety from ICAR-IARI, New Delhi, suitable for both open field and protected cultivation. Identified during the 43rd AICRP Vegetable Crops meeting and notified in 2025, it shows superior performance over Pusa Cherry Tomato-1 with about 15% higher yield. The indeterminate plants produce round, deep red fruits averaging 13.6 g, with high total soluble solids and lycopene content, ensuring better quality and consumer acceptability. The variety performs well across seasons in Indian plains, exhibiting continuous fruiting and adaptability. With an average yield of 35.78 t/ha, it offers significant economic benefits to farmers and meets market demand for attractive, nutritious cherry tomatoes. It is recommended for commercial cultivation under agro-climatic conditions.

Keywords: Cherry tomato, High yield, ICAR-IARI, Indeterminate variety, Lycopene, Protected cultivation

PUSA Red Cherry Tomato-3 is a promising tomato variety developed by Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, Pusa, New Delhi. This variety was identified for release during 43rd AICRP-Vegetable Crops group meeting during 3-5 March 2025, held at PAU, Ludhiana for Zone I (Uttarakhand, Himachal Pradesh, Jammu & Kashmir and Ladhak). It has been notified to vide S.O. 4000(E)) dated 1 September 2025. The cherry tomato growers will be benefited with this new variety because of its very high yielding ability, red and attractive fruits with better fruit quality traits. As per AICRP data, the average yield of this variety is 35.78 t/ha in open field in 6-7 months crop duration with an advantage of about 15.24% over check Pusa Cherry Tomato-1 (30.25 t/ha) which is a popular variety grown by farmers. It can be grown in Indian Plain areas during autumn-winter and spring-summer season under open field condition. Farmers have shown their interest in this variety as it is highly acceptable by the consumers and farmers based on its continuous fruiting ability, attractive red fruit, high TSS and other quality attributes.

Fruits of tomato variety Pusa Red Cherry Tomato-3 at maturity

Salient features of tomato variety Pusa Red Cherry Tomato-3

This variety has been developed through pedigree method:

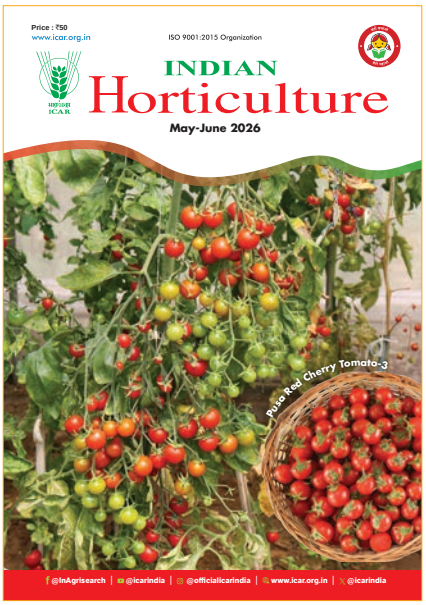
- It is an indeterminate variety of cherry tomato suitable for cultivation under open as well as protected condition.
- The fruits are round in shape, deep red in colour and have an average weight of about 13.6 g.
- The ripe red fruits have thick pericarp (3.5 mm), 10.1 °Brix TSS and 8.0 mg/100 g lycopene content.
- It gives an average yield of 358 q/ha and suitable for cultivation from October to May under protected cultivation and open field condition.

Package of practices for cultivation of Pusa Red Cherry Tomato-3

Climate

It requires a relatively

Turn to page 3



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CONTENTS

Innovation-driven diversification in Indian Horticulture

THE May–June 2026 issue of *Indian Horticulture* reflects a decisive shift in Indian agriculture toward resilience, diversification, and value-driven production systems. The collection of articles underscores a unifying message: the future of horticulture lies in integrating scientific innovation with sustainability and market responsiveness.

A prominent highlight of this issue is the emergence of improved varieties tailored for modern cultivation systems. The development of high-yielding, quality-rich vegetable varieties suited for both open and protected conditions signals a strong push toward enhancing productivity while ensuring consumer preference. Such advancements not only strengthen farmer income but also align production with evolving dietary patterns and urban demand.

Equally noteworthy is the emphasis on protected cultivation and off-season production technologies. Innovations enabling year-round vegetable production and efficient use of polyhouse systems demonstrate how technology can overcome climatic constraints and improve profitability. These approaches are particularly crucial for smallholders aiming to maximize returns from limited land resources. The issue also brings attention to diversification through underutilized and emerging crops. Fruits like Pummelo, Chinese Jujube, Strawberry and Jamun illustrate the vast untapped potential within horticulture for nutritional security, climate resilience, and niche market development. Similarly, the growing interest in microgreens highlights a shift toward functional foods, catering to health-conscious consumers and urban agriculture systems.

Sustainability emerges as a central theme, especially through natural farming approaches. The successful adaptation of ecological practices in perennial crops such as apple and leafy vegetables reinforces the viability of low-input, environmentally friendly systems. These models demonstrate that improving soil health and biodiversity can go hand-in-hand with higher economic returns. The inclusion of farmer-led innovations, such as improved selections in traditional crops, emphasizes the importance of participatory approaches in horticultural development. Recognizing farmers as innovators strengthens the bridge between research and field-level adoption.

The issue also highlights challenges, addressing pest dynamics and integrated management strategies remind us that intensification must be balanced with ecological safeguards. Sustainable pest management will remain critical as climate variability continues to influence pest behaviour and crop health.

In essence, this issue captures the evolving landscape of Indian horticulture, one that is technology-enabled, sustainability-oriented, and market-linked. Moving forward, the synergy between research institutions, extension systems, and farmers will be pivotal in translating these innovations into widespread impact.

The path ahead calls for continued investment in climate-resilient technologies, diversification strategies, and value addition. With such concerted efforts, horticulture will not only contribute to agricultural growth but also play a vital role in ensuring nutritional security, environmental sustainability, and enhanced livelihoods for farmers across the country.

AAgrawal

(Anuradha Agrawal)

Continued from Cover II

warm climate for proper growth and development. The optimum temperature for fruit set and colour development ranges between 20°C and 25°C during the day and night.

Sowing time

Tomato can be cultivated throughout the year in a fully controlled polyhouse environment. However, in low-cost or naturally ventilated polyhouses, transplanting is generally carried out during the last week of September, and the crop can continue up to April.

Soil

A well-drained sandy loam soil with a *p*H between 6.0 and 7.0 is ideal for optimum tomato growth and yield.

Seed rate

Approximately 100 g of seed/ha is recommended.

Raising of nursery

Nursery should be sown in the first week of September inside a polyhouse or insect-proof net house. A soilless growing medium comprising cocopeat, perlite and vermiculite in a 3:1:1 ratio is preferred for producing healthy, disease-free seedlings. After 22–25 days of sowing, when seedlings attain a height of 10–12 cm and develop four true leaves, they should be hardened for 2–3 days by withholding irrigation. Hardening minimizes transplanting shock and ensures better crop establishment.

Transplanting

Seedlings are transplanted on both sides of 10 cm high raised beds that are 0.75 m wide with 30 cm spacing between adjacent beds. Plants are spaced 45 cm apart within rows on either side of the bed. Transplanting should be done under a drip irrigation system with plastic mulch to enhance water and nutrient-use efficiency.

Manure and fertilizers

Soil testing should be conducted to assess nutrient status before planting. In general, apply 30 t/ha of well-decomposed FYM at land preparation. Incorporate 80 kg phosphorus and 90 kg potash/ha before transplanting. Apply 180 kg nitrogen/ha in split doses: one-third at transplanting and the remaining in four top dressings at 25-30 days, 50–60 days or flowering, after the first picking, and after the second picking. Foliar sprays of 1% urea after each harvest promote continued growth. During flowering, apply a 0.5% micronutrient mixture, particularly containing calcium and boron, as a foliar spray.

Irrigation

Maintaining uniform soil moisture is critical, especially during flowering and fruiting. Irrigation intervals vary with season, every 8-10 days in winter and every 4 days in summer, depending on weather conditions. Drip irrigation is recommended for efficient water and nutrient management. Black polyethylene mulch helps conserve soil moisture and suppress weeds.

Pusa Red Cherry...

Intercultural operations

Weed management is crucial as weeds compete for nutrients, light and moisture, and harbour pests and diseases. Frequent hoeing should be carried out as needed. Before mulching and transplanting, beds can be treated with Stomp @ 2 ml/L water to control pre-emergence weeds.

Training, pruning and trellising

Staking should be initiated 20–25 days after transplanting. Plants are tied loosely to vertical stakes using soft ties. All lateral shoots are removed early to maintain a single or double stem system. Plants are supported with plastic twine or clips attached to overhead support wires placed 8–10 feet above ground level. Continuous pruning of side shoots throughout the crop duration improves fruit quality. After the first harvest, lower leaves up to one foot above the ground should be removed to enhance ventilation and reduce disease incidence.

Plant of tomato variety Pusa Red Cherry Tomato-3 in fruiting stage

Pollination

Tomato is a self-pollinated crop, and normal fruit set occurs under sunny conditions. However, during cloudy or foggy weather, electric vibrators, air blowers or manual shaking can be used between 10–11 a.m. and 2–3 p.m. to ensure effective pollination.

Harvesting

Harvesting of tomato begins about 70–75 days after transplanting. The stage of harvest depends on the intended purpose and the distance of transportation. For long-distance marketing, fruits are harvested at the mature green stage; for short-distance transport, harvesting is done at the pink stage; and for processing purposes, fully ripe red fruits are preferred.

Average yield

Yield varies with environmental and cultural conditions. On average, tomato produces about 6 quintals/100 sq. m in polyhouse conditions and over 350 quintals/hectare under open field cultivation.

Plant protection

Warm and humid conditions in protected structures favours pest development. Sanitation, soil solarization, mulching and fumigation are key preventive measures. Common pests include whiteflies, mites and nematodes, which often enter the polyhouse through frequent human movement. Nematode is also a major problem in polyhouse. To minimize infestation, use UV-stabilized 200-micron polythene as cladding material. Install 40-mesh insect-proof nets and a double-door foyer to restrict insect entry. Raise seedlings in a protected nursery. Remove lower or diseased leaves to improve ventilation. For monitoring and control, whiteflies, aphids and leaf miner adults, place yellow sticky traps (8″ × 12″) @ 5/100 sq. m about 4-6 inches above the plant canopy. Replace traps once they are over 70% covered with insects. For effective management of pests and diseases, Integrated Pest Management (IPM) practices should be followed. If chemical control is required, Propargite at 2 ml/L of water or Spiromesifen at 1 ml/3L of water can be used to control mites. For managing whiteflies, Triazophos or Flonicamid at 1 ml/ 3L of water is recommended. In the case of fungal diseases, a mixture of Carbendazim (1 g/L of water) and Mancozeb (1 g/L of water) can be applied as a foliar spray.

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A D Munshi[1], Amish K Sureja[1]*, T K Behera[2], B S Tomar[1], J Singh[1] and S S Dey[1]

Pusa Pickling Cucumber-8: An early high yielding gynoecious parthenocarpic variety for protected cultivation and export

Pusa Pickling Cucumber-8 is an extra-early, high-yielding gynoecious parthenocarpic variety developed by ICAR-IARI, New Delhi for protected cultivation in North Indian plains. It is specifically suited for off-season (winter) production under low-cost polyhouse conditions, overcoming temperature limitations of open-field cultivation. The variety produces market-preferred fruits without pollination, ensuring consistent yield and quality. Fruits are uniform, dark green, glossy, cylindrical, and possess tender skin with crispy flesh, ideal for pickling and export. It records an average yield of 84.81 t/ha, which is 19.60% higher than the commercial hybrid Annaxo. With early maturity (40–45 days), high productivity, and superior fruit quality, this variety offers a cost-effective alternative to expensive hybrids for farmers and export-oriented production systems.

Keywords: Extra-early fruit, High yield, ICAR-IARI, North Indian plains, Off-season production, Polyhouse cultivation, Protected cultivation

PICKLING cucumber is an important cucurbitaceous crop grown extensively throughout the world mainly for pickling purpose. It is gaining importance in cities now because of its uniqueness as pickles, use in fast food chains and five star hotels. It also have high export value. According to APEDA, India exported 2,44,243 metric tonnes of cucumber and gherkins worth USD 256 million in the year 2024. Pickling cucumber is highly thermo-sensitive in nature and its cultivation in north Indian plains during winter season under open condition is hampered because of extremely low temperature prevailing in this part. Parthenocarpic gynoecious pickling cucumber varieties are suitable for polyhouse cultivation as these varieties develop fruits automatically without any pollination and can be successfully cultivated under polyhouse during winter season. At present many of the private seed companies are selling F_1 hybrid of parthenocarpic pickling cucumber at a very high price as their seeds are being sold on per seed basis. Keeping in view these facts, a gynoecious parthenocarpic pickling cucumber variety Pusa Pickling Cucumber-8 was developed by Division of Vegetable Science, ICAR-IARI, New Delhi. The variety was notified by central sub-committee on crop standards, notification and release of varieties of horticultural crops.

Tender Fruits of Pusa Picking Cucumber-8

Pusa Pickling Cucumber-8 (DG-8)

It is the first extra-early (40-45 days for first fruit harvest) improved variety of parthenocarpic gynoecious pickling cucumber suitable for cultivation in protected condition developed by ICAR-IARI for North Indian plains. It has distinct advantage in yield and quality characters over commercial private sector hybrid Annaxo. The average fruit yield is 84.8 t/ha (848 kg/100 m^2) during winter season (off-season, November-March) under low cost polyhouse which is 19.60% superior over Annaxo. Its fruits become ready for first harvesting in 40-45 days after sowing during winter season (off-season, November-March) under low cost polyhouse. The fruits have desirable marketable attributes and are attractive, uniform, dark green, glossy, cylindrical, straight, ribbed, warty with prickles, and has tender skin and crispy flesh. The fruits have dark green skin with light green faint stripes originating from the blossom end and dark green

Mean performance of Pusa Pickling Cucumber-8 (DG-8) at ICAR-IARI, New Delhi during winter season (off-season, November-March) under low cost polyhouse from 2021-22 to 2023-24

Variety	Yield (t/ha)			Average yield (t/ha)	Percentage increase over Annaxo
	2021-22	2022-23	2023-24		
Pusa Pickling Cucumber-8 (DG-8)	85.18	81.06	88.19	84.81	19.60
Annaxo (F_1) (Check)	70.61	69.67	72.46	70.91	

blotches near stem end. The shape of peduncle end and blossom end of fruit is obtuse. Average fruit length is 8 cm and width 2 cm. Average fruit weight is 18-20 g.

Performance of Pusa Pickling Cucumber-8

Pusa Pickling Cucumber-8 (DG-8) has been tested in yield trial at ICAR-IARI, New Delhi during winter season (off-season, November-March) under low cost polyhouse from 2021-22 to 2023-24 along with check Annaxo. The results indicated that Pusa Pickling Cucumber-8 yielded 84.81 t/ha which was 19.60% higher than check Annaxo.

Cultivation

It can be grown successfully on well-drained loam and sandy loam soils. Soil should be thoroughly ploughed, well prepared and basal dose of 200-250 kg FYM; 70-80 g N, 80-90 g P_2O_5 and 70-80 g K_2O per 100 m^2 should be applied the time of bed preparation under polyhouse. A spacing of 60 × 45 cm is recommended. Recommended seed rate is 15 to 20 g per 100 m^2 of polyhouse.

For a successful crop of pickling cucumber in a polyhouse during the off-season (winter season), direct sowing is done in the third week of October to the first week of November when temperatures are mild and conducive to crop growth. The seeds are treated with Captaf @ 2 g/kg of seed. Generally, 1–2 seeds are sown per pit, and after germination, when seedlings are established, thinning is done to retain one plant per pit.

To save time, seeds are also sown in polythene bags filled with a mixture of soil (2 parts), FYM (1 part), and sand (1 part) during the first week of October, and 3–4-week-old seedlings are transplanted in the last week of October or the first week of November. Nowadays, plug trays (pro-trays) are recommended for raising seedlings. Generally, medium-sized cells (5–6 cm in diameter) are required for optimum seedling growth. These trays facilitate proper germination, provide an independent area for each seed, reduce mortality, and ensure uniform and healthy seedling growth, while also being easy to handle, store, and transport.

Soilless media is commonly used for raising healthy and vigorous seedlings in plastic pro-trays. The medium typically consists of coco peat, vermiculite, and perlite in a 3:1:1 ratio, which is thoroughly mixed before filling the plug trays.

Hand weeding and hoeing should be carried out at regular intervals to keep the cultivated area clean. A fertigation schedule using soluble fertilizers N:P:K (19:19:19) @ 8–10 g/litre should be followed when seedlings are 3 weeks old. Supplementary doses of liquid fertilizers should be applied after transplanting in three

Plants of Pusa Pickling Cucumber-8 in low cost polyhouse

split doses @ 12–15 g/litre at 10-day intervals until flower initiation. The plants are trained vertically using nylon thread, and lateral branches, if any, are pinched off at regular intervals. Fruits are allowed to set only on the main stem.

Harvesting of fruits can begin from the last week of December to the first week of January and continue up to the first week of April. Fruits are ready for harvest 40–45 days after sowing when they attain an average length of 8.5 cm, width of 2 cm, and average fruit weight of 18–20 g. Deformed fruits and old leaves should be removed at regular intervals to improve aeration.

Drenching with ridomil @ 2 g/litre and Blitox @ 3 g/litre of water is necessary to prevent damping-off and other root-borne diseases. Need-based sprays of Imidacloprid @ 0.3 ml/l or Acetamiprid @ 0.3 g/l, followed by Dimecron @ 2 ml/l at intervals of 2-3 weeks, should be applied judiciously to manage sucking pests such as aphids and whiteflies.

SUMMARY

Pusa Pickling Cucumber-8 is the first extra-early (40–45 days to first fruit harvest) improved parthenocarpic gynoecious pickling cucumber variety developed by ICAR-IARI for protected cultivation in the North Indian plains. The fruits possess desirable marketable traits, being uniform, attractive, dark green, glossy, cylindrical, straight, ribbed, warty with prickles, and having tender skin with crispy flesh. The variety has demonstrated superior performance under low-cost polyhouse conditions during the winter (off-season, November–March), recording 19.60% higher yield compared to the check variety Annaxo.

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Niral V[1]*, Ranjini T N[2] and Nagaraja N R[3]

Newly released and notified varieties of coconut and arecanut developed by ICAR-CPCRI for enhancing farmers income

This article presents a brief overview of the characteristic features and commercial cultivation recommendations of four recently released high-yielding, multi-purpose coconut varieties and one arecanut variety developed by ICAR-CPCRI and approved by the Central Variety Release Committee. It aims to acquaint stakeholders with these notified varieties to enhance the productivity and profitability of coconut and arecanut farmers.

Keywords: Arecanut, Coconut varieties, High-yielding cultivars, ICAR-CPCRI, Notified varieties, Plantation crops

THE coconut palm (*Cocos nucifera* L.), revered in India as '*Kalpavriksha*' for its multipurpose uses, provides food, beverages, oil, fiber, timber, and other health oriented products such as tender coconut water, virgin coconut oil, and inflorescence sap (*Kalparasa*), while arecanut (*Areca catechu*) is widely used in Asian and Pacific cultures for chewing its dried kernel, known as betel nut. India is among the largest producers of coconut and arecanut globally. The ICAR-Central Plantation Crops Research Institute (ICAR-CPCRI), a premier national institute, is mandated to conduct research on coconut, arecanut, cocoa, and palmyra palm, with a considerable focus on developing improved varieties for diverse uses and agro-ecological zones. To date, the institute has released 23 improved coconut varieties and 11 arecanut varieties, including high-yielding, processable, and stress-tolerant types, capable of producing significantly higher yields than local varieties.

