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Good Agricultural Practices in Teasel Gourd Cultivation

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Teasel Gourd (*Momordica subangulata* Blume *ssp. renigera* (G. Don) de Wilde) is a semi-domesticated (or wild) vegetable species native to the Indo-Burma region, belongs to the family Cucurbitaceae. It is known by various local names in India, including Bhat Karela, Gol Kakra, Kantola, Kankad, Kartoli, Madahagalakayi, and Pedda aagakarakaaya and is commonly grown by tribal and smallholder farmers in Assam, Tripura, West Bengal, Odisha, and the Andaman Islands. It is also found in home gardens and forest margins.

Uses & Importance

The tender, relatively non-bitter fruits are consumed as a vegetable. Young leaves and shoots are also used in some South-East Asian cuisines. Like other Momordica species, teasel gourd is valued not just for its food role but also for its health benefits. Although the specific phytochemical studies on teasel gourd are fewer, close relatives show good nutritional profiles proteins, fibers, vitamins, minerals and traditional uses for ailments such as fever and diabetes.

Teasel gourd fruits and plant

Ecology, Distribution & Adaptation

It occurs both in truly wild habitats (forest margins, scrub jungles, riverbanks) and under cultivation. It thrives well in warm, humid climates. It tolerates a range of soils, but naturally occurs in disturbed sites and in regions with moderate to heavy rainfall. The plant is a dioecious climber (male and female flowers on separate plants), which has implications for propagation and pollination.

Soil and Climate

Teasel gourd grows best under warm and humid tropical to subtropical climates. It performs well in regions with high rainfall and abundant soil moisture, provided drainage is adequate to avoid waterlogging. Sandy loam, well-drained alluvial soils, and lateritic soils are considered ideal. The crop prefers slightly acidic to neutral soils (pH 5.5–6.8). Optimum growth and flowering occur at a temperature range of 25–30 °C. Prolonged exposure to very high temperatures (>35 °C) or water stress can reduce fruit set. It is often observed in the months of April and May during summer. During winter, especially when the night temperatures are low, the vines dry and the tubers go into dormancy. In the wild, when the temperatures rise, after the winter, when the initial rains occur in the spring, the tubers sprout. Areas with moderate to high rainfall and relative humidity (70–80%) support vigorous vegetative growth. For commercial cultivation, sites with good irrigation facilities, fertile soil, and provision for erecting trellises or pandals are preferred.

Varieties

Arka Neelachal Gaurav: Considering the economic significance of the crop, very little work has been done so far on crop improvement. A variety namely *Arka Neelachal Gaurav* was identified from ICAR-IIHR-CHES, Bhubaneswar for commercial cultivation in 2017. It produces an average yield of 10 kg/plant and shows moderate resistance to *Diaphania indica* infestation, and moderate susceptibility to anthracnose and downy mildew diseases in the field.

Arka Bharath: This high yielding variety is released from ICAR-IIHR-CHES, Chettalli. It is a selection from the germplasm collection. Plants are vigorous. Vine grows up to 6 m tall. Fruits are dark green, long oval with soft edible seeds at maturity. Fruit weight is around 100 g. Average fruit yield is 10 t/ha and suitable for cultivation in high altitude areas. CHES Chettalli introduced and popularized commercial cultivation of *Arka Bharath* teasel gourd in Kodagu, Uttara Kannada and Dakshina Kannada districts of Karnataka. Farmers realized a gross income of Rs. 80,000 from 0.25 acre land in Kodagu area of Karnataka.

Arka Neelachal Shanti: It was developed through hybridization between spine gourd and teasel gourd (IC 0598428). It produces a good number of tubers, aiding propagation. It has a high yield potential of 15–16 kg/vine and medium-sized fruits (20 g). The vine grows up to 10 m in length. Flower morphology is more like teasel gourd whilst its fruit morphology resembles spine gourd. Fruits are oval, dark green coloured with high culinary quality as that of spine gourd. It is suitable for planting from the middle of February to the second week of March. It has a longer harvesting duration than the parents. The plant starts flowering from 60- 70 days after planting and gives a marketable yield of up to 6 months The F1 hybrid is less damaged by *Diaphania indica*. The variety is moderately tolerant to anthracnose and downy mildew.

Propagation

Teasel gourd is usually propagated vegetatively. As the crop is dioecious and cross-pollinated, seed propagation does not ensure true-to-type plants, uniformity in sex ratio and plant performance. Two methods are commonly followed:

Tuber cuttings: Higher yields are obtained from tuber-raised plants. An average plant produces 20–25 adventitious tubers, each weighing 60–80 g. Large tubers can be cut into smaller pieces of >50 g weight (with at least one viable bud per piece) and used as propagules. These cut tubers should be treated with 2% Dithane M-45 solution to prevent fungal infection, then shade-dried before planting. For commercial cultivation, tuber propagation is generally recommended due to better establishment, uniform growth, and higher productivity.

Rooted vine cuttings: Alternatively, 25–30 cm long vine cuttings with 2–3 nodes can be rooted in sand or nursery beds and transplanted, but yield potential is usually lower than tuber-propagated plants.

Tissue culture: Micro propagation helps in rapid regeneration of healthy and quality plantlets in vitro conditions. But, unfortunately, its commercial use has not gained momentum. Nodal segments and shoot tips are frequently selected as explants for culture initiation. Shoot multiplication is achieved using nodal explants cultured on Murashige and Skoog (MS) medium supplemented with a combination of 6-benzylaminopurine (BAP) and kinetin. The resulting microshoots are rooted under ex vitro conditions, following treatment with root inducing hormones. Rooted plantlets are then acclimatized for 15–20 days under controlled conditions of high humidity and moderate temperature. The hardened plantlets are transplanted into the main field.

Season of Planting

Teasel gourd can be planted at two different times depending on the production window:

Early planting: November–December (utilizing residual soil moisture and cooler conditions).

Late planting: February to early March (taking advantage of spring growth and summer harvest).

Land preparation and Planting

The soil should be ploughed to a depth of about 30 cm, thoroughly harrowed, and levelled to ensure good tilth and drainage. Pits of 60 × 60 × 60 cm are dug at a spacing of 1.5 × 1.5 m, which allows sufficient vine growth and easy intercultural operations. Each pit should be filled with a mixture of topsoil and well-decomposed farmyard manure. The pits are applied with 100 g of a balanced fertilizer mixture (commonly 19:19:19 NPK or region-specific recommendation) per pit, along with organic amendments, to support initial growth. Tuber sprouts or rooted vine cuttings are placed in the prepared pits. The pits are lightly irrigated after planting to aid establishment.

Intercultural Operations

Proper crop management after planting is crucial for achieving high yields in teasel gourd.

Irrigation: Teasel gourd is highly sensitive to water stress, particularly during the critical stages of flowering and fruiting. Watering should be provided immediately after planting to ensure quick establishment. In February, if there is no rainfall, irrigation through drip should be given three times a week. Maintaining optimum soil moisture throughout the growing season is essential for uniform fruit set and quality.