Under the Seed Act, 1966, crop variety notification is essential for Seed Law Enforcement, as certified seeds can only be produced from notified varieties. At ICAR-CPCRI, coconut variety notification began in 2008 and arecanut in 2014, following the establishment of seed/seedling quality standards.

RECENTLY NOTIFIED VARIETIES

Four coconut varieties and one arecanut variety developed by the institute were notified in the recent past.

Coconut

Kalpa Suvarna: A dwarf coconut variety ideal for copra and tender nut production. Fruits are medium sized, oblong, green in colour. Palms commence flowering 30-36 months after planting. The tender nut water content is 431 ml, copra content is around 186 g, with oil content of 64.5%. The variety yields 108–130 nuts/palm/year, under good management. This variety is notified for the states of Kerala and Karnataka.

Kalpa Shatabdi: A high yielding, tall variety suitable for copra and tender nut production. Fruits are large sized, oval and greenish yellow in colour. Palms commence flowering 7 years after planting. Tender nut water content is 612 ml, copra content is around 273 g, with oil content of 64%. The variety yields 105-168 nuts/palm/year, under good management. Recommended for cultivation in Kerala, Karnataka and Tamil Nadu.

Kalpa Ratna: High yielding, moisture-deficit stress tolerant, multi-purpose tall variety, suitable for copra, tender nut and inflorescence sap (*neera*) production. Fruits are large sized, oval and green in colour. Palms commence flowering 5-6 years after planting. Tender nut water content is 500 ml, copra content is around 184 g, oil content is 64% and inflorescence sap yield is 31 L/inflorescence. The variety yields 148-187 nuts/palm/year, under good management. Recommended for cultivation in Kerala, Tamil Nadu and Karnataka.

Kalpa Vajra: A root (wilt) disease tolerant tall variety, produced by controlled pollination of healthy high yielding West Coast tall palms in the disease hotspots. Fruits are medium sized, oval and green in colour. The palms commence flowering 4-5 years after planting. The tender nut water content is 370 ml, copra content is around 216 g, with oil content of 68%. Average yield of 80-94 nuts/palm/year in root (wilt) disease affected areas. Suitable for cultivation in the root (wilt) disease affected tracts and notified for the state of Kerala.

Arecanut

Shatamangala: High yielding, semi tall, dual purpose arecanut variety, suitable for both tender nut and ripe nut processing. Fruits are round, medium sized and orange in colour. The average yield is 3.26 kg dry tender processed nuts/palm/year or 3.96 kg dry kernel/palm/year.

Coconut varieties **A.** *Kalpa Suvarna;* **B.** *Kalpa Shatabdi;* **C.** *Kalpa Ratna;* **D.** *Kalpa Vajra, Arecanut variety* **E.** *Shatamangala*

SUMMARY

Planting material of all these notified coconut and arecanut varieties are available at ICAR-CPCRI. To promote wider distribution, the institute licenses these varieties to nurseries, planters, and other stakeholders, with licensing fees of ₹ 1 lakh for coconut and ₹ 2 lakhs for arecanut. Licensees are provided with breeder seed material for establishment of mother gardens and also provided training and technical support to facilitate planting material production and establishment of nursery.

For more information, visit the ICAR-CPCRI website: https://cpcri.icar.gov.in.

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ICAR-Central Plantation Crops Research Institute

In tandem with the aim of the Government to enhance the income/benefits of farmers and sustain the environment, ICAR-CPCRI has chalked out future research programmes in the 2020–25 and 2020–30 roadmap documents that align with the key national agricultural priorities listed below:

• Increasing agricultural production / productivity • Farmer welfare programmes
• Doubling farmers income • Poverty alleviation projects • Sustaining environment

Case Study

Usha Sharma[1]*, Swati Gautam[2], Upinder Sharma[2] and Rajeshwar Singh Chandel[3]

Innovation from the Himalayas: Natural farming paves the way for sustainable apple production

Apple cultivation in Himachal Pradesh faces declining productivity, rising input costs, and soil degradation due to prolonged chemical-based farming. Subhash Palekar Natural Farming (SPNF) has emerged as a sustainable alternative emphasizing soil health, biodiversity, and ecological balance. Trials conducted at RHR&TS Mashobra during 2020–24 evaluated SPNF in apple orchards under different rootstock–variety combinations. The results indicated improved soil microbial activity, higher earthworm population, enhanced organic carbon, and better plant growth. SPNF practices, including Jeevamrit, Ghanjeevamrit, mulching, intercropping, and natural pest management, contributed to superior fruit quality attributes such as firmness and ascorbic acid content. Economically, SPNF recorded higher net returns (₹12,74,640/ha) compared to conventional farming (₹8,30,840/ha), demonstrating its potential as a viable, eco-friendly, and profitable approach for sustainable apple production in Himalayan regions.

Keywords: Apple cultivation, Himachal Pradesh, Natural farming, Subhash Palekar Natural Farming, Soil health, Sustainable agriculture,

THE cultivation of apples in Himachal Pradesh represents a significant case of agricultural transformation and economic empowerment. The region's apple orchards, situated at high altitudes in the Himalayan mountains, have historically played a central role in sustaining local livelihoods. These orchards, characterized by densely planted trees bearing red apples, contribute not only to the scenic landscape but also constitute a primary source of income for numerous farming households.

In recent decades, however, the apple industry has confronted unprecedented challenges. Farmers are increasingly confronted with declining yields, rising production costs, and mounting environmental pressures. Conventional cultivation practices, which once ensured economic prosperity, are now compromising the long-term sustainability of apple production in the region.

To address these challenges, Subhash Palekar Natural Farming (SPNF) has emerged as a promising, eco-friendly alternative. By emphasizing soil health restoration, biodiversity conservation, and alignment with natural ecological processes, SPNF offers a transformative approach to apple cultivation. Its implementation not only targets productivity improvements at the orchard level but also promotes resilience across the entire apple-growing ecosystem of Himachal Pradesh. The adoption of SPNF therefore represents a strategic intervention aimed at securing the long-term viability of a critical agricultural sector while simultaneously conserving the region's unique natural heritage.

APPLES OF THE HIMALAYAS

Historical context

Apples were introduced to Himachal Pradesh in the early 20th century by Samuel Evans Stokes, an American missionary and later Indian freedom fighter. Initially experimental, apple cultivation rapidly evolved into a widespread agricultural practice. The region's temperate climate and fertile soils proved ideal for the crop, and by the mid-20th century, apple cultivation had become synonymous with Himachal Pradesh.

Economic impact

The proliferation of apple orchards significantly transformed the state's economic landscape. Many households transitioned from subsistence farming to commercial horticulture. Presently, apple cultivation occupies approximately 46% of the total fruit crop area in Himachal Pradesh and contributes 76% of the state's total fruit production. The sector has been instrumental in improving living standards, supporting education, and fostering regional infrastructure development.

Current scenario and challenges

Despite its historical success, apple cultivation in Himachal Pradesh has faced several significant challenges in recent years:

Declining productivity: A notable and concerning trend is the substantial decline in apple productivity. From

a peak of 10.84 t/ha in 1981, yields decreased to 4.4 t/ha in 2016 and further to 4.3 t/ha in 2023, representing an approximate decline of 59% from the peak. This decline poses a serious threat to the economic viability of apple farming in the region.

Rising input costs: Conventional apple production relies heavily on chemical fertilizers and pesticides. These inputs account for a major share of production costs and have exhibited diminishing returns over time, thereby reducing overall profitability.

Soil degradation: Prolonged and intensive use of chemical inputs has contributed to soil degradation. Many orchards now experience reduced soil fertility, poor water-holding capacity, and a decline in beneficial soil microbial populations.

Climate change: Alterations in climatic conditions, including warmer winters and irregular rainfall patterns, have begun to adversely affect apple production. Traditional varieties are increasingly facing challenges in adapting to these changing environmental conditions.

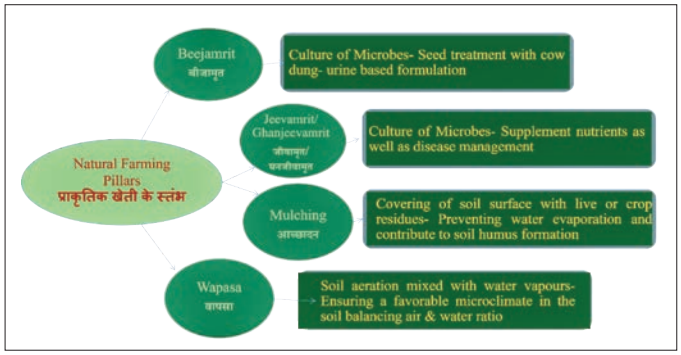
Market competition: With increasing globalization, Himachal apples are subject to competition from imported fruits, compelling farmers to enhance quality while simultaneously reducing production costs.

Health and environmental concerns: Growing awareness regarding the potential health risks associated with chemical residues in fruits, along with the environmental impacts of conventional farming practices, has further intensified the need for sustainable alternatives.

Collectively, these challenges have created a critical situation for the apple industry in Himachal Pradesh, necessitating the exploration of sustainable production systems. In this context, Subhash Palekar Natural Farming has emerged as a promising alternative, offering a pathway toward improved sustainability and resilience.

SPNF four fundamental principles

Subhash Palekar Natural Farming (SPNF) is built on four fundamental principles or pillars, which form the foundation of its ecological approach to agriculture:



Additional practices in SPNF: Beyond these core pillars, SPNF incorporates several complementary practices aimed at enhancing productivity, sustainability, and ecological balance:

- ***Use of indigenous cow products:*** SPNF places significant emphasis on the use of dung and urine from indigenous cow breeds. These are considered rich sources of beneficial microorganisms and natural growth-promoting substances that enhance soil fertility and plant health.
  - » ***Natural pest management:*** Instead of chemical pesticides, SPNF relies on botanical extracts and fermented preparations known as "*Astras*" for pest control. These include:
    - » ***Neemastra:*** Prepared from neem leaves and cow urine, effective against a wide range of pests.
    - » ***Agniastra:*** A mixture of tobacco, green chili, garlic, and cow urine, used to control soft-bodied insects.
    - » ***Brahmastra:*** A composite preparation made from multiple plant extracts, effective against diverse pest populations.
- ***Intercropping and crop diversity:*** SPNF promotes biodiversity through intercropping, crop rotation, and the maintenance of natural vegetation within the farming system, thereby improving ecosystem stability.
- ***Minimal external inputs:*** The system aims to minimize or eliminate reliance on external agricultural inputs, thereby reducing costs and enhancing farm self-reliance and sustainability.

Adapting SPNF to apple cultivation in Himachal Pradesh

Although Subhash Palekar Natural Farming (SPNF) was initially developed for annual crops, researchers and progressive farmers in Himachal Pradesh have been working to adapt its principles to perennial fruit crops, particularly apples. The Regional Horticultural Research and Training Station (RHR&TS), Mashobra, Shimla, has been at the forefront of this adaptation, playing a key role in evaluating and refining SPNF-based practices under local agro-climatic conditions.

Demonstration on natural farming practices at RHR&TS, Mashobra, Shimla

CASE STUDY AND RESULTS

Work done

During 2020–24, the Regional Horticultural Research and Training Station (RHR&TS), Mashobra, Shimla, under Dr Y S Parmar University of Horticulture and Forestry, implemented a comprehensive Subhash Palekar Natural

Farming (SPNF) programme for apple cultivation across four blocks with different rootstock–variety combinations (M9/Bright-N-Early, Top Red, Vance Delicious and Gale Gala; M7/Red Chief; Seedling/Oregon Spur; MM111/ Royal Delicious).

The approach focused on improving soil health through regular applications of bio-stimulants such as *Jeevamrit* and *Ghanjeevamrit*, along with intercropping of legumes and pest-repellent plants. Water conservation measures included contour bunding and the WAPASA technique. Mulching, both dry and live, was adopted to conserve soil moisture. Tree trunks were protected using *Poudhlep* applications applied four times annually. Pest and disease management was carried out using natural preparations at regular intervals. The programme also included seed treatment with *Beejamrit* and the use of *Saptdhanya Ankur* spray to enhance fruit quality. These year-round practices aimed to develop a balanced and sustainable orchard ecosystem while minimizing dependence on synthetic inputs. The study further compared SPNF with conventional chemical farming by assessing soil microbial load, earthworm population, fruit quality attributes, plant growth, and economic returns.

Methodology adopted at RHR&TS Mashobra, Shimla

The study employed several key principles and techniques of natural farming, primarily SPNF practices:

1. Soil microbiome management

- Focused on maintaining a healthy soil microbiome to enhance soil organic matter and fertility.
- Used bio-stimulant formulations (*Jeevamrit*, *Ghanjeevamrit*, etc.) based on fermented cow dung, cow urine and uncontaminated soil.

Soil Application

- *Jeevamrit* drenching at an interval of 21 days:
  - » In rootstock plants: 3 L/plant
  - » In seedling plant: 5 L/plant
- *Ghanjeevamrit* application at the time of field preparation:
  - » In rootstock plants: 200 gm/plant
  - » In seedling plant: 400 gm/plant
  - » Application at time of intercropping @1 t/ha

2. Intercropping

- Implemented leguminous crop intercropping (pea, rajmash, bean, fenugreek) with apple trees
- Cultivated garlic, marigold, and cabbage at orchard borders as insect repellents and trap crops

3. Water Conservation

- Constructed contours and bunds to preserve rainwater and reduce soil erosion
- Implemented WAPASA (Water and Air Percolation for Adequate Soil Aeration) technique
- Trenches of 3–4 inches depth were prepared outside the basin area and covered with dry grass mulch, which helped in conserving and retaining soil moisture.
- *Jeevamrit* was applied through drenching in these


Intercropping of pea


Intercropping of Rajmash


Intercropping of Wheat


Intercropping of cabbage and marigold


Intercropping of Garlic


Intercropping of Fenugreek

trenches, which contributed to an increase in the earthworm population in the soil, thereby indirectly improving soil aeration and enhancing soil fertility.

4. Mulching *(Aachadan)*

- Covered plant basins with dry grass mulch
- Used live mulch (bean, pea, cereals, etc.) between plant basins

5. Poudhlep Application

A protective coating was applied on tree trunks four times a year:

- *First application*: March (first or second week)
- *Second application*: May (second or third week)
- *Third application*: Last week of September or first week of October
- *Fourth application*: Between 21st December and 14th January

6. Natural Nutrient Management

- *Jeevamrit* was applied as a soil drench at 21-day intervals
- *Ghanjeevamrit* was applied during field preparation
- Leguminous crops were cultivated as a source of nitrogen to improve soil fertility

7. Pest and Disease Management

Natural preparations were sprayed at 15-day intervals or as and when required:

- For fungal foliar diseases: Sonthastra, Khatti Lassi, Ramban Rognashi, and Jeevamrit
- For insect pest management: Darekastr, Brahmastra, and Agniastra
- For woolly apple aphid control: Dashparni Ark

Foliar Application:

- *Jeevamrit*: 10 L in 100 L water
- *Khatti Lassi*: 5 L in 100 L water
- *Ramban*: 7 L *Jeevamrit* + 3 L *Lassi* in 100 L water
- *Sonthastra*: No dilution
- *Darekastr*: No dilution
- *Agniastra*: 5 L in 100 L water
- *Brahmastra*: 5 L in 100 L water
- *Dashparni Ark*: 5 L in 100 L water
- *Saptdhanya Ankur* spray was applied at 80% flowering, at fruit set, and 15 days before harvest to enhance fruit quality.

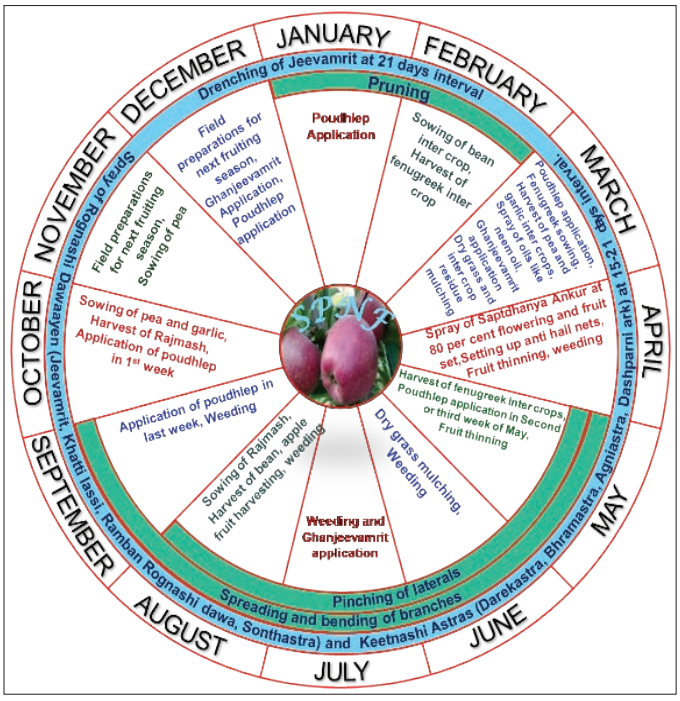
8. Seed Treatment

- Used *Beejamrit* for seed treatment

Achievements

The trials conducted at RHR&TS Mashobra, Shimla demonstrated the following outcomes:

- Successful implementation of Subhash Palekar Natural



Year-round operations of Subhash Palekar Natural Farming in Apple at RHR&TS, Mashobra, Shimla (HP)

Farming (SPNF) in apple orchards, including the integration of eight intercrops alongside the main crop.

- Improved soil health, reflected by increased organic carbon content and enhanced microbial population in SPNF-treated soils.
- Higher Arbuscular Mycorrhizal Fungal (AMF) spore counts in SPNF soils, indicating improved soil biological activity.
- Significant increase in earthworm population in SPNF-managed plots.
- Superior fruit quality parameters under SPNF, including higher fruit firmness, ascorbic acid content, and acidity levels.
- Better preservation of fruit quality under laboratory and refrigerated storage conditions.
- Positive vegetative growth responses, with increased plant height and trunk girth in SPNF treatments.
- Variable but notable effectiveness in managing pests and diseases using SPNF-based practices.
- Higher economic returns from SPNF compared to conventional chemical farming (CF), with net returns of ₹12,74,640.25/ha under SPNF versus ₹8,30,840.01/ha under CF in 2023.

Summary: A sustainable vision for the future

The adoption of Subhash Palekar Natural Farming (SPNF) in Himachal Pradesh's apple orchards represents more than an agricultural intervention; it signifies a strategic step toward a more sustainable and resilient production system. As this approach continues to evolve, it holds the potential to influence not only apple cultivation practices but also broader perspectives on agriculture, sustainability, and human interaction with natural ecosystems.

The success of SPNF under Himalayan conditions provides valuable insights for the development of sustainable agricultural systems globally. It encourages a shift from conventional, input-intensive farming toward an ecological approach that emphasizes harmony with natural processes. In this context, apple orchards in Himachal Pradesh are contributing not only to fruit production but also to the development of sustainable farming models that integrate productivity with environmental conservation. The coming decade will be critical in assessing the long-term scalability and impact of this approach in transforming agricultural systems at both regional and global levels.