Mulching: Application of plastic mulch is highly effective in conserving soil moisture, suppressing weeds, moderating soil temperature, and reducing leaching losses of nutrients. Mulching also helps in maintaining a favorable microclimate around the root zone. Mulching can also be done with weed mat which is eco-friendly and long lasting.

Nutrient management through fertigation: Application of water-soluble fertilizers such as NPK (19:19:19) @ 1–1.5 g per plant through drip once every 15 days ensures a steady and balanced supply of nutrients. Fertigation not only improves nutrient-use efficiency but also helps in conserving water and reducing labor. Micronutrients are essential for proper fruit development. Any micronutrient formulation or vegetable special solution can be sprayed @ 3 g per L during flowering and fruit development stages.

Weed management: Mulching significantly reduces weed infestation, but manual weeding may be done whenever necessary to avoid competition for nutrients, water, and light.

Training and Support System

Teasel gourd exhibits vigorous vegetative growth and requires a strong support system for optimum vine development, better fruit quality, and ease of management.

Need for support: Without proper support, vines tend to trail on the ground, which increases the risk of disease incidence, poor fruit set, and inferior quality produce. A well-designed support system allows better exposure of vines to sunlight, improves aeration, and facilitates hand pollination.

Types of support

Traditional systems: In this system, dried tree branches, bamboo poles, or locally available wooden sticks can be used to trail the vines.

Commercial systems: For large-scale cultivation, structured supports such as pandal, bower system, or single-line trellis are most suitable.

Single-line trellis method: This system is widely adopted in commercial production due to its efficiency and cost-effectiveness. Iron angles, bamboo, or wooden poles are erected along the length of the bed at a spacing of 3–4 m. Horizontal wires or GI wires are stretched across the poles at a height of 1.5–1.8 m (5–6 feet) and with a bed width of about 60 cm. Vines are trained onto these wires to spread uniformly.

Advantages of trellising

- Promotes healthy vine growth and uniform fruit set.
- Enhances accessibility for hand pollination, which is necessary for good fruit set in teasel gourd.
- Reduces the incidence of soil-borne diseases and fruit rotting.
- Facilitates intercultural operations such as weeding, fertigation, and drip irrigation management.
- Improves fruit quality by preventing fruit contact with the soil and ensuring uniform shape and colour.

Growing of teasel gourd in single-line-trellis system

Pollination Management

Natural pollination in teasel gourd is generally inadequate, with fruit set from nil to only 15–20% under open-pollinated conditions. This is primarily due to the dioecious nature of the crop and limited activity of natural pollinators. As a result, hand pollination is indispensable for commercial cultivation to achieve higher fruit set and yields.

Planting male and female vines: Since teasel gourd is dioecious, it is important to maintain a proper ratio of male to female plants. A commonly recommended practice is to plant one male plant for every 9 female plants. Male plants are usually grown separately in one corner of the field to serve as a pollen source.

Method of hand pollination

- Freshly opened male flowers are collected early in the morning.
- Between 6:00–10:00 a.m., when stigmas are most receptive, the stamens of male flowers are gently rubbed against the stigmas of female flowers.
- Alternatively, pollen can be dusted directly onto the stigma using a soft brush to enhance efficiency.

Benefits of hand pollination

- Increases fruit set from nil to as high as 80–90%.
- Ensures uniform fruit development, better shape, and higher marketable yield.
- Overcomes pollination failures during unfavorable weather conditions or when natural pollinator activity is low.

Additional considerations

- Training vines on trellises or bowers facilitates easy identification of flowers and efficient pollination work.
- Staggered planting of male vines can help ensure continuous pollen availability throughout the flowering period.

Female flower (top) and male flower (bottom)

Harvesting and Yield

Teasel gourd begins bearing within 60–70 days after planting, depending on season and crop management practices. Fruits are generally harvested 12–15 days after pollination/fruit set, when they are still tender, green, and suitable for culinary use. Harvesting should be done while fruits are green, tender, and before seeds harden. Delayed harvesting (beyond 18–20 days after fruit set) results in the development of a reddish hue in the rind, seed hardening, and a decline in cooking quality and market appeal. Regular weekly picking encourages continuous flowering and fruiting, thereby enhancing total yield. Careful handling during harvest is essential, as fruits are tender and prone to bruising. Yield varies with soil type, climatic conditions, and cultural practices such as trellising, irrigation, and pollination efficiency. On average, a healthy vine can produce 10–12 kg of marketable fruits per season. Under well-managed commercial systems with hand pollination and fertigation, yields may go up to 15–18 tonnes per hectare.

Post-harvest considerations

Harvested fruits should be graded and packed carefully to minimize damage. Since teasel gourd is highly perishable, produce should be marketed quickly or stored under cool conditions to extend shelf life. Use of perforated plastic crates instead of traditional gunny bags is recommended for better ventilation during transport.

Pest and Disease Management

Cucumber Moth (*Diaphania indica*)

The young larvae are bright green with a pair of white mid-dorsal lines. In the early stage, they scrape off the chlorophyll from leaves. As they grow, they fold and web the leaves, feeding from within. They also attack flowers and bore into developing fruits, causing significant damage.

Management

- Early-stage caterpillars should be collected and destroyed manually.
- Cultural practices like changing sowing dates and crop rotation, monitoring with pheromone traps is effective.
- In case of heavy infestation, spray Chlorantriniprole @ 0.5 ml/litre or Flubendiamide @ 0.3ml/litre or Bacillus thuringiensis (Bt) @ 2 ml/litre of water.

Larva eating the flowers and fruits

Spotted beetle (*Epilachna vigintioctopunctata*)

Both grubs and adults feed voraciously on the leaves, scraping the green matter and leaving behind only a network of veins, giving the foliage a skeletonized appearance. Severe infestation leads to defoliation, reduced photosynthesis, and poor yield.

Management

- Collect and destroy infested leaves along with grubs and adults during the early stage.
- In case of severe infestation, spray Carbaryl 50 WP @ 3g/lit of water or Triazophos 40% EC @ 2ml/litre or Neem-based formulations (neem seed kernel extract 5% or neem oil 3%) to reduce pest population.

Adult beetle feeding on the leaves and eggs can also be seen

Fruit Fly (*Bactrocera* spp.)

The maggots of fruit fly feed on the pulp of developing fruits, causing oozing of resinous fluid and resulting in distorted, malformed, and unmarketable fruits.

Management

- Collect and destroy all infested and fallen fruits by burning or burying them deep in soil to break the life cycle.
- Use pheromone traps to control adult populations. Traps can be prepared using a mixture of ethanol, cue-lure, and Malathion in the ratio of 6:4:1.
- Plywood blocks of 5 × 5 × 1.2 cm are soaked in this solution for 48 hours and then used as baited traps in the field.
- These can be used in bottle traps @ 10 blocks/ha. Under severe infestation, 100g jaggery or banana may be mixed in 1 litre of water with 2 ml carbaryl and sprayed on spots at the distance of 7 m.