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Vishal Singh Rana[1]*, Dinesh Singh Thakur and Pooja Kumari

Chinese jujube: A new potential introduction for diversifying fruit cultivation in Himachal Pradesh

Horticulture in Himachal Pradesh is increasingly challenged by climate variability, declining productivity of traditional crops, and market uncertainties. In this context, Chinese jujube (*Ziziphus jujuba* Mill.) emerges as a promising alternative for diversification. Introduced from Australia and evaluated across altitudes of 900–2,000 m, the crop has shown encouraging adaptability, early bearing, and suitability to diverse soil and climatic conditions. Its tolerance to drought, temperature fluctuations, and low input requirements makes it ideal under changing climate scenarios. Preliminary trials with varieties *'Li'* and *'Chico'* indicate good establishment and fruiting potential in mid- and low-hill regions. Additionally, its high nutritional value and scope for value addition enhance market prospects. Chinese jujube thus holds significant potential for sustainable and profitable fruit cultivation in the region.

Keywords: Climate resilience, Extreme temperature and water stress, Himachal Pradesh, Rootstocks, Value addition

THE horticulture industry in Himachal Pradesh is increasingly challenged by the uncertainty of global climate change, as most of the arable area is rainfed. Orchardists often remain uncertain about returns due to risks associated with weather variability and fluctuating market conditions. Existing fruit crops, particularly apple, have shown a decline in productivity, coupled with increasing incidences of biotic and abiotic stresses. However, some emerging fruit crops such as kiwifruit, pear, plum, persimmon, and strawberry have demonstrated promising potential in recent years. More recently, Chinese jujube has been introduced by Dr YSP UHF, Nauni, Solan (Himachal Pradesh), from Australia after obtaining the necessary import permit from NBPGR, New Delhi. It has been planted across different agroecological locations ranging from 900 m to 2,000 m above mean sea level. Preliminary observations indicate its potential for commercial cultivation in the Shivalik foothills and mid-hill regions, including Solan, Shimla, Sirmour, Hamirpur, and Kangra districts. In the current context, the introduction of hardy, non-traditional fruit crops like Chinese jujube, with wide climatic adaptability, could prove to be a valuable asset for future fruit farming.

Origin and importance

The jujube (*Ziziphus jujuba* Mill.), also known as Chinese jujube, is one of the oldest cultivated fruits in the world and belongs to the family Rhamnaceae. It holds considerable economic, ecological, and social importance. Its cultivation dates back to the Neolithic period, around 7,000 years ago, and it is believed to have originated from its wild relative *Z. spinosa* Hu. The Indian jujube (*Ziziphus mauritiana* L.) is widely cultivated in the Indian subcontinent for its fresh fruits and medicinal value, particularly in Ayurvedic preparations, and thrives in dry and marginal ecosystems. In contrast, Chinese jujube is a cold-hardy, deciduous species known for its excellent dehydration quality and high vitamin C and P content. In China, it has long been used both as food and in traditional medicine. The fruits are consumed fresh, dried, or processed into products such as bread, cakes, candy, chutney, pasta, purees, syrups, and jams. Dried fruits are also commonly used in porridges and broths, especially during festive occasions.

Botanical description

Chinese jujube exhibits wide adaptability to diverse soil types and climatic conditions. The plant is a deciduous tree, typically 15–30 feet tall, with hard and durable wood. Branches are often crooked, and young plants bear paired thorns. The canopy may range from wide-spreading to upright forms. Leaves are shiny, oval to elliptical, and arranged alternately on the branches. The flowers are small, fragrant, pale greenish-yellow, and appear singly or in clusters in the leaf axils. A distinctive feature of Chinese jujube is that flowering, fruit set, and fruit development occur within a single growing season. Botanically, the fruit is a drupe with a central stone containing up to two

seeds. Fruit size varies from thumb-sized to golf ball-sized, depending on the variety, and shapes range from round and oval to oblong and apple-like.

Pollination, bearing and yield: Most varieties are self-fruitful, although cross-pollination enhances fruit set and yield. Therefore, planting two or more varieties is recommended. Pollination is facilitated by insects such as ants, honeybees, wild bees, hoverflies, houseflies, and ladybirds. Jujube plants are precocious, bearing fruits within two to three years of planting, with reasonable yields achieved after four to five years. A mature tree can produce 18–40 kg or more of fruit, depending on variety, management practices, and location, and can remain productive for over 50 years. The crop performs well across a wide range of soil types–from sandy to clayey–and soil pH (6.0–8.5). It is drought-tolerant and generally easy to manage, although young plants require care similar to other fruit trees.

Fruit development and harvesting: Fruit colour changes from dark green to yellowish-green at the onset of ripening, followed by the development of brown or red spots. Eventually, the fruit turns fully red to reddish-brown, indicating maturity. As ripening progresses, the texture softens and the surface wrinkles. Fruit maturity is often non-uniform. Fresh fruits can be harvested from the creamy stage to the fully red stage while still firm. Fruits can be stored at 4°C for up to two weeks. Fully red fruits are preferred for drying, and manual harvesting is recommended.

Jujube is cultivated in over 50 countries, with China accounting for more than 90% of global production and a significant expansion in cultivation over the past three decades. In Himachal Pradesh, fruit cultivation is increasingly threatened by climate change, pest and disease pressures, and post-harvest losses. Considering the growing global popularity and economic importance of jujube, its commercialization as a new crop could play a vital role in horticultural diversification and expansion in the state.

Scope of jujube in Himachal Pradesh

Two varieties, *viz.,* 'Li' and 'Chico', along with seeds of three rootstocks, namely Jin Si Lin, Mystal, and P. Hybrid, of Chinese jujube were introduced by Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh), from Australia at the Regional Horticultural Research and Training Station, Dhaulakuan, Sirmour, in 2023. The plants of these varieties have been established at four different locations for multilocation testing across elevations ranging from 900 m to 2,000 m above mean sea level. The plants started bearing fruits in 2024, with higher yields expected in the summer season of 2025. In addition, rootstocks have been evaluated, and seedlings have been planted in the mid- and low-hill regions of Himachal Pradesh. The two commercial varieties have been successfully grafted onto the three rootstocks.

Table 1. Germination of different Jujube rootstocks

Rootstock	Seeds sown	Germinated	Germination (%)
Jin Si Lin	500	317	63.40
Mystal	475	228	48.00
P. Hybrid	475	278	59.00

(A) Germinated seedlings of Jujube rootstocks;
(B) Variety Li in Pot; and (C) Variety Chico in Pot

Table 1 presents the germination performance of three jujube rootstocks in the foothills of Himachal Pradesh. The Jin Si Lin rootstock recorded the highest germination percentage among all the rootstocks. A few fruits were also obtained from the imported plants. The preliminary results regarding the adaptation and fruiting of this new crop are encouraging at the experimental sites. After comprehensive evaluation and performance assessment over a period of 3–4 years, standardized propagation and cultivation practices can be developed for the commercialization of jujube as a potential fruit crop for diversification of hill horticulture.

Climate suitability

Himachal Pradesh experiences a wide range of

Flowering in Li and Chico variety of Jujube at RHR &TS, Dhaulakuan, District Sirmour

(A) Fruiting in Jujube at Dhaulakuan, Sirmour;
(B) Mashobra, Shimla

temperatures due to its varied topography. The lower and mid-hill regions provide ideal conditions for jujube cultivation. The crop thrives at temperatures between 25°C and 35°C, which align well with the prevailing conditions in these areas. Owing to its cold tolerance, jujube can also be successfully cultivated at higher altitudes, i.e., above 2,000 m, particularly in the context of rising temperatures due to climate change. Its ability to withstand cold spells and frost offers a significant advantage in higher elevations. Furthermore, being a drought-tolerant crop, jujube is well-suited to cope with irregular monsoon patterns and reduced water availability anticipated under changing climate scenarios.

Adaptation to climate change

With rising global temperatures, Himachal Pradesh is likely to experience more frequent heat waves and warmer winters. Chinese jujube, due to its tolerance to high temperatures, can serve as a reliable alternative in areas becoming less suitable for traditional fruit crops such as apple and other stone fruits, which are sensitive to heat stress. Under conditions of reduced rainfall and erratic water supply, jujube's ability to grow in water-limited environments provides a distinct advantage over water-intensive crops. Its low water requirement makes it particularly suitable for regions facing water scarcity, especially in the semi-arid zones of the state.

Economic and market potential

Chinese jujube is a high-value fruit with significant nutritional benefits, being rich in vitamin C, antioxidants, and other bioactive compounds. This makes it attractive for both fresh consumption and value-added products such as dried jujube, jams, juices, and herbal preparations. Increasing consumer awareness regarding health and immunity has further enhanced the demand for jujube-based products in international markets. Moreover, the growing preference for organic and functional foods presents a promising opportunity for jujube cultivation in Himachal Pradesh. Additionally, its cultivation in the scenic landscapes of the state could promote agro-tourism, allowing visitors to experience harvesting and local processing. This potential is particularly relevant for districts such as Kangra and Kullu, which are known for their natural beauty and increasing interest in sustainable tourism.

Environmental and sustainability benefits

Jujube cultivation can enhance soil fertility through its deep root system, which helps reduce soil erosion and improve soil structure. This is particularly important in hilly regions such as Himachal Pradesh, where soil conservation is a major challenge due to heavy rainfall and steep terrain. As a hardy and long-lived tree, jujube contributes to carbon sequestration, thereby helping to mitigate the effects of climate change. Compared to traditional fruit crops such as apple and citrus, jujube requires minimal chemical inputs, making it a more sustainable and eco-friendly option under changing climatic conditions.

Challenges and considerations

Although jujube is relatively pest-resistant, it remains susceptible to certain pests, including fruit flies, and to fungal diseases, particularly under humid conditions. These challenges may intensify with increased rainfall and unpredictable weather patterns associated with climate change. Despite its suitability to the agro-climatic conditions of Himachal Pradesh, jujube remains under-researched and unfamiliar to many farmers. Therefore, capacity building, training, and extension services will be essential for its wider adoption. Additionally, investments in infrastructure, irrigation, and market development are required. Although jujube has promising market potential, it is still a niche product in India; hence, increasing consumer awareness through effective marketing strategies will be crucial for its successful commercialization.

SUMMARY

The cultivation of Chinese jujube in Himachal Pradesh holds significant potential, particularly in the context of climate change. Its ability to withstand extreme temperature and water stress conditions makes it an ideal crop for the evolving agro-climatic scenario of the region. The growing demand for health and wellness products, coupled with its environmental and economic advantages, positions jujube as a sustainable and profitable option for orchardists. However, successful adoption will depend on addressing challenges related to pest management, market development, and capacity building. With appropriate support from government agencies, research institutions, and the private sector, Chinese jujube could emerge as a key crop contributing to both economic growth and environmental resilience. Its adoption can provide farmers with diversified income sources, enhanced profitability through value addition, and improved resilience to climate-related risks, making it a promising option for hill horticulture in Himachal Pradesh.

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Movable screens in rose production

- Use movable screen, an important tool for rose cultivation.
- It can help growers manipulate environment conditions — lowers temperature, changes humidity and influences production numbers.
- The movable screens can be used year-round and in a variety of climates — from the Netherlands to India.

Shivam[1]*, Kuldeep[2], M Sankaran[3] and Jai Prakash[4]

Pummelo: A future fruit for human health and wellness

Pummelo (*Citrus grandis*/*Citrus maxima*), the largest citrus fruit, is emerging as a promising crop for human health and climate resilience. Increasing climate variability and rising demand for nutraceutical-rich foods highlight its significance. The fruit is rich in vitamin C, dietary fibre, potassium, and bioactive compounds such as flavonoids, limonoids, and carotenoids, which impart antioxidant, anti-inflammatory, and antimicrobial properties. Pummelo demonstrates tolerance to heat, drought, and certain pests and diseases, making it suitable for diverse agro-climatic conditions. Its thick rind, longer shelf life, and suitability for processing and transport enhance its commercial and export potential. Thus, pummelo holds great promise for nutritional security, sustainable horticulture, and future health-oriented food systems.

Keywords: Antioxidant properties, Climate resilience, Nutraceutical value, Nutritional security, Phytochemicals

PUMMELO (*Citrus grandis* Osbeck/*Citrus maxima* (Burm.) Merr.), belonging to the family Rutaceae, is the largest fruit among citrus species. Native to Southeast Asia, it is commonly known as pomelo, shaddock, Chinese grapefruit, and locally as *chakotha* or *chakotara*. The fruit is round to pear-shaped, weighs 500–2,000 g, and has a thick, aromatic rind with 11–18 easily separable segments. The flesh is sweeter and milder than grapefruit, with low acidity and minimal bitterness, and varies in colour from light yellow to deep red. It is also grown as an ornamental fruit due to its large size and attractive peel.

Pummelo is a tropical fruit crop well adapted to subtropical conditions and is widely cultivated in countries such as Indonesia, India, Bangladesh, Thailand, and China. In India, it is mainly grown in homestead gardens, with rich diversity in the North-East region, eastern Uttar Pradesh, Bihar, West Bengal, Karnataka, and Kerala. It holds cultural importance in Bihar during *Chhat* Puja and symbolizes prosperity during Chinese New Year.

Despite being the largest citrus fruit, pummelo remains underutilized in India. However, its high nutritional value, antioxidant properties, vitamins, minerals, and beneficial phytochemicals enhance its medicinal and commercial potential. The thick rind ensures good shelf life and ease of transport, making it suitable for distant markets and export-oriented cultivation.

Nutritional and food value

The nutritional quality of pummelo fruit is remarkable, with several important constituents. It is a rich source of carbohydrates, proteins, vitamins, minerals, and dietary fibre, with negligible fat. It is also enriched with various bioactive compounds beneficial for human health, such as carotenoids, flavonoids, acridones, alkaloids, coumarins, monoterpenes, triterpenes, benzenoids, steroids, limonoids, essential oils, citric acid, and B-complex vitamins.

In addition to being consumed as a table fruit, pummelo is widely processed into products such as soft drinks, blended juices, squash, nectar, jam, wine, fortified bread, candies, and salads. The rind is used for preparing preserves, sweets, sugar pickles, salt pickles, essential oils, pectin, polyphenols, and coumarins. Braised pummelo pith is used in recipes that are low in fat and high in fibre. The highly fragrant flowers, particularly collected in North Vietnam, are used in perfumery. The wood is heavy, durable, and fine-grained, making it suitable for tool handles.

Medicinal and therapeutic values

Pummelo has gained widespread recognition for its phytochemical, ethnobotanical, pharmacological, and medicinal properties. It has been scientifically proven to possess therapeutic potential and is considered safe for human consumption, including cholesterol-lowering effects and support in weight management. Traditionally, pummelo is used as a functional food, and various parts of the plant, including leaves, pulp, peel, seeds, and gum, are utilized for medicinal purposes.

The leaves are known to exhibit antimicrobial, antioxidant, and anticancer properties. The pulp has traditionally been used to treat mental disorders, asthma, leprosy, hiccups, cough, and epilepsy, and is reported to possess antioxidant, antihyperlipidemic, appetizing, antitoxic, stomachic, and cardiotonic properties. The

Nutritional value of pummelo fruit per 100 g edible portion Source: USDA, 2018

Approx. composition/ (100 g edible portion)		Mineral composition/ (100 g edible portion)		Vitamin content/ (100 g edible portion)	
Composition	Value/100 g	Minerals	Value / 100 g	Vitamin	Value / 100g
Moisture	89.1 g	Sodium	1 mg	Vitamin A	20 I.U.
Energy	38 kcal	Phosphorus	17 mg	Thiamine (B1)	0.034 mg
Protein	0.76 g	Iron	0.11 mg	Riboflavin (B2)	0.02 mg
Fat	0.04 g	Magnesium	6 mg	Niacin (B3)	0.22-0.3 mg
Carbohydrates	9.62 g	Manganese	0.017 mg	Ascorbic acid	61 mg
Dietary Fibre	1.0 g	Potassium	216 mg	Vitamin B6	0.036 mg
Ash	0.48 g	Zinc	0.08 mg		
		Calcium	4 mg		

fruit peel exhibits analgesic, anti-inflammatory, antitumor, anticoagulant, antimicrobial, and antioxidant activities. Seeds are used to treat lumbago, dyspepsia, and cough, while the flowers are used for managing sleep disorders and anxiety.

In Brazil, gum obtained from declining trees is used as a remedy for cough. Leaf oil is applied topically to treat skin diseases, headaches, and stomach pain. Decoctions of leaves, flowers, and rind are widely used in Asian countries for their sedative properties in conditions such as epilepsy, chorea, oedema, and convulsive cough, as well as for cosmetic purposes.

Climate and soil

Pummelo grows best in hot, humid climates with an optimum temperature of 25–30°C and annual rainfall of 1,000–1,500 mm. It can be cultivated up to an elevation of 1,500 m and is adaptable to a wide range of climatic conditions. The crop prefers deep, well-drained, fertile soils with a *p*H of 5.5–7.5 and is sensitive to hot winds, extreme temperatures, and waterlogging.

Improved varieties

In India, pummelo varieties are broadly classified into white and pink/red aril types. Several improved varieties have been developed by ICAR institutes such as IARI, New Delhi; IIHR, Bengaluru; and CCRI, Nagpur.

Pusa Arun: A natural mutant, this seedless and highly juicy variety was released by ICAR-IARI in 2020. It is high yielding (34.30 kg/tree) with an average fruit weight of 500–600 g and 40–45% juice content. The variety matures about 20 days earlier than other sweet citrus types. Fruits have low acidity (0.4% citric acid), high TSS (12°Brix), and vitamin C content of 50–55 mg/100 ml juice. Trees are semi-vigorous and suitable for high-density planting at 4 × 4 m spacing.

Arka Chandra: Developed through clonal selection at ICAR-IIHR, Bengaluru, this variety has medium-sized trees and is a prolific bearer. Fruits weigh 0.8–1.0 kg, are spheroid in shape, with white pulp and a balanced sweet-acidic taste. TSS ranges from 11–12°Brix with moderate acidity (0.89%).

Arka Anantha: This high-yielding, pink-fleshed variety was developed through superior clonal selection at ICAR-IIHR, Bengaluru. The tree is medium-sized with a drooping growth habit. Fruits are spheroid, weighing 0.8–1.0 kg, with TSS of 11–12°Brix and acidity of 0.90%, having a sweet-acidic blend with low bitterness.

NRCC Pummelo-5: A promising high-yielding variety released by ICAR-CCRI, Nagpur. Fruits are yellow with attractive red segments, suitable for fresh consumption, and possess a good TSS–acid balance.

Pummelo US145: A high-yielding cultivar with medium-sized fruits, white flesh, high juice content (31.56%), and soft, tender segments suitable for both table use and juice extraction.

Propagation

Pummelo can be propagated asexually through air-layering, budding, and grafting. However, shield budding is the most standardized and preferred method for commercial propagation. Rangpur lime is commonly used as a rootstock. Micro-budding techniques have also been standardized for certain cultivars at ICAR-CCRI, Nagpur.

Planting

The ideal planting time is at the onset of the monsoon (July–August), avoiding heavy rains. Planting can also be done in spring with assured irrigation. A spacing of 8–10 m × 6–8 m is recommended depending on cultivar vigour and soil fertility, while high-density planting (4 × 4 m) is feasible with proper training and pruning.