Red Pumpkin Beetle (*Aulacophora foveicollis*)

This pest mainly attacks plants at the seedling stage. The adult beetles feed on the leaves, creating characteristic round holes in the foliage and reducing plant vigor.

Management

- Handpick and destroy adult beetles during the early stage of infestation.
- Spray Carbaryl @ 2 g/litre or Indoxacarb @ 1ml/litre of water at 6–7 day intervals to manage the pest population.

Root Knot Nematode (*Meloidogyne incognita*)

Root system of the infested plant is heavily knotted and vine growth is suppressed. Reduction in the leaf size and yellowing of leaves is observed. Finally, the vines wither, dry and eventually die.

Galls on the nematode infected roots

Management

- Deep summer ploughing, soil solarization and fumigation are required.
- Apply Carbofuran 3G in combination with neem cake (500g) in the pits at the time of planting.
- Dipping of vine cuttings and tubers in monocrotophos 1000 ppm 6 hr before planting.
- Basal application of Bionematon @ 10g per pit and a subsequent application at 40 days after planting are also effective.
- Treat seeds/tubers with Pseudomonas fluorescence powder formulation @ 10 g/kg of seed/tuber or mix P. fluorescence @ 1 kg per 100 kg of FYM or compost and apply as basal dose.

Downy Mildew (*Pseudoperonospora cubensis*)

The disease appears as pale green areas separated by dark green patches on the upper leaf surface, giving a mottled appearance. Under low temperature and humid conditions, the corresponding lower surface of the yellowish patches develops a faint purplish fungal growth. Severe infection leads to leaf curling, drying, and premature defoliation, reducing yield. The affected leaf dries up quickly.

Management

- Ensure good field sanitation and avoid overcrowding of plants to reduce humidity.
- Use of bed system with wide spacing along with good drainage, free air movement and exposure to sun help to check the disease development.
- Spraying of Moncozeb 0.2 % or Chlorothalonil 0.2% or Difolaton 0.2% or Metalaxyl + Mancozeb (0.2%) or Dimethomorph (0.1%) at 10–12 day intervals is recommended.
- Alternate fungicides with different modes of action to prevent resistance development.

Anthracnose (*Colletotrichum orbiculare*)

The disease is characterized by sunken, elongated stem cankers which are most prominent on vines. Large lesions girdle the stems, causing wilting and eventual vine death. Foliage affected by anthracnose appears scorched and dries prematurely.

Management

- Treat seeds with Carbendazim @ 2 g/kg before sowing.
- Spray Mancozeb @ 2 g/litre or Carbendazim @ 0.5 g/litre at 10–12 day intervals to control foliar infection.

Fusarium Wilt (*Fusarium oxysporum f. sp. cucumerinum*)

The disease causes progressive wilting and chlorosis (yellowing) of older leaves, most evident during the heat of the day. Plants may appear to recover by morning but wilt again in the afternoon. Stem cracks and brown streaks often appear near the crown region, associated with reddish-brown exudates. Vascular browning is visible in stem cross-sections.

Management

- Practice summer ploughing in severely infested fields to reduce soil-borne inoculum.

- Follow crop rotation with non-cucurbitaceous crops for at least 2–3 years.
- Use resistant or tolerant varieties wherever available.
- Ensure proper drainage and avoid waterlogging.

Sclerotium Wilt (*Sclerotium rolfsii*)

It appears commonly at the seedling to early vegetative stage, especially in warm, moist soils. Initial symptoms include sudden wilting of vines and yellowing of lower leaves, collar region showing water-soaked lesions that later turn brown. White, cottony mycelial growth develops around the base of affected plants under humid conditions. Formation of spherical, mustard-seed like sclerotia (white at first, turning brown) on the infected tissue and surrounding soil is clear indication of sclerotium wilt. Infected plants collapse and die rapidly; in severe cases, large patches of the field may be affected.

Management

- Practice crop rotation with non-host crops (cereals, maize, etc.) for 2–3 years.
- Soil application of *Trichoderma harzianum* or *T. viride* (2.5 kg/ha mixed with 50 kg FYM) as a biocontrol measure.
- Seed/tuber treatment with *Trichoderma* formulations enhances resistance to infection.
- Application of Hexaconazole or Tebuconazole (0.05–0.1%) helps in suppressing the pathogen.

Sclerotium wilt; mycelium and fruiting bodies

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Red Gold of Dirang: Monpa Chilli Empowering Monpa Tribes through Food and Livelihood

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The North-Eastern states of India are often called the country's treasure chest of biodiversity and culture. From unique plants and soils to rich agro-ecological zones, and from diverse human communities to rare animal species, this region represents one of India's most vibrant biological and cultural landscapes (Marschke et al., 2005; Berkes et al., 2006). Unlike many other parts of the country, the North-East (NEH region) hosts an extraordinary mix of flora, fauna, climates, food systems and indigenous traditions. Commonly known as the "Seven Sisters" Arunachal Pradesh, Assam, Meghalaya, Tripura, Nagaland, Mizoram and Manipur the region also shares international borders with Bangladesh, Bhutan, Tibet, China and Myanmar, adding to its cultural and ecological richness. With climates ranging from humid tropical valleys to cool temperate highlands, the NEH region is a natural laboratory of diversity. Among these states, Arunachal Pradesh stands out for its high-altitude horticulture and temperate ecosystem. The state's unique climate, stretching from 6,000 ft in Dirang to nearly 15,000 ft near Tawang and Bumla Pass, supports crops that are rarely seen elsewhere in India. Apples, pears, wild blueberries, persimmon, kiwifruit and walnuts are now becoming important livelihood crops for local farmers. The soils here are naturally acidic (pH 4.5–5.5) and the temperature ranges between 0–20°C, creating a perfect niche for temperate fruits and traditional hill farming systems (Singh et al., 2006).

All the tribes of Arunachal Pradesh are of Mongoloid origin and are settled down in different ecological settings and distinct territorial base. Arunachal Pradesh is also a cultural mosaic, home to over 26 major tribes and more than 100 sub-tribes, including the Adi, Apatani, Monpa, Nyishi, Mishmi, Galo, Tagin, Aka, Sherdukpen, Khampti, Wancho, Nocte and Singpho communities. Each tribe brings with it a distinct identity, language, food culture and farming wisdom. Among them, the Monpa (Monpa is used to address the people living in south of Tibet) tribe of West Kameng and Tawang is especially known for its deep connection with temperate horticulture and mountain agriculture. Their livelihood is closely linked to farming, animal husbandry and agro-tourism. Traditional Yak rearing, and products like yak churpi (hard cheese), along with the legendary Monpa chilli, have been part of their culture for more than a century. From sacred mountains to ancient food traditions, from native orchards to age-old eco-friendly practices, the North-East is not just a region it is a living heritage of nature, knowledge and resilience.