Pits of 3 × 3 × 3 ft should be dug at least one month before planting and left open for a few days. These are filled with a mixture of well-decomposed FYM and topsoil (1:1), along with 350 g SSP and 400 g neem cake, raised about 15 cm above ground level. Saplings are planted at the centre of the pit, followed by light irrigation.

Manures and fertilizers

The recommended dose of manures and fertilizers for pummelo cultivation is given in the table below. Organic manure should preferably be applied during December–January. Inorganic fertilizers should be applied in two split doses: the first before flowering and the second 4–6 months later.

Pummelo fruit salad

Cultivation of pummelo fruit at ICAR-Indian Institute of Horticultural Research, Bengaluru

Fruiting in pummelo

Pummelo variety: *Arka Chandra*

Pummelo variety: *Arka Anantha*

Annual requirement of manure and fertilizers in pummelo

Year	FYM (Kg)	N (g)	P (g)	K(g)
1st	10-15	80-100	60-80	80-100
2nd	20-25	160-200	160-180	160-200
3rd	30-35	300-350	260-280	300-350
4th	40-45	450-500	360-380	450-500
5th onwards	50-55	600-650	460-480	600-650

Irrigation and weed management

Irrigation should be provided to young trees twice a week during summer. Bearing trees require watering at 7–10 day intervals in summer and 30–40 day intervals in winter, with regular irrigation from flowering to harvest. Tree basins should be kept weed-free to avoid competition for moisture and nutrients.

Training and pruning

Generally, the open-centre system of training is followed in pummelo. Although heavy pruning is not required, light pruning should be carried out after planting to develop a proper framework. Regular removal of dead, dry, crisscross branches and water sprouts is essential. Bordeaux paste should be applied immediately after pruning to prevent secondary infection.

Flowering and fruiting

Pummelo plants generally start flowering after 4–5 years of planting. Flowering occurs during March–April, and fruits mature from October to November in North India. The fruit takes about 5–6 months to mature.

Harvesting and yield

Pummelo is a potentially heavy-bearing fruit crop. Mature trees generally produce about 70–100 fruits per year, with a total yield of 50–100 kg per tree. It is a non-climacteric fruit and should be harvested at full eating maturity. During ripening, oil glands become larger and glossier, and the rind colour changes from dull to bright yellow. Fruits can be stored for up to 12 weeks at 7–9°C and 85–90% relative humidity.

Diseases, pests, and physiological disorders management

The major diseases of pummelo include foot rot, root rot, crown rot, gummosis, powdery mildew, scab, and citrus greening. Major pests include soft green scale, citrus leaf miner, aphids, and citrus psylla.

Future prospect

There is a need to create awareness among the common men about the importance and benefits of pummelo. Its commercialization as a climate-resilient fruit crop can be strengthened through the large-scale availability of quality planting material, standardization of

Disease/pest/ disorders	Symptoms	Management
Phytophthora rot	Damping off of seedlings, crown rot till foot rot and brown rot of fruits	Use of resistant rootstocks Drenching of Ridomil MZ 72@ 2.75 g/l or Aliette (2.5 g/l) Biocontrol agent: *Trichoderma harzianum* 100-150 g/ pit
Powdery mildew	White powdery growth on plants specially leaves	Spraying: Wettable sulphur (2 g/l).
Citrus greening	Yellowing of new leaves, shoots, infected fruits remain green, small size, distortion, low juice and insipid taste.	Use of disease-free planting material. Removal of infected trees. Control psylla population.
Soft green scale	Suck the plant sap and secrete honeydew, which attracts the sooty mould.	Application of methyl parathion (0.075%) or methomyl (0.05%).
Citrus psylla	Vector for the citrus greening disease	Application of dimethoate (0.025%) or imidacloprid (0.003%)
Fruit fly	Makes small punctures on fruits and lay eggs in the fruits larvae eat the fruits and fruit become yellow and fall down.	Application of bait containing malathion 2 ml/l + carbendazim (0.1%) with 10 g of jaggery or sugar. The pheromone traps (4 to 6 No./acre) using methyl eugenol.
Fruit Splitting	Longitudinal cracks near stylar end and exposure of juice vesicles	Uniform irrigation Foliar spray of $CaCl_2$ (0.5–1%) Boron spray (0.1% boric acid) Mulching
Granulation	Hard, dry juice vesicles, reduced juice content, whitish, stiff segments	Balanced fertilization Timely harvesting

production technologies, adoption of safe plant protection measures, and the development of high-yielding dwarf cultivars suitable for high-density planting with deep pink/ red-coloured arils and enhanced processing potential.

SUMMARY

Pummelo is a promising fruit crop known for its valuable nutritional and therapeutic properties and numerous health benefits. It has the ability to adapt to adverse soil and agro-climatic conditions and shows tolerance to both biotic and abiotic stresses. Therefore, in the context of climate change, pummelo holds great potential for future cultivation in the country, owing to its large fruit size and high yield. Its consumption as a fresh fruit and in salads is increasing rapidly in oriental countries, as well as in India, where tourist footfall is also rising.

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Strawberry production technology for high altitudes of Tawang, Arunachal Pradesh

Farm income in the high mountain border state of Arunachal Pradesh is below the national average due to fragmented landholdings, lack of quality planting material, and reliance on traditional cropping systems. Furthermore, this fragile ecosystem experiences significant yield losses and economic distress due to harsh climatic conditions and the menace of wild animals. Therefore, to enhance farm income per unit area, interventions such as protected cultivation and the introduction of high-value crops offer a viable solution. Notably, about one-third of the geographical area of the Tawang district has a temperate climate suitable for strawberry cultivation. However, the use of protected structures covered with 6 mm polycarbonate sheets or 200 µ polythene is essential to safeguard the crop from high-altitude weather extremes. Protected cultivation of strawberry in the Tawang is economically viable, with a return of ₹1.74 and ₹3.26 per rupee invested during the first and second years, respectively, under polythene mulch. Similarly, the use of organic mulch, such as abundantly available red oak leaves, yields a benefit–cost (B:C) ratio of 1.31 and 2.16 during the first and second years, respectively, under high-altitude conditions.

Keywords: Cultivation practices, Mulching, Protected cultivation, Strawberry, Yield

STRAWBERRY *(Fragaria × ananassa)* is an aggregate fruit grown worldwide for its pleasant aroma, sweet–sour taste, and juicy, bright red fruits rich in essential nutrients, vitamin C, flavonoids, and antioxidants. It matures within a short period, requires a moderate cost of cultivation, and fetches premium prices, especially in tourist destinations like Tawang district, where market demand is high. Hence, its introduction can be a highly profitable agribusiness opportunity.

Its growth and development are favoured by temperate climates; therefore, protected cultivation can be successfully practiced throughout the year in the high mountainous and cold climate conditions of Tawang, with the potential to significantly enhance the income of frontier farmers.

Encouraging results from strawberry feasibility trials conducted at the Defence Research Laboratory Research and Development Centre, Tawang, Arunachal Pradesh, for its introduction in greenhouses at strategic locations have led to the development of the following agronomic practices for economical cultivation.

Ambient conditions

The optimum temperature for the growth and development of strawberries is 20–25°C during the day and 10–12°C at night. In high-altitude areas of Tawang, however, daytime temperatures range between 15–20°C, while night temperatures fluctuate between 5–8°C and may occasionally drop to near freezing even during summer nights.

The experimental site in Tawang receives an annual rainfall of 500–895 mm, characterized by highly irregular distribution throughout the growing season, which further accentuates temperature variability. However, the desired temperature range can be effectively maintained using a naturally ventilated polyhouse constructed with 6 mm thick polycarbonate cladding, even during peak winters at altitudes of 7,500–9,500 feet.

Construction of low-cost polyhouse

High initial investment costs, even with government subsidies, constrain small and marginal farmers in the Tawang district from adopting polycarbonate greenhouse structures. Except for a few holdings of approximately 0.5 acre, most cultivable land in the region is highly undulating with steep slopes, resulting in fragmented landholdings. Under these combined constraints of harsh climatic conditions and limited, uneven land availability, strawberry cultivation can be made feasible and economically viable through the adoption of low-cost polyhouses.

A low-cost polyhouse measuring 10 × 5 × 3 m (length × width × central height) has been found to be economically suitable and can be conveniently established at sites receiving adequate sunshine throughout the year. The structure utilizes 200 µm polyethylene as cladding

material (11 × 4 m) and locally available wood for framing, along with provisions for efficient drainage. The side flaps of the polythene covering can be rolled up during midday hours to prevent excessive heat build-up inside the polyhouse through adequate ventilation.

Soil

The soils of most cultivable fields in the Tawang are acidic (*p*H ~5.0) and loamy in texture, comprising approximately 45% sand, 35% silt, and 19% clay. The balanced addition of organic manures can make these soils suitable for strawberry cultivation, which prefers slightly acidic conditions.

Soil preparation

The soils of the Tawang are sandy and gravelly; therefore, ploughing is primarily carried out to remove boulders and perennial weeds. This is usually done using a spade and hand hoe to achieve a fine tilth up to 20 cm depth.

A minimum application of vermicompost at 5 kg/m^2 during final land preparation, followed by levelling, is recommended along with the appropriate dose of chemical fertilizers. It helps in moderating soil acidity and improving nutrient availability in the leached soils of the region. Preparation of raised beds measuring 2.7 × 1.2 × 0.15 m is advisable, even under protected structures, to prevent seepage and waterlogging during heavy rainfall.

Soil treatment

Soil solarization, which involves trapping solar heat by covering moist, well-prepared soil with transparent polythene mulch, is an effective non-chemical method for managing soil-borne pathogens, insects, and nematodes under the agro-climatic conditions of Tawang.

The soil should be thoroughly ploughed, made clod-free, levelled, and shaped into beds to eliminate air pockets and ensure uniform heat transfer. Adequate moisture (about 50% of field capacity) should be maintained prior to mulching. A 50 µm LDPE transparent sheet is tightly laid and sealed at the edges, and solarization is carried out for about 48 hours during periods of high ambient temperature in August.

Suitable cultivars

Varietal evaluation trials conducted over two years at the ICAR-DRL, R&D Centre, Tawang, indicate that the strawberry cultivars *Sweet Charlie* and *Winter Dawn*, both short-day types, are suitable for protected cultivation under the prevailing temperate climate.

Planting time

Strawberry runners can be planted throughout the year in Tawang. However, two main planting windows have been identified at altitudes of 7,500–9,500 ft AMSL: March–April (summer) and September–October (winter).

Winter planting is considered most suitable, as it coincides with receding rainfall and stable temperatures. In contrast, July planting promotes excessive vegetative growth and runner production, which reduces fruit yield and quality.

Plant spacing

Limited arable land is a major constraint in the Tawang dictrsict. Therefore, closer spacing of 30–35 cm between plants and rows ensures optimal utilization of space under protected conditions. However, a spacing of 50 × 25 cm may be adopted in soils with low to medium fertility.

A raised bed of 2.7 × 1.2 × 0.15 m accommodates four rows and approximately 36 plants, facilitating efficient cultural operations and maintaining optimal plant density.

Mulching

Polythene mulching is an essential practice in strawberry cultivation to ensure high-quality fruit production. Planting runners in holes of 5–7.5 cm diameter made in black–silver polythene mulch (30–50 µm) protects fruits from direct soil contact, conserves moisture, and maintains a favourable microclimate by suppressing weeds.

The mulch should be laid just before planting, with the silver surface facing outward. Although polythene mulch is most effective, organic mulching using locally available oak leaves at 5 kg/m^2 can serve as a partial alternative.

Nutrient management

In the absence of chemical fertilizers, raised beds should be enriched with vermicompost at 10–15 kg/m^2, applied 15–20 days before planting during the initial years. The soils in Tawang are generally medium in nitrogen, low in phosphorus, and high in potassium.

An optimum dose of N, P_2O_5, and K_2O (10 g, 12.5 g, and 8 g/m^2, respectively), preferably based on soil test results, along with 2.5 kg/m^2 vermicompost, is recommended. Due to heavy rainfall and sloping terrain, higher doses of vermicompost are advisable to ensure a balanced supply of secondary and micronutrients.

Nitrogen should be applied in two equal splits–at establishment and before flowering–using the band placement method. Phosphorus and potassium should be applied during final land preparation. Fertigation of nitrogen and potassium is recommended throughout flowering and fruiting.

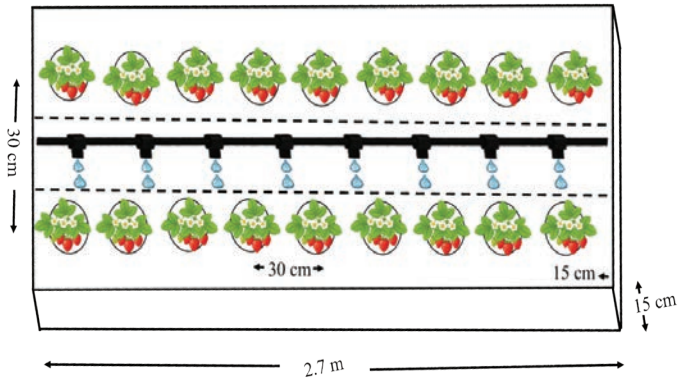
Foliar spray of N:P:K (19:19:19 or 20:20:20) at 3–5 g/l, applied twice a week during flowering and fruit set, enhances plant vigour and fruit quality.

Water management

Maintaining optimal humidity and adequate soil moisture (around 50% field capacity), particularly during critical stages such as establishment, budding, flowering, and fruit set, is essential under polyhouse conditions to prevent grey mould incidence.

Instead of conventional furrow irrigation using water with total dissolved solids (TDS) below 450 ppm, the integration of a double-row planting system with a centrally placed drip line significantly improves water and nutrient use efficiency. The drip line is positioned between two rows under the polythene mulch, minimizing direct moisture contact with plant stems and reducing the risk of fungal diseases.

Irrigation should be scheduled during morning hours, avoiding the warmest part of the day and evening periods.



Diagrammatical illustration of raised bed with central drip system (dashed line showing drip line under the silver mulch

Intercultural operation

Clean cultivation with soil solarization and polythene mulching in the protected structure does not require interculture operations. However, the removal of sand eaves (lower most senescing leaves) once in 15 days helps in reducing the incidences of insects and diseases (fruit rot).

Insect pest and disease management

Two-spotted mites (*Tetranychus urticae* Koch), aphids (*Chaetosiphon fragaefolii* Cockerell), white flies (*Bemisia tabaci*) and thrips (*Scirtothrips dorsalis* Hood) are the major insect pests of strawberry. However, in Tawang region, the attack of aphids and thrips is periodic while white flies are sporadic under protected conditions. The preventive measures such as the use of yellow, blue and white sticky traps are desirable in this region. A prophylactic spray of 0.5% neem seed kernel extract (NSKE) at 15 days interval is suggested when the incidence of insects is more than 10/plants.

Gray mould (*Botrytis cinerea*) is a major disease of strawberry under protected conditions, however, in Tawang its outbreak is not a serious concern in winter crop because of the cold temperature during fruit set. In the summer season, maintaining ventilation during mid-day along with ensuring nil contact of fruits with soil through polythene mulching is the most efficient preventive measure for the disease.

Picking and yield

September planted crop started to set flowers in the last week of December and fruit in the first week of January coinciding with light snowfall incidences in Tawang region. Early (May or July) planting favours more vegetative growth and late planting (November-December) take more than 100 days to set flowers and fruits due to the increased establishment phase. Three pickings can be taken from a timely planted crop with an average of 500 to 600 g fruits per plant under optimally managed protected conditions.

Special care

- The temperature inside greenhouses in the Tawang region may rise up to 40°C, leading to mid-day depression and high humidity levels. Therefore, proper ventilation should be ensured at noon, while vents and double doors should be closed before evening to prevent a sudden drop in temperature.
- Runner formation coincides with the fruiting stage and may adversely affect fruit production; hence, runners should be removed regularly.
- Once planted, strawberry remains productive for up to three years; however, yield declines after the third year. Therefore, to optimize the cost of protected structures, fresh runners should be planted every alternate year.
- Vermicompost and FYM can substitute up to 50% of the inorganic fertilizer requirement.

Hence, fertigation and foliar application during critical growth stages are essential for economical strawberry production in Tawang region.

Economics of strawberry cultivation under greenhouse in Tawang (9,300 feet AMSL)

Particulars	Polythene mulching		Organic mulching	
	I year	II year	I year	II year
Average yield (g/m²/picking)#	1,150.0		1,050.0	
No. of pickings/season!	03			
Final yield (g/m²)	3,450.0		3,150.0	
Gross return (INR/m²)	1,725.0		1,575.0	
Gross return (INR/50m²)	86,250.0		78,750.0	
Cost of cultivation (INR/50m²)	31,477.5	20,227.5*	31,102.5	19,852.5*
Net returns (INR)	54,772.5	66,022.5	40,647.5	51,857.5
B:C ratio	1.74	3.26	1.31	2.61

#Average yield of 3 picking/year pooled over 2 years; !Only 3 pickings were taken considering fruit quality; *Cost of strawberry runners at 25/plant is deducted during II year; Market price of strawberry fruit (INR/g): 0.50 considering initial introduction of the strawberry in local market of Tawang, transportation cost and break-even point of demand and supply.

Although the benefit–cost (B:C) ratio may be lower during the first year, it improves from the second year onwards as returns increase. The B:C ratio can be further enhanced through efficient utilization of the vertical space within the polyhouse.

Training and demonstration (9,300 ft.)

Training and demonstration (9,300 ft.)

Successful production of strawberry in strategic location (10,800 ft.)

SUMMARY

The farming sector in high-altitude regions faces several challenges, including limited availability of quality planting material, harsh climatic conditions, and traditional farming practices. Despite these constraints, there is significant potential to enhance productivity and farm income through the adoption of protected strawberry cultivation in Tawang.

Cultivation following the recommended package of practices under protected conditions is both economically viable and environmentally sustainable, as evidenced by favourable net returns under prevailing climatic conditions. Large-scale frontline demonstrations, along with regular hands-on training and financial support for establishing low-cost protected structures, are essential. A coordinated effort by researchers, extension workers, and policymakers will facilitate wider adoption of this technology, enabling farmers to utilize the lean, snow-bound winter period effectively and improve their livelihoods.

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Innovative farmer selections revitalizing jamun cultivation in Karnataka

Jamun (*Syzygium cumini* Skeels) is an underutilized fruit tree valued for its nutritional richness and potential in dryland horticulture. In Nagadasanahalli village, Bengaluru Rural district, farmer-scientist Dr N C Patel has selected and conserved three elite types, *Patel Jumbo, Patel Samruddhi,* and *Patel Akal,* which have been scientifically characterized by ICAR–IIHR. These selections differ in fruit size, sweetness, pulp colour, and maturity period, offering advantages for both fresh consumption and processing. *Patel Jumbo* produces large, sweet fruits; *Patel Samruddhi,* with purple pulp, is rich in anthocyanins and phenolics; while *Patel Akal* extends the harvesting season into July–August. Biochemical profiling highlights their high antioxidant activity, making them promising for nutraceutical applications. From a farmer's perspective, farmer-led selection of jamun represents a practical, low-input, and climate-resilient livelihood option capable of generating substantial economic returns in rainfed and dryland regions. The complementary strengths of *Patel Jumbo, Patel Samruddhi,* and *Patel Akal* enable farmers to cater simultaneously to fresh fruit, processing, and extended-season markets, thereby diversifying income sources and reducing market and climatic risks.

Keywords: Biochemical, Custodian farmer, Jamun, Morphological, *Patel Akal*, *Patel Jumbo*, *Patel Samruddhi*, Promising selection

JAMUN *(Syzygiu m cumini* Skeels), commonly known as black plum or Indian blackberry, is a multipurpose evergreen fruit tree belonging to the family Myrtaceae. Native to the Indian subcontinent, it is widely distributed across diverse agro-ecological regions, ranging from humid tropical zones to semi-arid and dryland ecosystems. The species is characterized by a tall, vigorous growth habit, a dense canopy, and a deep taproot system, which together confer tolerance to drought, high temperatures, and wind stress. Once established, jamun trees require minimal external inputs and can remain productive for several decades, making the crop inherently suitable for sustainable and low-input farming systems.

Jamun fruits are oblong to oval in shape and turn deep purple to nearly black at maturity, with a characteristic sweet–acidic flavour highly appreciated by consumers. Beyond fresh consumption, jamun has long been valued in traditional medicine systems such as Ayurveda, Unani, and folk medicine. The seeds are extensively used for managing diabetes due to their hypoglycaemic properties, while the pulp and bark are traditionally employed in the treatment of diarrhoea, ulcers, and inflammatory disorders.

Jamun fruits are recognized as a rich source of bioactive compounds with strong antioxidant potential. Studies have reported that jamun pulp contains anthocyanins ranging from ~50 to 250 mg C3GE/100 g fresh weight, total phenolics between ~120 and 350 mg GAE/100 g, and flavonoids in the range of ~40 to 120 mg CE/100 g, depending on genotype, maturity stage, and growing environment. In addition, the fruits provide appreciable amounts of vitamin C (10–30 mg/100 g), iron (0.5–1.6 mg/100 g), and calcium (15–25 mg/100 g), further enhancing their nutritional value.

The high antioxidant activity of jamun, largely attributed to anthocyanins and phenolic compounds, has attracted increasing interest from the functional food and nutraceutical industries. Extracts from jamun pulp, seed, and peel have been shown to exhibit strong free radical scavenging activity, along with potential anti-diabetic, anti-inflammatory, and cardioprotective effects.

Jamun is a highly cross-pollinated species and has been propagated predominantly through seeds for centuries. This reproductive behaviour has resulted in enormous genetic and phenotypic variability across India, manifested in differences in tree vigour, fruit size, pulp colour, sweetness, seed size, maturity period, and biochemical composition. Numerous local landraces exist; however, only a limited number of improved varieties are available for commercial cultivation. Consequently, consumer-preferred traits such as bold fruits, high pulp recovery, attractive pulp colour, extended harvesting period, and enhanced nutraceutical value are not adequately addressed by currently released varieties.

Selection from seedling populations remains the most effective and practical crop improvement strategy in jamun. Farmer-managed orchards, where long-term observation and selection occur under real field conditions, represent valuable yet underexplored reservoirs of elite genotypes.

In recent years, participatory selection programmes and systematic surveys have gained momentum to identify superior jamun genotypes directly from farmers' fields. One such initiative in the Bengaluru Rural district of Karnataka, undertaken under the aegis of ICAR–Indian Institute of Horticultural Research (IIHR), Bengaluru, documented substantial variability in fruit and tree traits and led to the identification of promising farmer-selected genotypes with superior pomological and biochemical attributes.

Within this framework, the contributions of farmer–scientist Dr N C Patel of Nagadasanahalli village are noteworthy. Through sustained on-farm observation and selection, he conserved and developed three elite jamun selections, *Patel Jumbo*, *Patel Samruddhi*, and *Patel Akal*–which combine high pulp recovery, desirable fruit quality, distinct pulp pigmentation, and adaptability to dryland conditions. Scientific validation of such farmer-led selections through morphological and biochemical characterization is essential for their recognition, wider dissemination, and integration into formal improvement programmes.

Keeping this in view, the present study was undertaken with the following objectives:

(i) To characterize the morphological and pomological traits of three farmer-selected jamun genotypes in comparison with a released check variety, and

(ii) (ii) To evaluate their biochemical composition, including sugars, anthocyanins, phenolics, flavonoids, and antioxidant activity.

Plant material

The study was conducted on three elite farmer-selected jamun (*Syzygium cumini* Skeels) genotypes–*Patel Jumbo*, *Patel Samruddhi*, and *Patel Akal*–conserved and maintained by custodian farmer–scientist Dr N C Patel at Nagadasanahalli village, Bengaluru Rural district, Karnataka. These selections were identified through long-term on-farm observation based on superior fruit size, pulp recovery, bearing regularity, pulp colour, and taste.

For comparative evaluation, the released variety '*Dhupdal'* was included as a check. All genotypes were evaluated under in situ field conditions, and fruits were collected and brought to the laboratory at ICAR–Indian Institute of Horticultural Research (IIHR), Bengaluru, for morphological and biochemical analyses.

The study site represents a typical dryland agro-ecosystem where jamun is traditionally cultivated with minimal external inputs, allowing a realistic assessment of genotype performance under farmer-managed conditions.

Ten mature fruits per genotype were randomly sampled for morphological and biochemical measurements.

Morphological and pomological characteristics

The three Patel selections–*Patel Jumbo*, *Patel Samruddhi*, and *Patel Akal*–exhibit clear advantages over the check variety '*Dhupdal'*, particularly in fruit size, pulp yield, and market suitability.

Patel Jumbo: It is the largest among the selections, with an average fruit weight of 12.65 g, comparable to '*Dhupdal'* (12.63 g). However, it has a distinct advantage in pulp recovery, recording a pulp percentage of 89.41%, much higher than that of '*Dhupdal'* (83.45%). Its fruits are elliptical with pinkish-white pulp, and their larger size, combined with a reduced seed proportion, makes them highly attractive for fresh consumption. Harvested in June, *Patel Jumbo* is suitable for premium markets where demand for larger, sweeter fruits is high.

Patel Samruddhi: Although smaller (7.1 g/fruit), it has a pulp percentage of 84.51%, again higher than that of '*Dhupdal'*. Its distinctive purple pulp gives it a unique identity in both fresh and processed markets. Farmers value this selection for its heavy bearing capacity, ensuring higher yields per tree compared to '*Dhupdal'*. Despite its smaller size, its unique pulp colour and higher productivity give it an edge in market differentiation.

Patel Akal: It occupies an intermediate position, with a fruit weight of 11.35 g and a pulp percentage of 89.96%, clearly surpassing '*Dhupdal'* in pulp recovery. Its greatest advantage is its late maturity, extending fruiting into July–August, well beyond '*Dhupdal's* early-season harvest in June. This seasonal extension allows growers to supply fresh jamun when other varieties are no longer available, thereby ensuring continued market presence and better returns.

Biochemical composition and nutritional potential

The biochemical profiling of the Patel selections underscores their superior nutritional value compared to the check variety '*Dhupdal'*.

Patel Jumbo: It offers a sweeter fruit profile, recording the highest total sugars (10.49 g) and reducing sugars (7.63 g) among the selections. Although its phenolic (140.9 mg GAE) and anthocyanin (94.85 mg C3GE) contents are lower than those of *Patel Samruddhi* and *Patel Akal*, it provides a balanced option for consumers who prioritize sweetness over astringency and nutraceutical richness.

Patel Samruddhi: It emerges as the most nutritionally rich cultivar, recording 136.41 mg anthocyanins, 246.38 mg phenolics, and 88.89 mg flavonoids, which translate into strong antioxidant capacity (FRAP 528.18 mg TE and DPPH 506.75 mg TE). These attributes clearly surpass the biochemical profile of '*Dhupdal'*, making it highly suitable for the functional food and nutraceutical sectors.

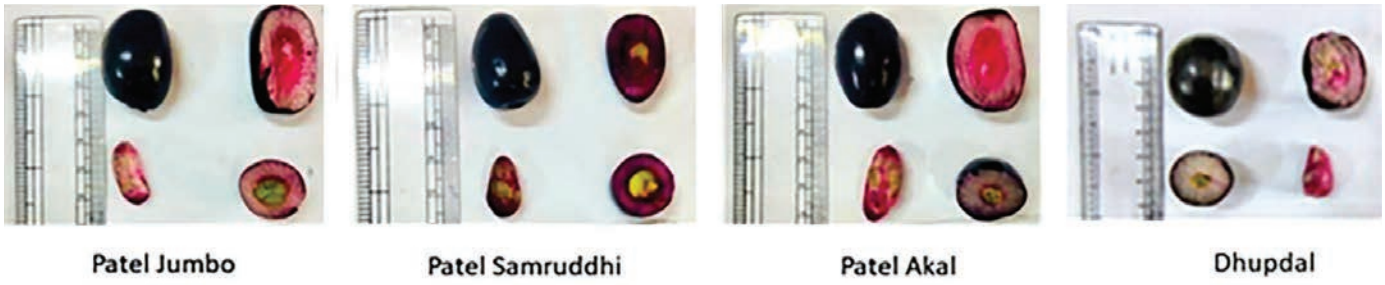
Patel Akal: It closely parallels *Patel Samruddhi* in biochemical strength, with 246.01 mg phenolics, 86.23 mg flavonoids, and antioxidant activity measured at FRAP 529.77 mg TE and DPPH 511.18 mg TE. Its values not only match but also exceed those of '*Dhupdal'* (FRAP 332.25 mg TE; DPPH 778.83 mg TE) in terms of balanced antioxidant potential.

In contrast, although '*Dhupdal'* demonstrates high radical scavenging capacity (DPPH 778.83 mg TE), its relatively lower phenolic (145 mg GAE) and flavonoid content (70.23 mg CE) limit its nutraceutical diversity.

Overall, *Patel Samruddhi* and *Patel Akal* stand out as

Morphological and biochemical traits of promising jamun farmer's selections compared to check variety *(Dhupdal)*

Trait	*Patel Jumbo*	*Patel Samruddhi*	*Patel Akal*	*Dhupdal*
Fruit length (cm)	2.99	2.08	3.18	3.21
Fruit width (cm)	2.13	1.13	2.36	2.04
Fruit weight (g)	12.65	7.1	11.35	12.63
Pulp weight (g)	11.31	6	10.21	10.54
Seed length (cm)	1.65	1.41	1.08	2.07
Seed width (cm)	0.81	0.72	0.84	0.96
Seed weight (g)	1.21	1.02	1.14	2.09
Fruit: seed	10.45	6.96	9.96	6.04
Pulp: seed	9.35	5.88	8.96	5.04
Pulp %	89.41	84.51	89.96	83.45
TSS (oBrix)	14.02	10.79	13.3	15.67
Titratable acidity (%)	0.59	0.57	0.59	1.21
Total sugars (g)	10.49	9.56	9.19	13.13
Reducing sugars (g)	7.63	7.05	6.74	6.47
Anthocyanin (mg C3GE)	94.85	136.41	129.2	79.74
Total phenolic content (mg GAE)	140.9	246.38	246.01	145
Total flavonoids content (mg CE)	67.85	88.89	86.23	70.23
FRAP (mg TE)	272.6	528.18	529.77	332.25
DPPH (mg TE)	355.35	506.75	511.18	778.83



Whole fruit, longitudinal and transverse section of fruit and whole seed of *Patel Jumbo, Patel Samruddhi and Patel Akal* in comparison with check *Dhupdal*

nutraceutical-rich cultivars, combining high anthocyanins, phenolics, and strong antioxidant activities. Their profiles make them especially valuable for functional foods, health supplements, and value-added processing, whereas *Patel Jumbo* retains an advantage in the fresh market due to its higher sugar content and consumer-friendly sweetness.

Relevance for farmers and consumers

The three farmer-led jamun selections–*Patel Jumbo*, *Patel Samruddhi*, and *Patel Akal*–collectively cater to diverse market segments, addressing both fresh consumption and processing needs. *Patel Jumbo* produces large, premium fruits suited for direct consumption; *Patel Samruddhi* offers smaller, vividly coloured fruits with high antioxidant value for processing industries; and *Patel Akal* extends the harvesting season, enabling farmers to generate income over a longer period.

Together, these selections provide a diversified portfolio that enhances both consumer choice and farmer profitability. Beyond their market appeal, jamun as a crop is highly sustainable. Once established, trees require minimal irrigation and chemical inputs and can tolerate dry spells effectively. This makes them ideally suited for cultivation in rainfed and dryland regions where farming is often risky.

ICAR-IIHR team with Dr N C Patel at his jamun orchard

Model orchards developed by Dr Patel demonstrate that jamun cultivation can generate substantial annual revenue while also supporting biodiversity and improving soil health.

With scientific support from ICAR–IIHR, these jamun selections hold significant promise for strengthening nutritional security, climate resilience, and farmer livelihoods in India.

SUMMARY

Patel Jumbo, *Patel Samruddhi*, and *Patel Akal* illustrate the potential of farmer-led selection in diversifying horticultural crops. Each selection combines unique pomological and biochemical attributes, making it valuable for distinct market niches. Their resilience under low-input conditions ensures sustainability, while their nutritional richness enhances consumer appeal.

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Microgreens: Emerging functional food crop

Microgreens are a new class of specialty food products that are gaining increasing popularity. They are delicate, young, cotyledonary leafy greens characterized by a wide range of colours, textures, and flavours. Microgreens are harvested at an early stage, when the cotyledonary leaves are fully developed but before the emergence of true leaves. Due to their suitability for small-scale and indoor production, microgreens are widely cultivated under controlled environment agriculture. This indoor farming approach is particularly important for meeting the growing food demands of urban populations. Microgreens are gaining recognition as a novel culinary component and are commonly used in salads or as edible garnishes in a variety of dishes. They are valued for their higher concentrations of bioactive compounds, including vitamins, minerals, and antioxidants, compared to mature greens, making them beneficial for human health. Research on microgreens is still in its early stages; however, their popularity has increased significantly over the past decade.

Keywords: Microgreens, Novel culinary element, Indoor farming, Bioactive elements

MICROGREENS, young edible seedlings harvested at the cotyledon stage, are gaining popularity as nutrient-dense functional foods. They contain higher concentrations of vitamins, minerals, and bioactive compounds than their mature counterparts, making them valuable for enhancing dietary nutrition. Their rapid growth, minimal resource requirements, and adaptability make them ideal for urban and remote farming, thereby supporting food security and sustainability. Cultivated in trays using soilless media, microgreens can be grown year-round in limited spaces, reducing dependence on conventional farming systems.

Urban farming initiatives increasingly incorporate microgreens to combat malnutrition, improve local food production, and reduce environmental impact. Their cultivation aligns with Sustainable Development Goals such as Zero Hunger and Responsible Consumption. By integrating microgreens into modern food systems, individuals and communities can promote healthier diets while reducing pressure on agricultural land.

This article explores the nutritional benefits, cultivation techniques, market potential, and role of microgreens in sustainable horticulture. It also highlights their health and environmental advantages, business opportunities, and future trends in microgreens production.

Unique characteristics of microgreens

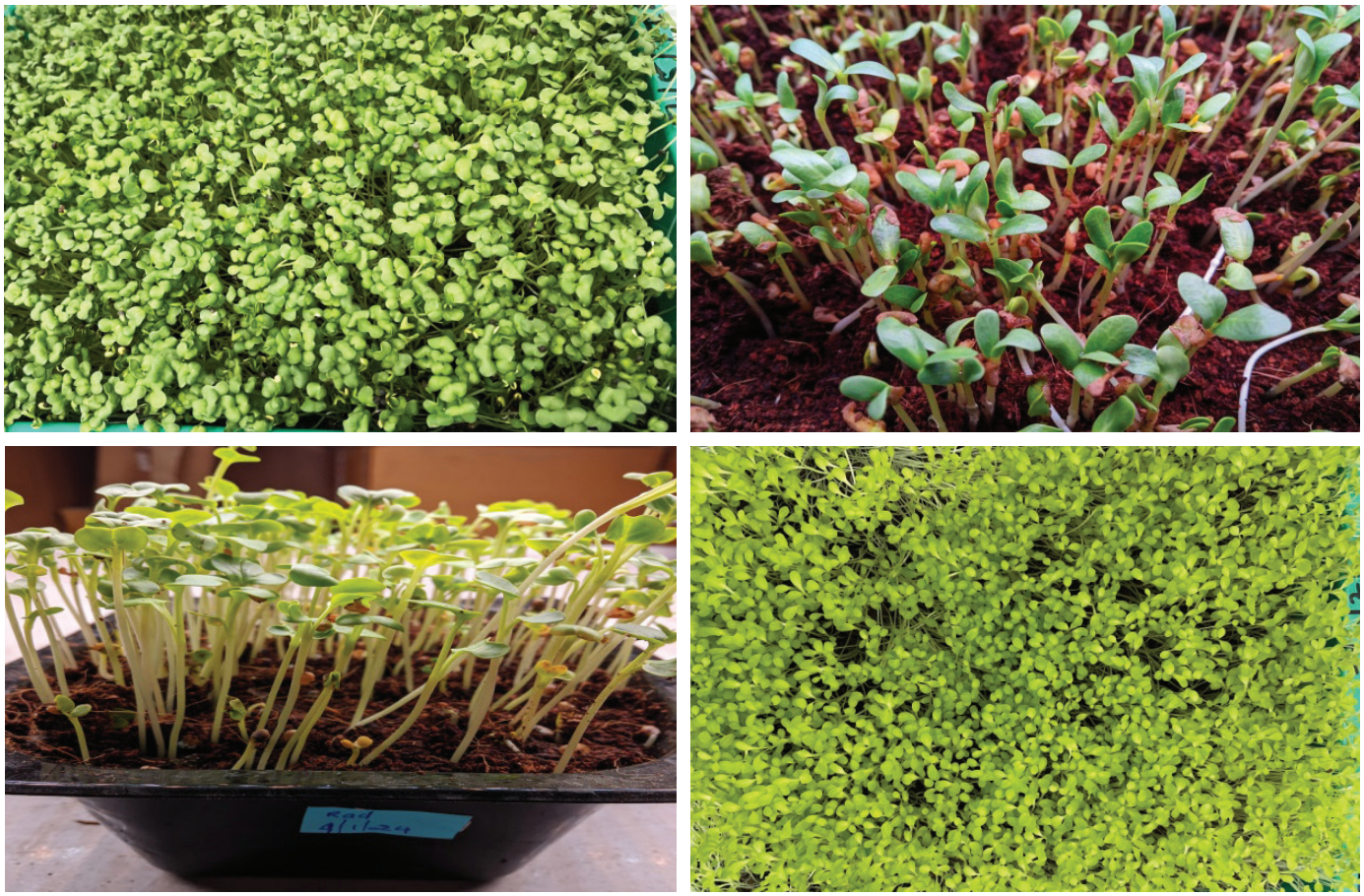
Tender, immature greens known as microgreens are larger than sprouts but smaller than baby greens or mature vegetables. They typically possess a primary stem bearing one pair of small true leaves and two fully developed, non-senescent cotyledonary leaves.

These tiny plants are rich in flavour, colour, and nutrients, often representing a more concentrated form of their mature counterparts. Studies conducted both *in vivo* and *in vitro* have demonstrated that microgreens possess antibacterial, anti-inflammatory, anticancer, and antihyperglycaemic properties. These attributes enhance their appeal as a novel functional food beneficial for human health.

Research indicates that, compared to mature plants, microgreens may contain 4–40 times higher concentrations of vitamins and minerals. Additionally, microgreens have a short growth cycle of 7–9 days, requiring fewer resources while offering higher nutrient density.