The Monpa community has long been involved in both internal and external trade. Traditionally, they followed a well-organized barter system not only among neighbouring tribes but also with non-tribal groups in Assam. Traders from the Kalaktang region often travelled to the Udalguri market in Darrang district, where they exchanged or sold items such as dried Monpa chillies, local maize, khum rice, Ara (traditional liquor), livestock, pepper, and various vegetables. In return, they brought back goods like silk and cotton yarn, clothing, utensils, and other household items (Singh et al., 2004).

Monpa Chilli (*Capsicum* sp.) continues to play a vital role in the daily life of the Monpa tribes. Morphologically, it resembles paprika chilli, though it is not identical. This chilli variety has adapted over many years to the high altitudes of Arunachal Pradesh, and it also performs well in the plains of India. Monpa chilli is primarily cultivated by the three sub-groups of the Monpa community: Northern Monpa (Tawang), Central Monpa (Dirang), and Southern Monpa (Kalaktang region). Among all three groups, it has gained popularity due to its cultural acceptance and traditional food habits. There is noticeable diversity in fruit shape and size among the different regions.

However, with modernization and the introduction of other Indian chilli varieties and hybrids, the purity of Monpa chilli has been declining. Cross-variability has resulted in a significant loss of genetic purity, especially in West Kameng. There is an urgent need to conserve this unique landrace, and Geographical Indication (GI) registration is one of the most scientific and effective ways to protect Monpa chilli for future generations of the Monpa community.

Monpa chilli exhibits an annual to biennial growth habit and is highly adapted to high altitudes and acidic soils. The fruits are mildly to moderately pungent, but they are exceptionally rich in red pigments such as capsanthin and capsaicin. This chilli performs well not only in the high-altitude regions of Arunachal Pradesh but also under low-temperature conditions in other parts of India. ICAR–Central Institute of Temperate Horticulture, Regional Station, Dirang (West Kameng, Arunachal Pradesh) has been working on the GI registration and DUS characterization of Monpa chilli since 2020. To identify its unique traits, Monpa chilli is being evaluated across four major chilli-growing states of India: Karnataka, Nagaland, Odisha, and Meghalaya.

Some of the distinguishing characteristics of Monpa chilli

- Biennial growth habit
- Purple pigmentation at nodal regions and calyx
- White, large flowers similar to Capsicum annuum, with fused petals
- Purple to bluish anthers at the bud stage (one day before anthesis)
- Inserted stigma inside the anther cone, restricting natural cross-pollination

Monpa Chilli Diversity: A single landrace, many shapes and sizes

These traits, repeatedly observed over two seasons in Dirang and other evaluation sites, clearly differentiate Monpa chilli from other GI-protected chillies like Naga chilli and Mizo chilli.

Monpa chilli is highly susceptible to Cercospora leaf spot and thrips during the summer months, although the incidence is considerably lower in winter.

Based on traditional knowledge of the Monpa community, sowing is carried out from March to June, while harvesting begins in August and continues until November–December for both fresh consumption and drying. The fruits are small to medium in size, initially deep green, turning pinkish-blue at the intermediate stage, and finally developing a deep red colour when fully ripe. The fruiting habit is pendulous, and a high pollen load has been consistently recorded during anthesis in two consecutive seasons at ICAR-CITH, Dirang. At full maturity, the fruits exhibit a wrinkled and curled pericarp, similar to Guntur and Kashmir chillies commonly used for red chilli powder production. Most Monpa farmers, particularly rural women, continue to use traditional seed-saving practices, carrying forward seeds from one season to the next. Because Monpa chilli has an inserted stigma that largely restricts cross-pollination and favours self-pollination or very limited accidental cross-pollination, genetic purity has been relatively well maintained over generations. This characteristic makes it possible to identify and conserve the true indigenous Monpa landrace through selfing and fixation of original traits.

Future breeding strategies should focus on the selection and evaluation of superior Monpa breeding lines, with comparison against national and state check varieties to improve yield and adaptability. Introgression of resistance genes against Cercospora leaf spot and incorporation of high-yield meta-QTLs should be prioritized as key breeding objectives. Establishing a defined geographical area for Monpa chilli cultivation, along with characterization of desirable agronomic and quality traits, will support long-term conservation and utilization. Formation of Farmer Producer Organizations (FPOs) and expansion of large-scale production for value-added products such as red chilli powder would significantly benefit the Monpa community. Strong institutional and government support is essential to achieve these goals, along with GI registration to secure the crop's cultural and commercial identity.

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Biophysical Determinants of Crispiness in Cucumber

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Crispness is a key quality attribute in fresh produce, particularly in cucumbers (*Cucumis sativus*), which directly influences consumer preference, marketability, and postharvest value. Unlike firmness, which reflects resistance to deformation, crispness is a sensory trait associated with the fracturability and acoustic response of the fruit during biting. Firmness is measured as resistance to mechanical force, often quantified using puncture or compression tests. Crispness involves rapid fracture under stress, producing a distinct sound and tactile sensation; it is more complex and less directly measurable. Understanding the biophysical traits that govern cucumber texture is essential for breeding programs, postharvest handling, and quality assurance. This paper explores the structural, mechanical, and cellular traits that contribute to the crisp texture of cucumbers.

Defining Crispiness: A Biophysical Perspective

Crispiness is a sensory property characterised by a sharp, brittle fracture under stress, often accompanied by an audible crunch. In biophysical terms, it is governed by:

- Cell wall rigidity
- Turgor pressure
- Intercellular adhesion
- Fracture mechanics of tissue

Unlike chewiness or firmness, crispiness involves rapid deformation and rupture, making it a dynamic mechanical response rather than a static one.

Structural Contributors to Crispiness

Cell Wall Composition

The cell wall of the cucumber is primarily composed of cellulose, hemicellulose, and pectin. The relative abundance and cross-linking of these polymers determine wall stiffness:

- Cellulose microfibrils provide tensile strength.
- Pectin influences wall porosity and adhesion between cells.
- Lignification, though minimal in cucumbers, can increase rigidity in other produce.

Higher cellulose content and lower pectin solubilization correlate with increased crispiness.

Turgor Pressure

Turgor pressure is the hydrostatic pressure within plant cells. It plays a pivotal role in maintaining tissue firmness and crispness. It is influenced by:

- Water content
- Osmotic balance
- Membrane integrity

Loss of turgor due to dehydration or senescence leads to flaccid tissues and diminished crispiness. Studies show that cucumbers with higher internal water pressure exhibit more pronounced fracture behaviour upon biting.

Cellular Arrangement

Crispness is also affected by the spatial organisation of cells:

- Smaller, tightly packed cells with uniform size contribute to consistent fracture.
- Air spaces between cells can amplify sound during rupture, enhancing perceived crispiness.

Microscopic imaging reveals that crisp cucumbers have a more homogenous parenchyma structure compared to softer cultivars.

Mechanical Properties and Texture Analysis

Fracture Force and Acoustic Response

Texture analysers and acoustic sensors are used to quantify crispiness:

- Fracture force: The peak force required to break the tissue.
- Sound amplitude and frequency: Correlate with sensory perception of crispness.

Crisp cucumbers typically exhibit high fracture force and distinct acoustic profiles, often described as “snap” or “crack.”

Elastic Modulus and Brittleness

The elastic modulus reflects the tissue’s resistance to deformation. Crisp cucumbers show:

- High elastic modulus
- Low plasticity
- Rapid stress-strain failure curves

These traits indicate a brittle, rather than ductile, mechanical behaviour ideal for crisp texture.

Postharvest Factors Affecting Crispiness

Storage Conditions

Temperature and humidity significantly affect cucumber crispiness:

- Low humidity accelerates water loss and reduces turgor.
- Cold storage can preserve crispness but may induce chilling injury if too low.

Modified atmosphere packaging (MAP) has shown promise in maintaining texture by regulating moisture and gas exchange.

Genetic and Cultivar Variation

The cucumber types differed greatly in flesh crispness, skin firmness and fruit shape components. Although environmental factors are important to fruit quality traits, the great differences observed here suggest strong genetic control of these traits. Recent studies have identified over 25 QTLs associated with crispness traits, including flesh crispness index and fractal dimension scores. These QTLs often overlap with loci for fruit morphology and disease resistance, suggesting pleiotropic effects or genetic linkage.

Different cucumber cultivars exhibit varying degrees of crispiness due to genetic differences in:

- Cell wall biosynthesis
- Water retention capacity
- Growth rate and maturity

Breeding programs increasingly target crispiness as a desirable trait, using molecular markers linked to cell wall integrity and water transport.

Environmental and soil factors

High relative humidity helps maintain cucumber firmness during growth, but can accelerate post-harvest spoilage. Temperature extremes (especially high heat) can reduce cell wall integrity, leading to softer fruits.

Soilless media like cocopeat mixed with perlite have shown to improve water retention and firmness in cucumbers.

Water stress (either excess or deficit) negatively impacts fruit texture. Adequate irrigation is crucial for maintaining crispness

Conclusion

Crispiness in cucumbers is a multifaceted trait rooted in biophysical properties such as cell wall composition, turgor pressure, and mechanical behavior. Advances in texture analysis and plant physiology have enabled a deeper understanding of these determinants, paving the way for improved postharvest handling and cultivar development. By integrating structural biology with sensory science, researchers and producers can better preserve and enhance the crisp texture that defines cucumber quality. For breeders and researchers, integrating these insights into cultivar development and postharvest protocols is key to enhancing quality and market competitiveness.

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Integrating Renewable Energy in Vegetable Farming: Reducing Carbon Footprints with Solar, Biogas and Wind

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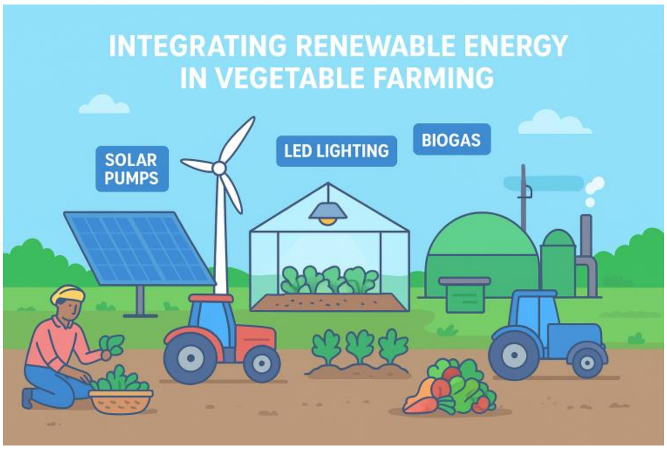
The vegetable sector is a crucial pillar of Indian agriculture, contributing to nutritional security and rural livelihoods. India produces more than 215 million tonnes of vegetables annually, accounting for around 15% of global production (FAO, 2023). However, conventional farming practices in vegetables are energy-intensive due to frequent irrigation, fertilizer use, mechanization and reliance on fossil fuels for pumping and post-harvest processing (Patra et al., 2022). This results in significant greenhouse gas (GHG) emissions with protected cultivation systems often recording higher carbon footprints compared to field systems.

Renewable energy technologies, especially solar, wind and biogas, are being increasingly promoted as solutions to cut emissions while improving resource efficiency. Government initiatives such as the PM-KUSUM scheme have already enabled widespread adoption of solar irrigation pumps, while biogas and solar dryers are being piloted in vegetable clusters (ICAR, 2023). This article highlights the scope and benefits of integrating renewable energy in vegetable farming with a focus on solar pumps, solar dryers, LED lighting in polyhouses and biogas production from vegetable residues.



Solar Applications in Vegetable Farming

Solar Pumps

Solar-powered irrigation pumps are emerging as a sustainable alternative to diesel and electric pumps in vegetable farming. They help reduce dependency on fossil fuels, cut irrigation costs and provide assured water supply for crops such as tomato, brinjal and okra (Kumar et al., 2021). Studies suggest that solar pumps can save up to 1.5–2 tonnes CO_2-equivalent per pump annually, making them an effective climate-smart technology (Gupta et al., 2023).

Solar irrigation pump setup in vegetable farm under Indian scheme

Solar Dryers

Post-harvest losses in vegetables in India are estimated at 20–25%, mainly due to poor storage and drying facilities (Sharma et al., 2022). Solar dryers provide an eco-friendly way of dehydrating surplus produce like onions, chilies and leafy greens, reducing wastage and enhancing shelf life. Compared to traditional sun drying, solar dryers ensure hygienic drying in less time, improve product quality and save energy costs (Verma et al., 2021). Their adoption not only curbs carbon emissions but also adds value through dried products in local and export markets.

Table 1. Comparison of Diesel vs. Solar Irrigation

Parameters	Diesel Pump	Solar Pump
Installation Cost (₹)	45,000	1,20,000
Annual Operating Cost (₹)	50,000	5,000
CO_2 Emission (tonnes/year)	2.1	0.3
Lifespan (years)	7	15

LED Lighting in Polyhouses

Protected cultivation is rapidly expanding in India, covering over 70,000 hectares under polyhouses and net houses (NHB, 2023). However, conventional lighting and heating in polyhouses are energy-intensive. The use of energy-efficient

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LED lights enables longer photoperiods for crops like cucumber, capsicum and lettuce, resulting in higher productivity and improved quality (Rao et al., 2022). LEDs consume up to 60% less energy than traditional lamps and can be powered by solar panels, further reducing the carbon footprint of protected vegetable production (Choudhury et al., 2023).