Microgreen selection crops grown from seeds are used for microgreen production. Selection of suitable crops is based on seedling colour, texture, flavour, and market demand. The selected crops should exhibit rapid germination, ease of growth, and high nutritional value.

Most potential microgreens are derived from vegetable crops belonging to the families Amaranthaceae, Chenopodiaceae, Brassicaceae, and Apiaceae. A few crops from the family Fabaceae are also suitable. Commonly grown microgreens include broccoli, radish, mustard, sunflower, pea shoots, basil, cilantro, and amaranth. These



Different microgreens grown in our lab.

Key differences between microgreens and mature greens

Microgreens	Mature Greens	Reference
Young vegetable greens harvested just after the first true leaves develop.	Fully developed plants harvested at their mature stage.	Xiao Z. *et al.* 2012
Harvested within 7–21 days after germination.	Require 6–12 weeks, more space, agro-inputs, and environmental resources to reach harvest.	Ebert, 2022, Treadwell *et al.* 2020
Rich in glucosinolates, polyphenols, antioxidants—effective against inflammation and chronic diseases.	Lower per gram in bioactives; benefits still present but less concentrated as compared to microgreens.	Marchioni *et al.* 2021
Lower in nitrates, oxalates, and phytates; grown chemical-free and usually consumed raw.	Higher nitrate and anti-nutrient content; may contain pesticide residues if not properly handled.	Pinto *et al.* 2015
Contain 4–40× more vitamins (C, E, K), antioxidants, and minerals per gram than mature greens.	Lower nutrient concentration per gram due to dilution during plant growth.	Xiao Z. *et al.* 2012

are widely cultivated due to their high nutrient content, short growth cycle, and appealing flavours.

However, not all edible vegetable seeds are suitable for microgreen cultivation. It is important to note that crops from the family Solanaceae (e.g., tomato, pepper, potato, and eggplant) should not be used as microgreens due to the presence of potential anti-nutritional compounds during the seedling stage. It highlights the importance of chemical and biological safety considerations in microgreen production. Ensuring safe cultivation practices is essential not only for maintaining nutritional quality but also for avoiding harmful compounds that may be present in certain plant species at early growth stages.

Growing conditions

Successful cultivation of microgreens depends on maintaining optimal environmental and management conditions that support rapid growth and high-quality produce. The key growing conditions are outlined below:

- ***Containers:*** Microgreen containers should be shallow (1.5–2.5 inches deep) with proper drainage holes to prevent waterlogging. Common materials include BPA-free plastic, biodegradable fibre trays, or stainless steel. Standard sizes are 10″ × 20″ or 10″ × 10″, with smooth surfaces for easy cleaning and efficient stacking.
- ***Growing Medium:*** Use a sterile, soilless medium such as peat moss, coconut coir, or a specialized microgreen growing medium.
- ***Seeds:*** Select high-quality, untreated seeds specifically labelled for microgreen production.
- ***Light:*** Provide adequate light, preferably natural sunlight or artificial grow lights. Microgreens typically

require 4–6 hours of direct light per day.

• ***Temperature:*** Maintain a moderate temperature range of 15–24°C for optimal growth.

• ***Watering:*** Mist seeds lightly after sowing and maintain consistent moisture without waterlogging. Bottom watering is recommended in tray systems to reduce the risk of mould development.

• ***Ventilation:*** Ensure proper air circulation to prevent disease and promote sturdy growth.

• ***Harvesting:*** Harvesting time varies depending on the crop and variety, generally ranging from 7 to 21 days after sowing. Fast-growing crops like radish may be ready within 6–10 days, whereas others like basil or beetroot may take up to 20 days. Harvesting is usually done when the first true leaves appear.

Comparative table showing the nutrient benefits of microgreens over its mature counterpart

Species	Effect	Reference
Lettuce (*Lactucasativa* L. var. capitata)	Compared to their fully developed counterpart, lettuce microgreens showed decreased NO_3^- level and greater concentrations of Ca, Mg, Fe, Mn, Zn, Se, and Mo. The concentration of NO_3^- in mature lettuce was four times greater than that in microgreens.	Pinto *et al.* 2015
Red Cabbage (*B. oleracea* var. capitata), Red and purple mustard (*B. juncea* L. czern.)	Compared to their fully developed counterparts, microgreens had a more complex polyphenol profile and a wider diversity of polyphenol components.	Sun *et al.* 2013
Fenugreek (*Trigonella foenum-graecum*)	Microgreens have higher quantities of ascorbic acid and α-tocopherol when compared to their mature state.	Ghoora *et al.* 2020
Cucumber (*Cucumis sativus*)	Greater amounts of ascorbic acid in comparison to their mature phases	Yadav *et al.* 2019
Mungbean *(Vigna radiata)*	Comparing mungbean microgreens to their mature counterparts, the former demonstrated stronger antioxidant activity (AA) and higher levels of total phenolic (TPC) and total flavonoid (TF).	Pajak *et al.* 2014
Arugula (*Eruca sativa*)	It has been found that arugula microgreens had lower nitrate content and higher levels of β-carotene, phylloquinone, and ascorbic acid than their fully developed counterparts.	Xiao *et al.* 2012
Cilantro (*Coriandrum sativum*)	The contents of lutein and zeaxanthin in cilantro microgreens are 11.2 times higher than in mature cilantro.	Xiao *et al.* 2012

Microgreen nutrient content

Microgreens, despite their small size, are highly nutritious. Their macronutrient composition–including carbohydrates, proteins, and lipids–varies among species. Carbohydrates are primarily present as soluble sugars and dietary fibre. Protein content typically ranges from 1.8 to 4.4 g/100 g of fresh weight, depending on the plant species and growing conditions.

Lipid content is generally low, similar to leafy vegetables, contributing to an energy value of approximately 70–100 kJ/100 g. The nutritional advantages of microgreens over their mature counterparts are summarized in the table.

Essential micronutrients further enhance the nutritional value of microgreens. Iron is the most abundant microelement, followed by zinc, manganese, and copper. Varietal differences result in diverse mineral compositions, with some species exhibiting higher potassium or calcium content. Microgreens are also rich in vitamins such as vitamin C, provitamin A, vitamin E, and vitamin K_1, all of which play vital roles in antioxidant activity and overall health. Notably, microgreens generally contain higher vitamin concentrations than their mature counterparts.

Pigments such as chlorophylls, anthocyanins, and carotenoids contribute not only to colour but also to health benefits. Chlorophylls are essential for photosynthesis and possess antioxidant properties, influenced by genetic and environmental factors such as light. Anthocyanins exhibit anti-inflammatory and antioxidant properties and vary widely among species, with broccoli microgreens showing particularly high levels. Carotenoid-rich microgreens, such as barley and wheat, often surpass common vegetables in carotenoid content and respond positively to varying light conditions.

Microgreens generally contain lower levels of antinutritional factors compared to their mature counterparts. For example, oxalates, which hinder calcium absorption, are present in higher amounts in mature spinach than in spinach microgreens. Similarly, phytates, which reduce mineral bioavailability, are more concentrated in mature grains and legumes than in their microgreen forms. Lectins, commonly found in legumes, are significantly reduced in microgreens, making them easier to digest. Overall, microgreens provide a nutrient-dense food option with fewer antinutritional concerns.

Edible safety

Ensuring chemical safety is crucial in microgreen production. The quality of water used for cultivation must be carefully monitored to prevent contamination with harmful substances. Hydrogen peroxide, commonly used for disinfection, is considered safe at recommended concentrations for various microgreens. However, concerns remain regarding nitrate accumulation and the presence of certain metals. Although microgreens generally contain low nitrate levels, some wild species may accumulate higher levels and trace amounts of harmful metals, especially when grown on natural fibre substrates. Therefore, alternative substrates with lower nitrate accumulation are being explored.

Since microgreens are often consumed raw, there is a risk of contamination by pathogens such as *Escherichia coli*, *Salmonella*, *Listeria*, and norovirus. Contamination may arise from seeds, growth media, or irrigation water.

Studies have shown that *E. coli* present on seeds can proliferate during growth, although at reduced levels in harvested microgreens. Hydroponic systems have been reported to show higher contamination levels compared to soil-based systems. Waterborne contamination can lead to significant microbial colonization, highlighting the importance of maintaining water quality. The survival and growth of *Salmonella* are influenced by factors such as inoculum level, seed storage conditions, and irrigation practices. Similarly, murine norovirus has been detected in kale and mustard microgreens, persisting initially and declining over time after harvest.

Potential beneficial effects

Microgreens exhibit several health-promoting properties. Red cabbage microgreens have shown potential in reducing body weight gain and lowering LDL cholesterol and triglyceride levels in experimental studies. These effects are attributed to bioactive compounds such as polyphenols and glucosinolates, although further research is needed to identify the exact mechanisms.

Fenugreek microgreens, rich in polyphenols and antioxidants, have demonstrated potential antidiabetic effects by inhibiting α-amylase activity and enhancing glucose uptake in cells.

Microgreens from Brassicaceae crops, such as broccoli, have shown anti-proliferative effects against human colon cancer cells. Compounds like glucosinolates and polyphenols are believed to contribute to these anticancer properties.

Certain microgreens with lower potassium content may be beneficial for individuals with impaired kidney function. Hydroponically grown microgreens of chicory, lettuce, and Brassicaceae species have shown reduced potassium levels, making them suitable for specialized diets.

Watercress microgreens are rich in glucosinolates, polyphenols, vitamins, and bioelements, and exhibit antioxidant, anti-inflammatory, cardioprotective, and antibacterial properties. It may also help in reducing oxidative stress and liver damage, although further studies are required.

Microgreens are also recognized for their strong antioxidant potential, which helps combat oxidative stress associated with ageing and chronic diseases such as cardiovascular disorders, diabetes, and cancer. Species from the cruciferous and umbelliferous families, such as broccoli and soybean, exhibit high antioxidant capacity due to their phenolic compounds and isothiocyanates. Enhanced lighting and biofortification techniques can further improve their antioxidant potential.

How to use microgreens

Microgreens can be incorporated into a wide variety of dishes, including salads, wraps, and sandwiches. They can also be used in juices and smoothies, with wheatgrass being a commonly juiced microgreen. Additionally, they serve as attractive garnishes for hot dishes such as pizza, pasta, soups, omelettes, and curries, enhancing flavour, texture, and visual appeal.

In rice preparations, microgreens can be lightly cooked or used as a fresh garnish to retain their texture. They can also be added to raita, either whole or finely chopped, to enhance freshness and presentation. Incorporating microgreens into dal can improve its nutritional quality, making it a wholesome dish suitable for all age groups. Fenugreek microgreens are also used in traditional recipes such as methi thepla, offering a milder flavour compared to mature fenugreek while retaining its characteristic aroma.

Future trends

Microgreens hold significant potential in functional food development by enhancing the nutritional and bioactive profile of traditional foods. For example, incorporating legume-based microgreens into staple foods such as bread can improve their nutritional value without compromising quality.

They are also being explored as a viable food source for space missions due to their ease of cultivation, minimal resource requirements, and high nutritional value.

Utilization of surplus or unsold microgreens is another emerging area, with research focusing on developing value-added products to reduce waste. Additionally, microgreens show promise in bioenergy production and phytoremediation, including the removal of heavy metals from soil and water.

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Seema Thakur[1]*, Ishant Dutta[3], D K Mehta[2] and Rajesh Thakur[1]

Novel year-round production technology of leaf lettuce through natural farming in Solan district of Himachal Pradesh

Solan is endowed with diverse agro-climatic conditions suitable for lettuce cultivation. Year-round production technology can be adopted to produce lettuce during the off-season, thereby generating higher returns for farmers. Lettuce is a cool-season, low nutrient-demanding crop and is inherently well suited to natural farming systems. Natural farming enhances crop productivity by reducing input costs and increasing farmers' net income, thereby promoting climate-resilient agriculture. Year-round production of leaf lettuce in hilly regions can be achieved by transplanting during February, April, August, and October. These planting windows ensure optimal growth, development, and yield throughout the year. Among the treatments evaluated, the combination of Ghanjeevamrit @ 1 t/ha + Jeevamrit drenching @ 15% + Saptadhanyankur @ 3% + sour buttermilk @ 3% significantly improved yield and quality by enhancing nutrient availability, microbial activity, and plant uptake. This treatment also resulted in the highest net returns and benefit–cost ratio, making it the most profitable option for year-round lettuce production.

Keywords: Ghanjeevamrit, *Jeevamrit,* Lettuce, Natural Farming

LETTUCE is a cool-season crop, and the favourable climate of Solan district makes it suitable for year-round cultivation. A major constraint in lettuce production is the sharp decline in prices due to market glut, which often results in economic losses for growers. Therefore, the development of year-round production technology is essential to ensure stable income for farmers.

Lettuce is a low nutrient-demanding crop and is inherently well suited to natural farming systems. Unlike many vegetable crops that require high levels of chemical fertilizers, lettuce performs well in soils enriched with organic matter and beneficial microorganisms. This makes natural farming an ideal and sustainable approach for lettuce cultivation, especially since lettuce is consumed raw and is increasingly popular due to changing dietary preferences.

Natural farming offers a "triple-win" opportunity by enhancing crop productivity, reducing input costs, and increasing farmers' net income, thereby promoting climate-resilient agriculture. It emphasizes soil biology over soil chemistry by encouraging practices such as multi-cropping, continuous soil cover, and the use of organic formulations prepared from cow dung and urine to stimulate microbial activity. These practices ultimately contribute to higher net returns and a better benefit–cost ratio, making natural farming a profitable option for year-round lettuce production.

Year round production technology under natural farming

The development of year-round production technology under natural farming involved four years of experimentation (2021–2024) at the experimental farm of KVK, Solan, located at Kandaghat, Himachal Pradesh. Observations were recorded for key plant and soil parameters. Different planting times and nutrient management strategies were evaluated to identify the most effective combinations for maximizing lettuce yield and quality while maintaining soil health. The major findings are summarized below:

- Transplanting of the leaf lettuce variety '*Solan Kriti*' during February, April, August, and October was found to be most suitable for ensuring optimal growth, development, and yield in a year-round production cycle. These months provide favourable climatic conditions that meet the crop's physiological requirements, highlighting the region's potential for continuous lettuce cultivation.
- The application of Ghanjeevamrit @ 1 t/ha + Jeevamrit drenching @ 15% + Saptadhanyankur @ 3% + sour buttermilk @ 3% significantly improved lettuce yield and quality, while also enhancing profitability due to reduced cost of cultivation. Natural farming practices were also found to support beneficial soil microorganisms and insects. Laboratory analyses

further confirmed improvements in soil health and crop quality.

- Benefit–cost analysis across different planting months demonstrated the economic viability of year-round lettuce production under natural farming systems.

Yield and productivity

The developed production technology resulted in significant improvements in yield and productivity. Trials conducted under natural farming systems showed better growth and higher yields compared to conventional chemical farming systems. Optimized agronomic practices, suitable lettuce varieties, and location-specific management strategies enabled consistent production, improved land-use efficiency, and enhanced overall productivity throughout the year.

The combined application of Ghanjeevamrit @ 1 t/ha + Jeevamrit drenching @ 15% + Saptadhanyankur @ 3% + sour buttermilk @ 3% showed superior performance for several parameters, including days to maturity, number of leaves per plant, leaf length, leaf breadth, plant height, fresh leaf weight, yield per plot, and micronutrient content (iron and calcium).

Pooled data over three years (2022–2024) for the variety '*Solan Kriti*' revealed that fresh leaf weight recorded during February, April, August, and October was 14.57 g, 13.31 g, 13.82 g, and 15.73 g, respectively, under M_3 level (Ghanjeevamrit @ 1 t/ha). Among liquid manures, L_4 (Jeevamrit drenching @ 15%) resulted in maximum fresh leaf weight (14.27 g, 12.92 g, 13.22 g, and 15.37 g, respectively).

The interaction effect (M_3L_4: Ghanjeevamrit @ 1 t/ha + Jeevamrit @ 15% + Saptadhanyankur @ 3% + sour buttermilk @ 3%) recorded the highest fresh leaf weight (14.34 g and 16.27 g during August and October, respectively), whereas the lowest values (9.22 g and 10.35 g) were observed under the control (M_1L_1) treatment (Table 1).

This improvement may be attributed to the synergistic effect of organic manures and liquid formulations, which enhance photosynthesis, energy storage, cell division, and cell enlargement, ultimately leading to increased fresh leaf weight.

Soil health parameters

Application of Ghanjeevamrit and natural liquid formulations (Ghanjeevamrit @ 1 t/ha + Jeevamrit drenching @ 15% + Saptadhanyankur @ 3% + sour buttermilk @ 3%) had a significant impact on soil microbial populations, including viable fungal, bacterial, and actinomycetes counts, which in turn enhanced nutrient uptake by plants.

The application of Ghanjeevamrit @ 1 t/ha + Jeevamrit drenching @ 15% recorded maximum N, P, and K uptake during different transplanting months, i.e., February (48.22, 16.79, 42.14 kg/ha), April (40.46, 14.94, 33.88 kg/ha), August (44.89, 15.71, 38.08 kg/ha), and October (52.32, 18.88, 46.12 kg/ha).

Cost effectiveness including B: C ratio

This technology is cost-effective due to optimized resource use, lower cost of cultivation, and higher productivity. By standardizing agronomic practices and improving yield consistency, it reduces input costs and enhances profitability. Its ability to ensure year-round production makes it a sustainable, high-return farming model suitable for both small and large-scale farmers.

Application of Ghanjeevamrit and natural liquid formulations significantly improved lettuce yield and overall crop equivalent yield, thereby enhancing the benefit–cost ratio. Among different transplanting months, the maximum B:C ratio was recorded in February (4.41) under treatment T_9 (Ghanjeevamrit @ 1 t/ha + Jeevamrit drenching @ 15%), followed by August (4.26) under T_{11} (Ghanjeevamrit @ 1 t/ha + Jeevamrit drenching @ 10%), October (3.73) under T_{12}, and April (3.69) under T_{12}.

SUMMARY

- Year-round, off-season production of lettuce can serve as a key strategy for crop diversification in Solan district, where farmers predominantly cultivate solanaceous crops (e.g., tomato and bell pepper), leading to a higher incidence of soil-borne diseases such as bacterial wilt. Diversification through the

Year Round Schedule developed for the cultivation of leaf lettuce

Sowing time	Transplanting Month	Harvesting Time	Key Observations
Late December to early January (under controlled conditions due to harsh winter)	February	March end to Ist week of April	Higher yield and good economic returns due to favorable growth conditions
Late February to March	April	May end (timely harvesting is critical as bolting may occur due to higher temperature)	Lower yield, but higher market prices as off season produce, ensuring profitability. Proper and timely irrigation is important to maintain optimum soil temperature.
Late June to July	August	September end to Ist week of October	Lower yield, but higher market prices as off season produce, ensuring profitability. Care should be taken for proper drainage due to rainy season.
Late August to September	October	December	Higher yield and good economic returns due to favorable growth conditions.

Leaf lettuce production in Solan district

introduction of exotic vegetables like lettuce is therefore essential in the mid-hill regions.