Table 2. Reduction in Post-Harvest Losses by Solar Dryers

Vegetables	Traditional Loss (%)	With Solar Dryer Loss (%)
Onion	25	10
Tomato	20	8
Chili	22	9
Leafy Greens	30	12

Large scale greenhouse LED lighting layout

Biogas from Vegetable Residues

India generates over 50 million tonnes of vegetable waste annually, much of which is either dumped or left to rot, releasing methane into the atmosphere (FAO, 2023). Biogas technology provides a circular solution by converting this waste into renewable energy and nutrient-rich slurry. Vegetable market waste such as cabbage leaves, tomato rejects and pea shells can be fed into biogas digesters to produce methane for cooking and electricity (Singh et al., 2021). The slurry by-product serves as an organic fertilizer, reducing dependence on chemical inputs. Studies show that adopting biogas plants in vegetable clusters can reduce methane emissions by 30–40% while meeting household energy needs (Das et al., 2022).

Wind Energy and Hybrid Models

Wind power, though less explored in vegetable farming compared to solar, has great potential in coastal and plateau regions of India. Small-scale wind turbines can supplement farm energy requirements for irrigation, cold storage and greenhouse operations (Mishra et al., 2020). Integrating wind with solar systems ensures a hybrid energy model, providing round-the-clock power availability. This hybrid approach minimizes reliance on grid electricity and diesel, thereby lowering the farm's carbon footprint and improving long-term sustainability.

Benefits and Carbon Footprint Reduction

Integrating renewable energy into vegetable farming offers multiple environmental and socio-economic benefits. It reduces greenhouse gas emissions by displacing fossil fuels, enhances energy security and brings down production costs. For example, replacing a 5 HP diesel pump with a solar pump can save around ₹50,000 annually in fuel costs while avoiding significant CO_2 emissions (Gupta et al., 2023). Similarly, solar dryers and LED lights enhance quality and shelf life of produce, thus improving farmer income. Biogas plants transform waste into valuable energy and organic manure, creating a circular economy model. Together, these interventions make vegetable farming more resilient, climate-friendly and sustainable (Patra et al., 2022).

Indian Success Stories

Maharashtra: Farmer groups in Nashik have adopted solar-powered cold storages for onions and tomatoes, reducing spoilage by 30% and saving on diesel costs (Sharma et al., 2022).

Odisha: Pilot projects on solar dryers in tribal belts for leafy greens have increased women farmers' incomes by 25–30% (ICAR, 2023).

Gujarat: Large-scale use of solar pumps under PM-KUSUM has made vegetable irrigation independent of erratic electricity supply (Kumar et al., 2021).

Karnataka: Vegetable markets in Bengaluru are using biogas plants to process unsold residues into cooking fuel for canteens (Das et al., 2022).

Conclusion

Renewable energy integration in vegetable farming represents a transformative step toward achieving low-carbon agriculture. Solar pumps, solar dryers, LED-based protected cultivation and biogas plants not only reduce greenhouse gas emissions but also improve farm profitability and resilience. However, challenges such as high initial investment, lack of awareness and inadequate technical support remain. Policies must focus on financial incentives, capacity building and community-based renewable energy models to encourage adoption.

As India moves towards its net-zero carbon target by 2070, renewable energy-driven vegetable farming will play a vital role in achieving sustainable intensification, ensuring food security and protecting the environment (FAO, 2023; ICAR, 2023).

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Applications and Future Prospects of Tissue Culture in Genetic Improvement of Cucumber

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Cucumber (*Cucumis sativus* L.) is a significant vegetable crop cultivated worldwide for its edible fruits. It belongs to the Cucurbitaceae family and is consumed fresh, pickled, or processed. However, cucumber cultivation faces several challenges, including susceptibility to diseases, environmental stressors, and limitations in traditional breeding techniques. The increasing demand for cucumber and the necessity for improved varieties have led to adopting of biotechnological approaches, particularly tissue culture, in cucumber breeding and genetic enhancement. Tissue culture techniques have revolutionized cucumber improvement by enabling rapid propagation, disease elimination, genetic transformation, and the development of stress-resistant varieties. This paper explores cucumber tissue culture and its applications in cucumber improvement.

Importance of Cucumber and Challenges in Cultivation

Cucumber is valued for its high-water content, low-calorie profile, and essential nutrients such as vitamins C and K, potassium, and antioxidants. It plays a crucial role in human nutrition and the agricultural economy. However, cucumber cultivation faces several challenges, including susceptibility to fungal, bacterial, and viral diseases, vulnerability to environmental stressors such as drought and salinity, and limitations in traditional breeding methods. Conventional breeding techniques are often time-consuming and constrained by genetic barriers, necessitating alternative approaches like tissue culture.

The Role of Tissue Culture in Cucumber Improvement

Plant tissue culture involves the in vitro propagation of plant cells, tissues, or organs under sterile conditions. This technique enables rapid multiplication, genetic modifications, and the development of superior cucumber varieties. Several tissue culture methods have been successfully employed to enhance cucumber breeding, including micropropagation, somatic embryogenesis, callus culture, and genetic transformation and are briefly explained in this article.

1. Micropropagation

Micropropagation is the rapid multiplication of plant clones using tissue culture techniques. In cucumbers, this method allows the production of a large number of disease-free, genetically uniform plants. The key steps in cucumber micropropagation include:

- ***Explant Selection***: Typically, shoot tips, nodal segments, or cotyledons are used as explants.
- ***Sterilization and Culture Initiation***: The explants are disinfected and cultured in a suitable medium containing essential nutrients, plant growth regulators (PGRs), and carbon sources.
- ***Multiplication Phase***: Cytokinins like benzylaminopurine (BAP) promote shoot proliferation.
- ***Rooting and Acclimatization***: Auxins such as indole-3-butyric acid (IBA) aid in root development, followed by the hardening of plantlets for field conditions.

2. Somatic Embryogenesis

Somatic embryogenesis is the process by which somatic cells develop into embryos without fertilization. In cucumbers, this technique enhances genetic stability and uniformity in propagated plants. The advantages of somatic embryogenesis include:

- Rapid regeneration of plants.
- Development of synthetic seeds.
- Efficient conservation of elite germplasm.

3. Callus Culture and Its Applications

Callus culture involves the induction of undifferentiated plant cells (callus) from explants using high concentrations of auxins and cytokinins. This technique is crucial for:

- ***Genetic Transformation***: Callus tissue serves as a medium for introducing desirable genes through Agrobacterium-mediated transformation or biolistics.
- ***Somaclonal Variation***: Genetic variability generated through callus culture is useful for

selecting stress-tolerant and disease-resistant cucumber variants.

4. Genetic Transformation for Cucumber Improvement

Genetic transformation allows the incorporation of specific traits into cucumber plants, enhancing their resistance to diseases, pests, and environmental stressors. Some notable genetic modifications in cucumbers include:

- ***Disease Resistance***: Introduction of genes conferring resistance to fungal pathogens (e.g., *Fusarium* and *Pseudoperonospora cubensis*).
- ***Abiotic Stress Tolerance***: Incorporation of genes that improve drought and salinity tolerance.
- ***Nutritional Enhancement***: Genetic modifications aimed at increasing the nutritional value of cucumbers.