- Lettuce can be successfully transplanted in February, April, August, and October under year-round production systems, as these periods provide favourable agro-climatic conditions for optimal growth and development.
- Among natural farming practices, the treatment combination of Ghanjeevamrit @ 1 t/ha + Jeevamrit drenching @ 15% + Saptadhanyankur @ 3% + sour buttermilk @ 3% significantly improved yield and quality by enhancing nutrient availability, microbial activity, and plant uptake. Growth, yield, quality, and soil parameters were all superior under this treatment.
- The same treatment also resulted in the highest net returns and benefit–cost ratio, making it the most profitable option for year-round lettuce production. Among transplanting months, the highest benefit–cost ratio was recorded in February, followed by August, October, and April. While February and October plantings achieved higher yields and returns, April and August crops, despite relatively lower yields, fetched premium prices as off-season produce, highlighting the economic advantage of year-round production.

Overall, year-round lettuce production under natural farming systems offers a promising approach for enhancing farmer income and sustainability in the mid-hill regions of Himachal Pradesh.

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Tackling the musk melon fruit fly: A threat to favourite summer fruit

The melon fruit fly, *Zeugodacus cucurbitae*, is a major pest of muskmelon and other cucurbit crops, causing severe yield losses ranging from 30% to 100%. Infestation begins with egg laying in tender plant parts, followed by larval feeding that leads to fruit rotting and reduced market value. Its rapid life cycle, wide host range, and increasing resistance to chemical insecticides complicate management. Sustainable control requires an integrated pest management (IPM) approach combining cultural, mechanical, and biotechnical strategies. Key practices include field sanitation, deep ploughing, fruit bagging, and timely crop management. Techniques such as Male Annihilation Technique (MAT) using Arka Cucurlure and Bait Application Technique (BAT), along with botanical insecticides, offer eco-friendly and effective solutions for long-term suppression.

Keywords: Arka Cucurlure, Bait Application Technique, Integrated Pest Management, Melon fruit fly, Muskmelon, *Zeugodacus cucurbitae*

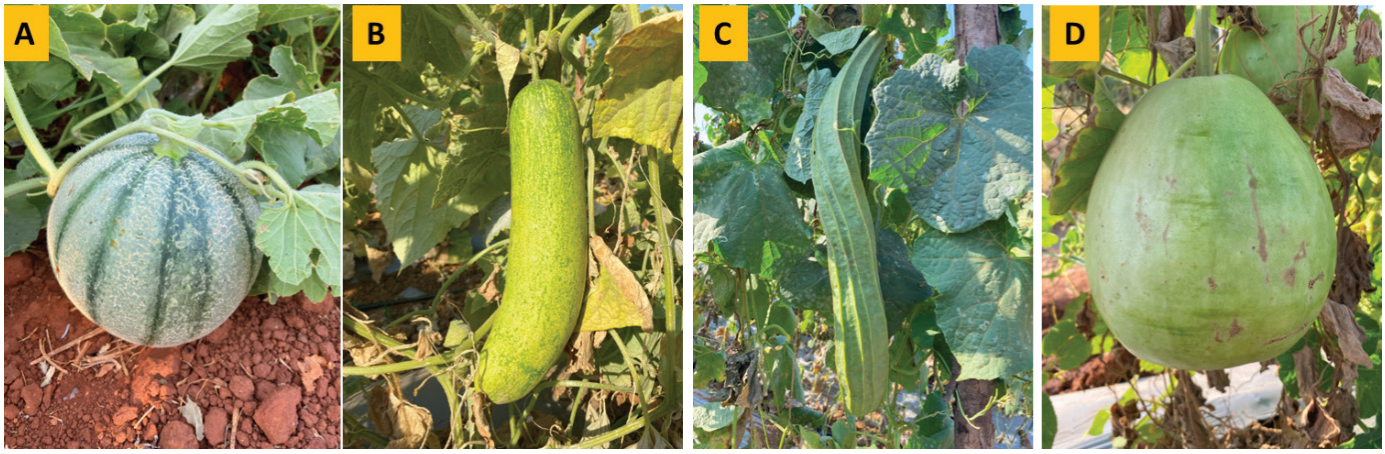
THE melon fly, *Zeugodacus cucurbitae* (Coquillett) (Tephritidae: Diptera), is a serious pest of muskmelon and other cucurbitaceous crops, causing significant economic losses to farmers. Female flies deposit their eggs in the delicate vines and fruit rinds. The larvae that hatch from these eggs feed voraciously, resulting in the rotting of fruits and vines.

The impact of melon fly infestation extends beyond crop losses, as it often necessitates the use of chemical insecticides, thereby increasing production costs and posing risks to human health and the environment. Due to its wide host range, rapid reproductive cycle, and ability to develop resistance to insecticides, the melon fly remains a persistent challenge for farmers. Effective management strategies, particularly integrated pest management (IPM) approaches, are essential to minimise crop losses and mitigate the impact of this pest.

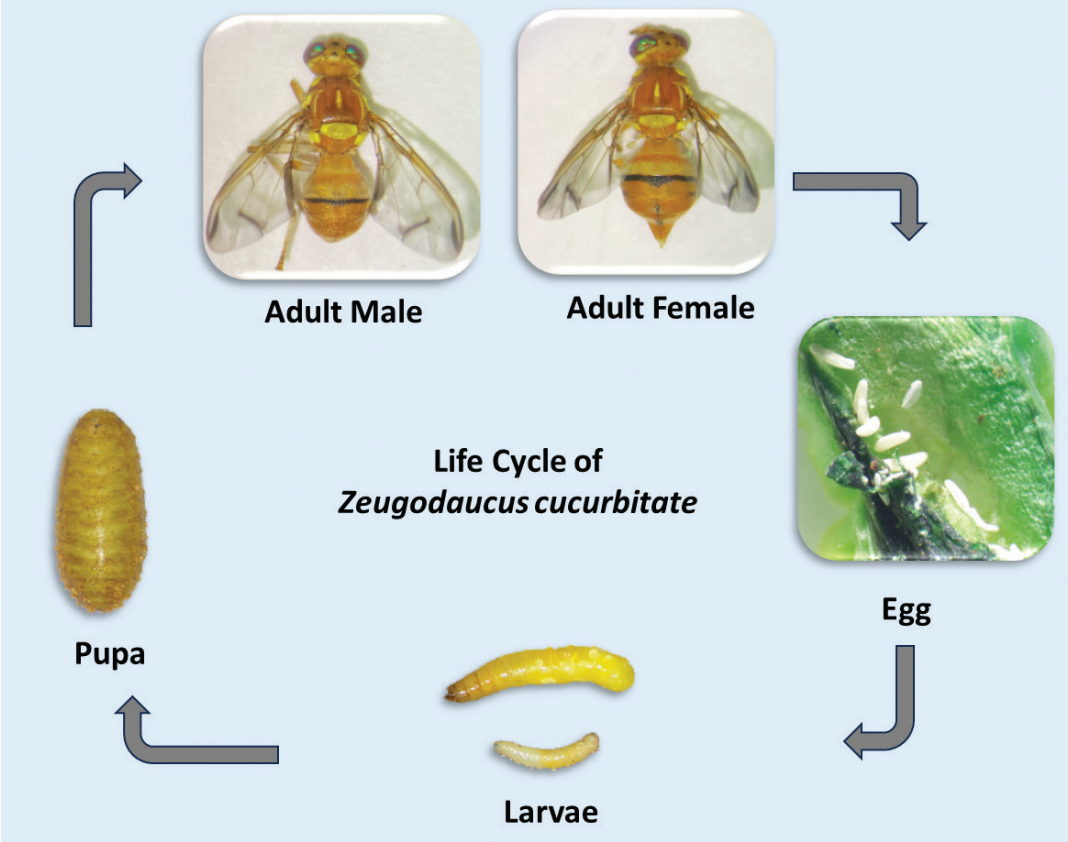
Host plants: Melon flies infest at least 125 host plants. Economically important hosts include muskmelon, watermelon, cucumber, pumpkin, squashes, and gourds (ridge gourd, bitter gourd, bottle gourd), among others.

Biology of melon fruit fly

Life cycle: The melon fly undergoes four distinct stages in its life cycle: egg, larva, pupa, and adult. The development from egg to adult typically takes 15–30 days. A single female can lay up to 1,000 eggs. Eggs are usually laid in young fruits at a depth of 2–4 mm, although they may also be deposited in the succulent stems of host plants. Using its sharp ovipositor, the female creates



Economically important host plants of melon fruit fly.
A) Musk melon, B) Cucumber, C) Ridge gourd, D) Bottle gourd



Life cycle of melon fruit fly (*Z. cucurbtae*)

cavities in which the eggs are placed. Pupation generally occurs in the soil. The melon fly completes about 8–10 generations per year.

Egg

The egg is elliptical, about 2 mm long, and creamy white in colour. It is nearly flat on the ventral surface and more convex dorsally. Eggs often show a slight longitudinal curvature. The incubation period ranges from 4.0 to 4.2 days.

Larva

The larva is elongated and cylindrical, with a ventrally curved anterior end. Fully grown larvae (last instar) measure 7.5–11.8 mm in length. The larval stage lasts 3–21 days. Mature larvae create one or two exit holes in the fruit before dropping to the soil to pupate. They typically pupate at depths ranging from 0.5 to 15 cm in the soil.

Pupa

The puparium is about 5–6 mm long and varies in colour from dull red or brownish-yellow to dull white. The pupal period usually lasts 6–9 days during the rainy season and up to 15 days in winter.

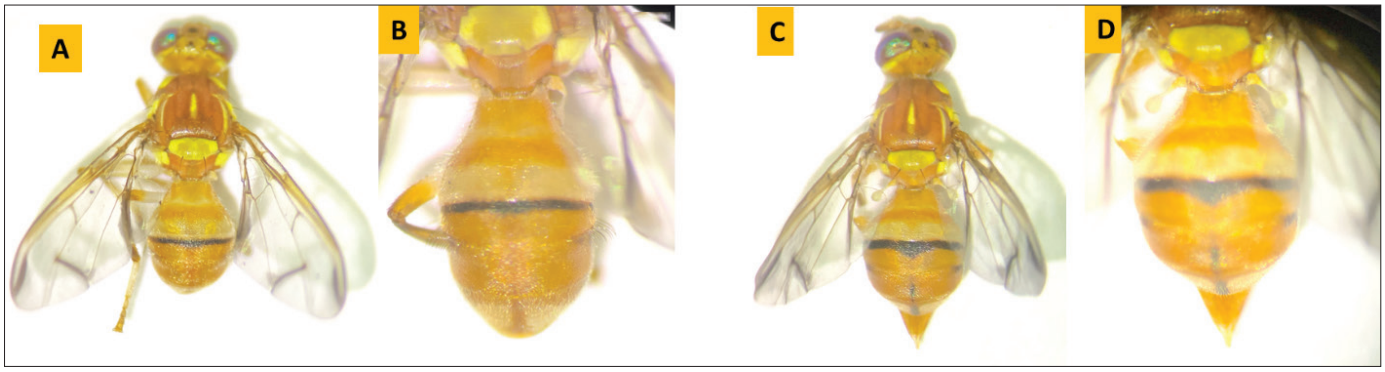
Adult fly

Adult melon flies measure 6–8 mm in length. They are distinguished by their characteristic wing pattern, a reddish-yellow thorax with light yellow markings, and a yellowish head. Females are larger and possess a pointed ovipositor for egg-laying, whereas males are smaller with a more curved, blunt abdomen. Females generally live longer (21.7–32.7 days) than males (15.0–28.5 days). The average adult lifespan ranges from 27.5 to 30.7 days.

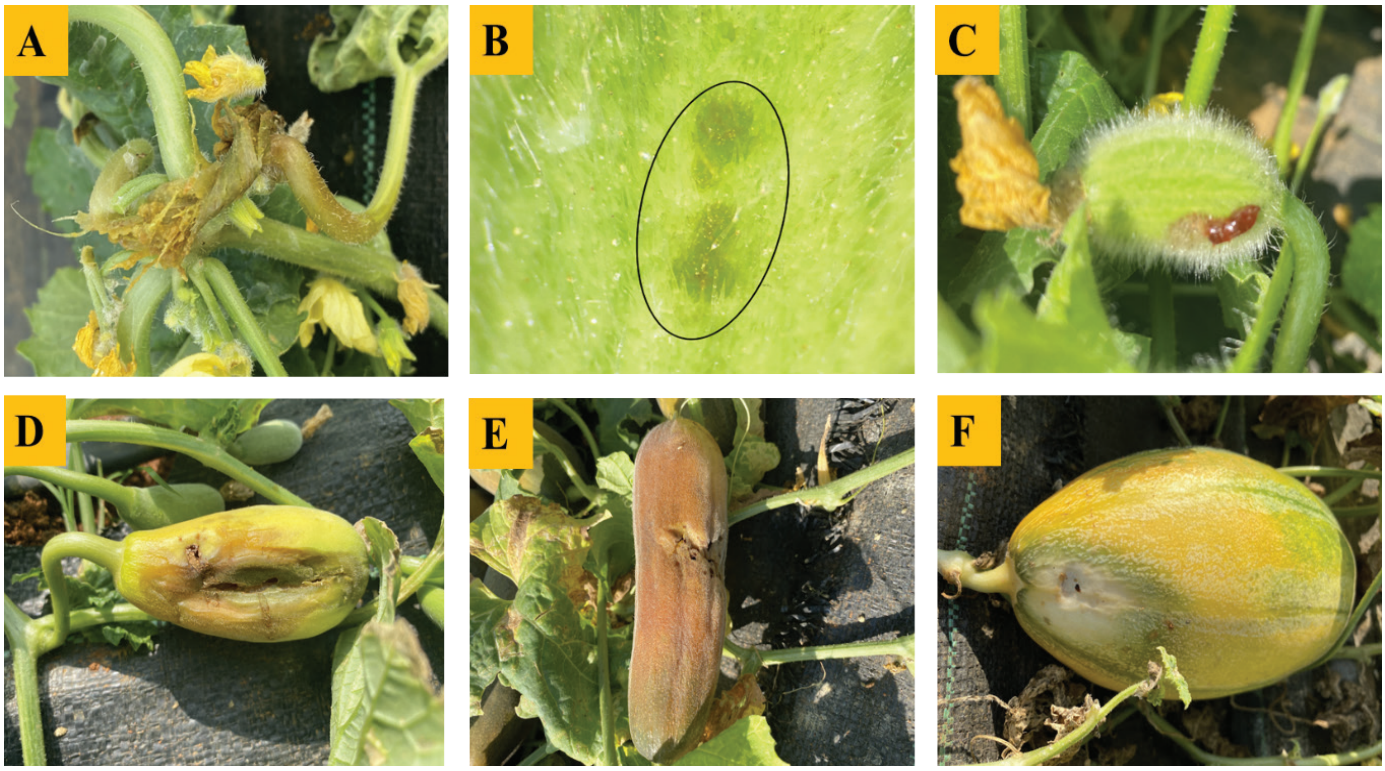
Nature and extent of damage

The melon fly is one of the most destructive pests of muskmelon crops. It attacks the crop at various stages, with maggots feeding on the delicate vines and fruits. Females generally prefer to lay their eggs in soft, tender fruit tissues by piercing them with their ovipositor. The punctures exude a watery fluid that later dries into a brown, resinous deposit and forms slight depressions as the fluid seeps out, thereby reducing the market value of the fruits.

After hatching, the maggots bore into the pulp tissue and feed, creating galleries within the fruit. As a result, the fruits rot or become deformed. The extent of losses varies from 30 to 100%, depending on the cucurbit species and the season.



A) Adult Male; B) Abdomen of adult male; C) Adult female; D) Abdomen of adult female with ovipositor



Nature of melon fruit fly damage. A) Stem damage; B) Oviposition punctures; C-F) Fruit damage.

Strategies for integrated management of melon fruit fly

- Adopting proper field sanitation practices can significantly reduce melon fly populations. Infested fruits should be collected, destroyed, and buried deep in the soil to prevent further multiplication.
- Deep ploughing after harvest helps expose and kill pupae present in the soil.
- Timely planting, proper irrigation, and balanced soil fertility enhance plant vigour and reduce susceptibility to melon fly infestation.
- Area-wide management through collective efforts by farmers is effective for long-term suppression of melon fly populations.
- The fruit initiation stage is the most critical period for melon fly attack. Therefore, management practices should be implemented before this stage in muskmelon. Bagging of fruits after fruit set helps prevent egg-laying by female flies.
- ***Male Annihilation Technique (MAT):*** Adult male flies can be monitored and controlled using cue-lure traps, which are highly effective in attracting males. A recently developed formulation, *Arka Cucurlure* (ICAR–Indian Institute of Horticultural Research, Bengaluru), combining plant volatiles with cue-lure, has shown higher efficacy (about 50% more attraction) compared to conventional cue-lure traps.
- ***Bait Application Technique (BAT):*** Spot application of bait–a liquid mixture of 100 g jaggery + 20 g yeast + deltamethrin @ 2 mL per litre of water–can be applied on leaves using a brush to attract and kill both male and female melon flies.
- Need-based spraying of azadirachtin 0.03% @ 3 mL/L can also be used as part of an integrated management approach.

Arka Cucurlure trap

SUMMARY

The melon fruit fly has emerged as one of the most destructive pests of muskmelon and other cucurbitaceous crops in India, posing a major challenge to growers, particularly during the summer season. Its infestation not only leads to substantial yield losses but also increases reliance on chemical insecticides, thereby affecting farm economics and environmental health.

To effectively manage this pest, an integrated pest management (IPM) approach incorporating cultural, mechanical, and eco-friendly biotechnical strategies is essential. Area-wide management, timely monitoring, and active community participation are critical for reducing pest populations and ensuring sustainable muskmelon production. The adoption of innovations such as the *Arka Cucurlure* trap (MAT) and the BAT method can further enhance the effectiveness of IPM practices.

A coordinated and informed approach is therefore vital to safeguard this important summer crop and support the livelihoods of farmers.

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Santosh C Kedar[1]*, Omprakash Navik[2] and K M Kumaranag[3]

Emerging insect pests problems in basil (*Ocimum basilicum*) and their management

Basil (*Ocimum basilicum* L.) also known as *'Tulsi'*, is an important medicinal and aromatic plant, widely cultivated in India for its essential oil, used in pharmaceuticals, cosmetics, food, and traditional medicine. However, increased cultivation has led to rising insect pest problems, causing significant yield and quality losses. Basil is attacked by leaf-eating insect pests, such as leaf folder, perilla leaf moth, *Helicoverpa armigera,* tobacco caterpillar, and Bihar hairy caterpillar, as well as sap-sucking pests like lace bugs, aphids and thrips. These pests damage foliage, shoots, buds, and flowers, resulting in reduced photosynthesis, stunted growth, and lower essential oil yield. Climate variability and intensive monocropping have further aggravated pest incidences. Timely diagnosis of pest problems, regular monitoring, and preventive measures are essential for effective management. Integrated Pest Management (IPM) strategies involving neem based formulations, biological control, mechanical removal, pheromone and light traps, and conservation of natural enemies ensure sustainable and residue free basil production. This article provides practical guidelines for farmers and extension personnel to manage key insect pests and safeguard basil cultivation.

Keywords: Basil, Tulsi, *Ocimum basilicum*, emerging insect pest, management, IPM

OCIMUM BASILICUM L., commonly known as Basil or Tulsi, is a highly valued medicinal and aromatic plant (MAP) belonging to the family Lamiaceae. It is widely cultivated in India for its essential oil, which is rich in compounds such as linalool, methyl chavicol, eugenol, and cineole. These bioactive constituents make basil an important raw material for pharmaceutical, cosmetic, perfumery, and food industries, while also giving it a prominent place in traditional systems of medicine like Ayurveda, Siddha, and Unani. With the growing demand for natural products, the cultivation of *O. basilicum* has expanded rapidly across different agro-climatic regions of India. However, this increased cultivation has led to the emergence of several insect pest problems that significantly affect crop health, yield, and oil quality. Among the major pests reported are leaf folders, leaf eating caterpillars, lace bugs, aphids, and thrips which cause extensive damage to foliage and flowers, thereby reducing the plant's photosynthetic efficiency and overall biomass. In recent years, the challenges have been further compounded by climate variability and intensive monocropping, which have altered pest dynamics and facilitated the incidence of secondary pests. Insecticide misuse to control these pests not only raises production costs but also leads to pesticide residues in the essential oil, threatening its export potential. Hence, there is a growing emphasis on adopting integrated pest management (IPM) strategies, combining cultural, biological, mechanical, and need-based chemical control measures to ensure sustainable and residue-free production. This article highlights the key insect pests of *O. basilicum* in India, their nature of damage, and practical management strategies to help farmers and stakeholders safeguard this economically important aromatic crop.

Ocimum leaf folder, *Orphanostigma abruptalis*

Ocimum leaf folder larva Infested shoot

Nature of damage: It is a major pest of *O. basilicum.* The larvae fold tender leaves and bind them with silken threads, feeding inside the folds and causing skeletonization of leaf tissues. Severe infestations lead to defoliation, reduced photosynthesis, stunted growth, and

loss of biomass and essential oil yield, especially during warm and humid conditions from July to October.

Management: The Ocimum leaf folder can be effectively managed by spraying 5% NSKE or 2 ml neem oil per litre, or 2 ml pongamia oil per litre of water. Regular monitoring and early application during the July-August infestation period help reduce damage and protect crop yield.

Perilla leaf moth, *Pyrausta panopealis*

Pyrausta panopealis larva

Nature of damage: *Pyrausta panopealis*, commonly known as the Perilla leaf moth, is an important pest of basil. The larvae feed on young shoots, tender stems, and flower buds, causing shoot wilting, bud drop, and poor flowering. Heavy infestations lead to reduced plant growth, decreased leaf area, and significant loss in essential oil yield. The damage is most noticeable during the active growing season, especially from July to October, when the crop is tender and lush.

Perilla leaf moth infested plant

Management: The pest can be effectively managed by spraying Azadirachtin 1500 ppm (1%). For enhanced control, Spinosad 45 SC (150 ml/ha) can be applied. The first spray is recommended 15 days after transplanting, followed by a second spray 45 days after transplanting.

Helicoverpa armigera larva

Helicoverpa armigera

Nature of damage: *Helicoverpa armigera* is an important pest of basil, primarily acting as a defoliator. The larvae feed on leaves and flowers, causing skeletonization of foliage and damage to flower buds. Heavy infestations seen from August to October lead to reduced plant growth and poor flowering.

Management: Infestations can be controlled by spraying 5% NSKE or neem oil 2%, or Pongamia oil 2%. Installation of pheromone traps for monitoring and release of egg parasitoid *Trichogramma chilonis* is effective in controlling pest at early stage of infestations. Early intervention during August-October helps to protect the crop.

Tobacco caterpillar, Spodoptera litura

Nature of damage: *Spodoptera litura* larvae cause severe damage to basil by scraping leaf surfaces in early stages, while the later stages defoliate the leaves completely. In heavy infestations, they cut tender shoots and reduce biomass and essential oil yield.

Tobacco caterpillar

Management: For effective organic management, regularly monitor the crop and collect and destroy egg masses and early stage larvae. Use pheromone traps (12-15/ha) to monitor and mass-trap adult moths. Spray neem-based formulations (Neem oil 3% or Azadirachtin 1500 ppm @ 2-3 ml/L) to deter feeding and oviposition.

Bihar hairy caterpillar, Spilarctia obliqua

Bihar hairy caterpillars

Infested plant

Nature of damage: This pest occasionally attacks basil. The larvae feed voraciously on leaves, often consuming the entire lamina and leaving only midribs. Severe infestations lead to defoliation, reduced plant growth, and lower essential oil yield, particularly during July to October when the crop is tender.

***Management*:** During early stages, collect and destroy gregarious larvae and egg masses to prevent spread. Install

light traps to catch adult moths and spray neem-based formulations (neem oil 3% or Azadirachtin 1,500 ppm@ 2-3 ml/L).

Lacebug, *Cochlochila bulita*

Adult and nymphs of lacebug Infested plant

Nature of damage: Lace bugs are sap-sucking pests of basil. Both nymphs and adults feed on the underside of leaves, causing yellowing, stippling, and a speckled appearance. Infestation initiates in June and severe infestations can lead to leaf curling, reduced photosynthesis, and stunted plant growth, affecting overall biomass and essential oil yield.

Management: Lace bug infestations can be managed by using Azadirachtin 1.5% or neem oil 2%, or NSKE 5%. Regular monitoring, removal of infested leaves, and encouraging natural predators like geocorid bugs, ladybird beetles, and spiders help reduce populations in organic basil cultivation.

Aphids, *Aphis gossypii*

Aphids Infested plants

Nature of damage: Aphids are sap-sucking pests that feed on young shoots, leaves, and tender stems of basil. Nymphs and adults feeding causes leaf curling, yellowing, and stunted growth, and heavy infestations can lead to reduced leaf area and lower essential oil yield. Additionally, aphids excrete honeydew, which promotes sooty mould growth on leaves, further affecting plant health.

Management: Non-chemical management of aphids in basil includes regularly removal of infested shoots, conservation of natural enemies like ladybird beetles and lacewings, and spraying 5% neem seed kernel extract (NSKE) or 2% neem oil.

Thrips, *Scirtothrips* sp., *Thrips* sp.

Thrips infested plant

Nature of damage: Thrips infest young leaves, buds, and flowers of basil, sucking cell sap and causing silvery streaks, curling, and distortion of leaves. Heavy infestation leads to reduced photosynthesis, poor flowering, and lower essential oil yield, particularly during warm and dry conditions.

Management: For managing thrips in basil, use blue sticky traps for monitoring and mass trapping, apply neem oil (Azadirachtin 0.03%) as a botanical spray, and conserve lacewings, ladybird beetles, or predatory mites for natural control.

Spider Lady bird beetle Geocorid bug

SUMMARY

Effective management of insect pests in basil is essential to maintain plant health, optimize biomass production, and ensure high quality essential oil yield. Timely diagnosis, regular monitoring, and preventive measures are vital to minimize crop losses. Adopting eco-friendly Integrated Pest Management (IPM) strategies provides a sustainable approach for residue free basil production, benefiting both farmers and the aromatic industry.

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Rohini Sharma, Subhash Chander Verma, Vishav Gaurav Singh Chandel and Sushmita

Environmental evaluation: A unique Decomposer in the Syrphid Family, *Syritta pipiens* L. (Diptera: Syrphidae)

***Syritta pipiens,* a widely distributed syrphid species, holds a distinctive ecological position due to its saprophagous larval habits. While most syrphid larvae are predators or plant feeders, the immature stages of *S. pipiens* utilize organically rich, decomposing substrates as developmental sites, thereby contributing to the turnover of biological waste. Adults, which rely on floral resources, act as effective pollinators and are sensitive to habitat modifications, making them valuable indicators of environmental quality. Occasional reports of this species from forensic investigations further highlight its diverse ecological associations. This article outlines the distribution, morphology, habitat selection, ecological significance, and research potential of *S. pipiens,* emphasizing its utility in ecosystem functioning, environmental assessment, and decomposition studies.**

Keywords: Biological waste, Ecosystem functioning, Nutrient cycling, Pollination, Saprophagous larvae

SYRPHIDS, commonly known as hoverflies or flower flies, comprise over 6,674 species in 284 genera. They are distributed worldwide, except in Antarctica and a few remote islands, with the majority of species occurring in tropical and temperate regions. Adults frequently visit flowers to obtain nectar and pollen, and many species exhibit mimicry of bees or wasps, which provides protection from predators (a phenomenon known as Batesian mimicry).

The family encompasses several functional groups, including saprophages, predators, filter feeders, and herbivores. Larvae belonging to the subfamily Eristalinae play an important role in processing organic residues, whereas Syrphinae larvae primarily act as predators of soft-bodied insects. *Syritta pipiens* (Linnaeus) represents a noteworthy exception within the family, as its larvae develop in organically enriched, decomposing matter. This feeding strategy makes *S. pipiens* larvae effective agents in organic matter turnover and nutrient transformation across diverse ecosystems.

S pipiens as a unique decomposer

Syritta pipiens, commonly known as the thick-legged hoverfly, is a cosmopolitan species distributed across multiple biogeographic regions. Its common name is derived from its distinctly thick hind femur (Fig. 1b). Adults are fast and agile fliers, while the larvae develop in wet, decaying organic matter. This species is commonly found in farmland, gardens, and urban parks, particularly in areas with abundant flowering plants.

Distribution and habitat

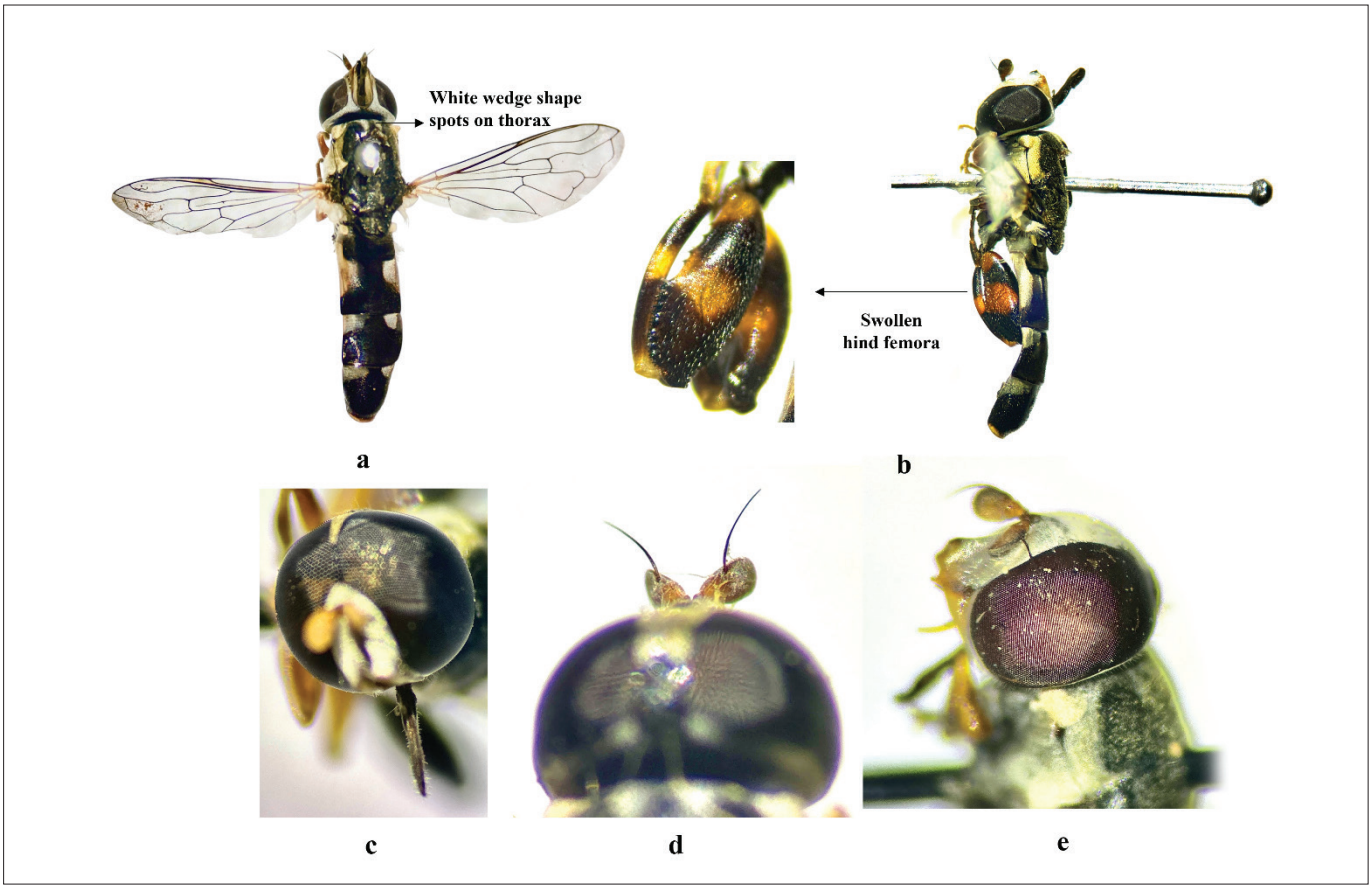
Syritta pipiens has been recorded throughout North America and Asia following its introduction from Europe in the 1800s. In Ontario, this hoverfly is active from mid-April to mid-October, whereas in Europe it is typically observed from March to November; in warmer regions of southern Europe, it may remain active year-round.

Himachal Pradesh, located in the north-western Himalayas at elevations ranging from 350 to over 2,200 m above mean sea level, comprises diverse agro-climatic zones with distinct environmental conditions suitable for its habitation. This species has been reported from all four agro-climatic zones of Himachal Pradesh, including Nurpur, Sundernagar, Chamba, Sarahan, Solan, Manali, Theog, Kalpa, and Sharbo. Recently, it was also recorded in Lari village of Lahaul–Spiti by scientists from Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP).

Morphology

Syritta pipiens is a small, robust hoverfly measuring about 6.5–9 mm in body length, with wings spanning approximately 4.25–7 mm. The hind femora are characteristically thickened and bear small spines near the tips, along with two small white wedge-shaped spots on the thorax just behind the head. The hind femur also has a moderately narrow, complete orange ring at the base.

Males exhibit holoptic eyes that meet at the top of the head, with enlarged facets between the clypeus and ocellar triangle, and a distinctly thickened third femur.



Morphological features of *Syritta pipiens*
a) Adult b) Broad hind femur c) Sponging mouthparts d) Aristate antenna e) Compound eyes

Both sexes display pale markings on tergites 2 and 3, along with dusted thoracic margins.

The larva is pale yellow and tapers at both ends, being widest between the 5th and 9th body segments. It narrows gradually toward the anterior end and more sharply toward the posterior. A characteristic "false head" at the posterior end helps deter predators by diverting attacks away from the true head. The body is covered with fine white hairs and bears three posterior protrusions, with the first being shortest and the third longest. It possesses seven pairs of prolegs, each tipped with approximately 24 tiny hooks.

During pupation, the larva transforms into an oval-shaped puparium, which ranges in colour from pale yellowish-white to dull brown. The three posterior protrusions remain visible, while the prolegs disappear.

Importance

Syritta pipiens contributes to several ecological functions. Adults visit a wide range of flowering plants, including *Dianthera americana*, *Verbena urticifolia*, *Phytolacca decandra*, *Stevia rebaudiana*, and *Campanula rotundifolia*, as well as various crop species in Himachal Pradesh. Their frequent visits to flowers support pollination in both natural and agricultural ecosystems.

In Himachal Pradesh, this species has been recorded on *Lantana camara*, *Brassica campestris*, *Coriandrum sativum*, and *Triticum aestivum*. The larvae facilitate the breakdown of organic matter by enhancing fragmentation and microbial activity in decomposing substrates. Their presence is often associated with vegetation quality and habitat stability, making them useful indicators for environmental monitoring.

Interestingly, *S. pipiens* has also been reported in forensic studies; it was recorded on human remains in Italy in a 2013 case, indicating its occasional association with decomposing organic material beyond typical substrates.

Role as a decomposer

The saprophagous larvae of *S. pipiens* utilize nutrient-rich, decomposing substrates such as agricultural residues, plant debris, and other fermented organic matter. Their feeding and burrowing activities accelerate decomposition by improving aeration and dispersing microbial communities within the substrate. This process contributes to soil enrichment and enhances nutrient availability for plant growth.

Future prospects

Syritta pipiens offers promising avenues for future research. Detailed investigations into its interactions with microbial communities could provide valuable insights into nutrient cycling. Studies on its gut microbiota may reveal adaptations to decomposing environments, with potential applications in organic waste management. Its sensitivity to environmental changes also makes it a potential candidate for ecological monitoring programs. Expanding research in these areas can support sustainable agriculture and improved ecosystem assessment.

SUMMARY

Syritta pipiens is a widely distributed hoverfly inhabiting farmland, gardens, and other vegetated areas. Its larvae develop in moist organic matter, where they accelerate decomposition and enhance soil nutrient availability. Adults depend on floral resources and contribute to pollination in both natural and agricultural systems. The species exhibits clear sexual dimorphism, with males having enlarged hind femora and distinctive eye morphology. Larvae are well adapted to decomposing environments through specialized structural features. Owing to its ecological roles and sensitivity to habitat conditions, *S. pipiens* holds significant potential for environmental monitoring and decomposition studies.

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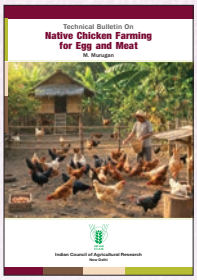

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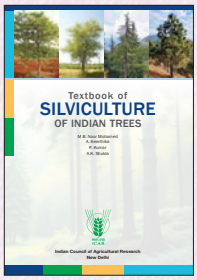

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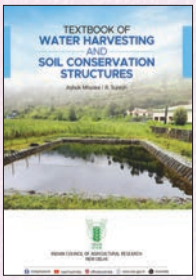

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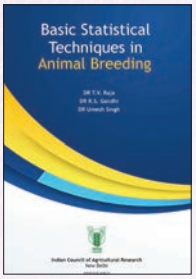

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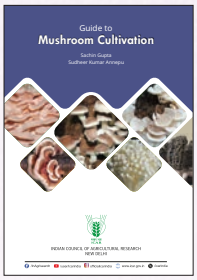

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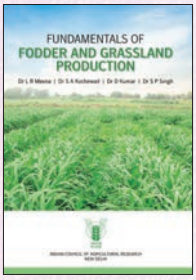

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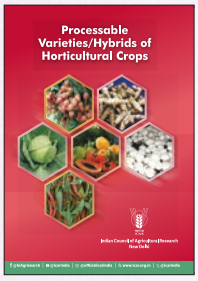

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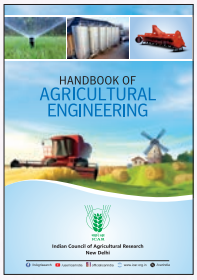

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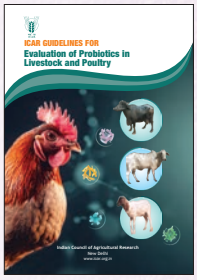

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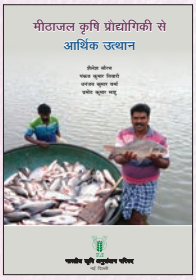

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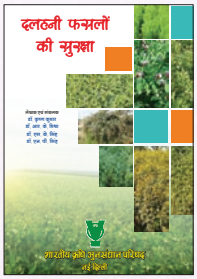

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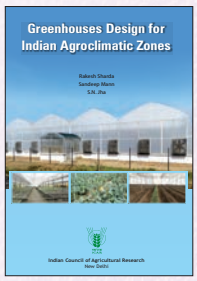

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