Applications of plant tissue culture in Cucumber Improvement

Tissue culture plays a crucial role in cucumber breeding and genetic improvement. Some key applications include:

1. Production of Disease-Free Plants: Cucumber plants are susceptible to bacterial wilt, powdery mildew, downy mildew, and viral infections. Tissue culture helps in developing pathogen-free plants through meristem culture and micropropagation, ensuring healthy and vigorous growth.

2. Genetic Transformation for Disease and Pest Resistance: Genetic engineering, combined with tissue culture techniques, allows for the introduction of resistance genes into cucumber plants. Agrobacterium-mediated transformation and biolistic (gene gun) methods help in developing transgenic cucumbers resistant to viral, fungal, and bacterial pathogens.

3. Development of Stress-Tolerant Varieties: Abiotic stresses such as drought, salinity, and extreme temperatures affect cucumber yield. Tissue culture aids in selecting and propagating stress-tolerant genotypes. Somaclonal variation and in vitro selection can be used to develop stress-resistant lines.

4. Hybrid Breeding and Polyploid Induction: Tissue culture facilitates hybrid breeding through embryo rescue and anther culture. Embryo rescue allows for the development of interspecific hybrids that may not survive naturally. Polyploidy induction using colchicine leads to improved traits such as larger fruit size and higher yield.

5. Conservation of Germplasm: Cucumber tissue culture is useful for the long-term conservation of genetic diversity. Cryopreservation and in vitro storage techniques enable the preservation of elite and endangered germplasm, ensuring future breeding programs have access to diverse genetic resources. Through micropropagation, somatic embryogenesis, callus culture, and genetic transformation, researchers and breeders can develop disease-resistant, stress-tolerant, and high-yielding cucumber varieties.

6. Rapid Propagation of Elite Varieties Micropropagation enables the large-scale production of elite cucumber cultivars with desirable traits such as high yield, disease resistance, and improved fruit quality. This helps in meeting the increasing market demand for high-performing cucumber varieties.

Future Prospects and Challenges

The advancements in tissue culture techniques provide immense potential for cucumber breeding. However, some challenges remain, including:

Somaclonal Variation: While beneficial for genetic diversity, uncontrolled somaclonal variation may lead to undesirable traits.

Regeneration Efficiency: Some cucumber cultivars exhibit recalcitrance, making tissue culture-based improvements difficult.

Biosafety and Regulatory Concerns: The application of genetically modified cucumbers may face regulatory hurdles and consumer acceptance issues.

Conclusion

Tissue culture plays a pivotal role in the genetic improvement of cucumbers, offering sustainable solutions to agricultural challenges. Cucumber tissue culture has emerged as a powerful tool in plant biotechnology for enhancing cucumber breeding and genetic improvement. Through micropropagation, somatic embryogenesis, callus culture, and genetic transformation, researchers and breeders can develop disease-resistant, stress-tolerant, and high-yielding cucumber varieties. With continued research and technological advancements, the integration of tissue culture techniques with modern breeding strategies will revolutionize cucumber cultivation, ensuring higher yields, disease resistance, and improved stress tolerance. As plant biotechnology progresses, cucumber tissue culture will remain a cornerstone in enhancing global food security and sustainable agriculture.

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Blueberries in Uplands: A New Prospect for North East Indian Horticulture

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The blueberries are the most delicious and popular fruits of Ericaceae family which is suitable for cultivation in the acidic soils. The importance of Blueberries is reaching every people so the demand for the fruit is increasing in every part of the country. These berries are considered as super foods because of its high antioxidant properties, especially anthocyanins, which give them blue colour. Apart from this, berries are also excellent source of Vitamin C that boosts immune system. They are significant contributors to health, agriculture, and the economy, and their value goes beyond their wonderful flavour and culinary variety.

The health benefits of this fruits include protection of cardiovascular system, cancer prevention, diabieties management and improve the memory and cognitive function. The countries like United States, Canada, Europe has well established blue berry industries, which exports large qualities to the other countries to meet the global demand.

In Himachal Pradesh and Uttarakhand, the cultivation of the crop is becoming more common. Earlier the planting material was imported every year for cultivation but recently one nursery got registered as first blueberry nursey from Himachal Pradesh, Kangra district that is authorized to produce and sell blueberry planting material. In Arunachal Pradesh, this crop was introduced in the year 2017 in West Kemang district, through initiatives from the State Department. After that, crop is being cultivated by some of the progressive farmers. However, there is a lot scope available for expansion of the crop as the climatic conditions of the state also matches with the Climate of Himachal Pradesh and Uttarakhand.

Favourable climatic conditions

The north eastern region of India has diverse agro climatic conditions that can be suitable for growing blueberries, especially in the hilly region. The hilly areas include parts of Meghalaya, Arunachal Pradesh, Nagaland, Mizoram that experiences mild summer and cool winters, which is most suitable for blueberries. The bushes need chilling requirement from 400-1100 hours, which varies from variety to variety. The minimum and maximum temperatures in the growing period may range from 15 to 25 0C. This particular region receives good rainfall particularly in the month of monsoon from June to September making it good for cultivation of blueberry as it is moisture loving plant. To prevent water logging, it is advised to plant in raised beds.

The soils of this region are naturally acidic (pH 4.5 to 5.5) and rich in organic matter, which is beneficial for blueberry plants. Moreover, hilly areas receive more sunlight, essential for plants growth. Overall, the ideal climatic conditions of this region make it promising for diversifying agriculture by cultivating blueberries.

Varietal Considerations

The selection of the appropriate variety is the most important criteria for successful cultivation of the blueberries as it directly impacts the growth, yield and quality of the crop.

Half-high blueberries: These are cross between low bush and high bush blueberries. These are self-fertile, but if cross-pollination occurs, they get benefit. The chilling requirement of these varieties is 800-1000hrs.

Varieties: Northblue, Northcountry, Northsky, Polaris, Northland, Top Hat, Burnswick

Northern high-bush blueberries: These are self-fertile and needs consistent pruning. The chilling requirement of these varieties is 800-1000hrs.

Varieties: Duke, Patriot, Reka, Blueray, Bluecrop, Bluegold, Chandler

Southern high-bush blueberries: They are self-fertile in nature but it gets benefited from cross-pollination. They need 200-800hrs of chilling.

Varieties: Legacy, Sharpblue, Biloxi, Misty, Colibri, Jewel, Jubilee

Rabbiteye blueberries: These are cross-pollinated in nature. The chilling requirement is around 400-700hrs.

Varieties: Brightwell, Climax, Premier, Tifblue, Powderblue

By selecting appropriate varieties and managing soil and water conditions effectively, blueberry cultivation in Northeast India can be a successful venture.

Economic and agricultural significance of blueberries

The global demand for the blueberries is increasing and this creates significant economic returns for the growers and contributes to the economy of farmers. The blueberries are well suited for the temperate climate and the acidic soil conditions of north east India. Their cultivation creates crop versatility, providing variable source of income. These are high value crops, so if the cultivation is done in a scientific way to meet the export standards, the fruits can be exported to the neighboring countries in the fresh or dried form. These are less susceptible to the insect and pest attack compared to other crops, so their cultivation can be integrated with the other crops and this can be a part of sustainable farming.

Success stories

The introduction of blueberries in Arunachal Pradesh has showed very good results. Many progressive farmers have taken initiative to grow blueberries in a small scale and plants are showing outstanding growth and adaption to the local agroclimatic conditions. This success is because of the regions soil and climatic conditions, which resemble the natural habitat of the crop ensuring the overall growth of the plant.

Flowering and bearing in blueberry plants in State Horticulture Fram, Shergaon and Lubrang, Arunachal Pradesh

Remarkably, State Horticulture Farm in Shergaon has emerged as model for the successful cultivation of the blueberries. By adopting the advanced horticultural practices and proper crop management, the farm has achieved significant success in cultivation, further showcasing the crops potential as option for high value crop. This initial success is encouraging the more farmers to take up the cultivation. This shift will not only help in crop diversification but also it improves the livelihood of the farmers, given the high market demand and profitability.

The success of these efforts shows potential of blueberries as a productive and sustainable horticultural crop of the hilly regions of North-East India, setting a platform for large scale adoption in future.

Challenges and solutions

There are certain challenges in the cultivation of the blueberries which mainly includes initial investment for setting up of blueberry farm will be high including the land preparation and procurement of plant. The planting materials are also not easily available to the farmers and selection of the variety plays a key role in success of the cultivation. In addition, there is lack of traditional knowledge in cultivation of this crop. To address this, government should take initiatives to provide subsidies and training programs to farmers.

As it is highly perishable in nature, proper logistics and storage facility is needed. Establishing proper cold chain facility can be a solution to mitigate this problem. Creating awareness about the benefits of this fruit and promoting this in domestic market is essential. By addressing these challenges blueberry cultivation can be successfully done in Arunachal Pradesh.

Conclusion

Blueberry farming in Arunachal Pradesh holds a significant potential because of its favorable soil and climatic conditions. Strategic planning and implementation of the best agricultural practices can optimize the yield and profitability. Even though the fruit has lot of scope, it needs similar care. The most important things to consider while growing blueberries are selection of variety and the soil type, as it is very much sensitive to the varying pH of the soil. The pH of the soil should be well maintained. Additionally, advanced research and collaboration between farmers, researchers and policy makers is essential for getting the full potential of this crop.

By tapping the unique agroclimatic condition available in this region, the state can also contribute in diversification of the crop and also it can increase the economic status of the farmers.

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Epigenetic Modifications in Plants under Abiotic Stress : From Chromatin Dynamics to Phenotypic Plasticity

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Plants are always subject to both biotic and abiotic stress in order to adapt themselves for modifications happen at molecular level within plant cell. Epigenetic is defined as the study of mitotically and/or meiotically heritable changes in gene function that cannot be explained by changes in DNA sequence. These changes affect the phenotypic plasticity which in turn helps the plants to survive in adverse conditions. These changes are not related to the DNA sequences but to chemical modifications inherited from one generation to the next. There are three main types of epigenetic marks in plants namely histone modification, DNA methylation, and small RNAs. These modifications will always improve the adaptability of plants towards various stresses. There are three distinct types of epigenetic memory in plants classified into cellular, transcriptional, and transgenerational. The heritable transcriptional states that arise from developmental signals refer to cellular memory whereas the heritable changes that improve the response to environmental stress refer to transcriptional memory. Gene expression that is heritable through meiosis which enables the plant to tolerate different stress is referred as transgenerational memory.

DNA methylation in plants

DNA methylation occurs adding a methyl group at the fifth carbon position of a cytosine ring, by cytosine methyltransferases in sequence specific mode. The methyl group will provide platform for the attachment of protein complexes that modify the histone scaffolds which alters the gene expression. In plants methylation happens in CG, CHH and CHG (where H is A, C, or T) (Law and Jacobsen, 2010). Methylation in genomic DNA to an increased level in plants results in down regulation of the genes which in turn helps the plants to survive for a long period by conserving energy in various stress conditions. At the same time reduction of methylation in genes related to resistance leads to chromatin activation and expression of novel genes for long term.

Histone modifications in plants

The eukaryotic nuclei are structured in the form of nucleosome wrapped by histone proteins. Nucleosomes are mainly composed of histone octamers that comprise two copies each of H2A, H2B, H3, and H4. A total of 147 base pair of DNA sequence is wrapped around the histone core. The N termini of histone proteins called N terminal tails undergo various chemical modifications and generally these histones usually regulate the post-translational modifications (PTMs) in plants. The major histone modifications include acetylation, methylation, biotinylation, suphonylation, ubiquitination and phosphorylation. Acetylation and phosphorylation are mostly associated with induced gene expression while suphonylation and biotinylation are associated with repression of gene expression. These modifications interrupt the DNA accessibility and also affect the transport of specific proteins involved in DNA transcription, replication and repair.

miRNA directed DNA methylation

In epigenetic regulations various classes of noncoding RNAs viz small RNAs and long noncoding RNAs are also involved. These RNAs modify the chromatin structure and repress the transcription by forming RNA scaffolds using histones and DNA methyl transferases. In plants RNAi is sequence specific gene regulation mechanism mediated by miRNA, siRNA and lncRNA (long non coding RNA).

Various epigenetic changes in crops against abiotic stress

The major abiotic factors that cause epigenetic modulation are stress induced due to salinity drought, heat and cold. Salt stress will lead to alterations in gene expressions by increase in DNA methylation and decreased methylation observed salt-sensitive plants. The methyltransferases (MTases) genes were upregulated in *Pyrus betulaefolia* (a wild pear) due to salt stress (et al., 2023). The DNA methyaltion was increased in alfalfa (*Medicago sativa*)due to salt stress (Yang et al., 2024). Temperature is one of the most important environmental signals that regulate plant development and growth. Extreme high temperatures can disrupt cellular homeostasis, which leads to inhibition of plant growth and development. It also induces drastic changes in chromatin architecture of plants. The epigenetic regulation allows plants to adapt to heat stress without change in DNA sequences. This regulation involves DNA methylation, histone modifications, RNA modifications and other epigenetic regulation which contribute to gene expression in response to heat stress. Heat stress in plants cause higher methylation in sensitive genotypes compared to resistant genotypes with more demethylation events and affect cytosine methylation across various genes (Hilker et al., 2016). Alteration in expression of stress related genes and DNA methyaltion was observed during somatic embryogenesis due to high temperature in *Pinus halepensis* (Guan et al., 2013). DNA methylation and demethylation mechanisms were observed in *Arabdiopsis* due to high temperature (Guihur et al., 2022). Heat induced transcription factors HsfA1s (heat shock transcription factors) always play important role for both drought and heat stress responses. Mutations in three HsfA1a, HsfA1b, and HsfA1d genes significantly lead to loss of heat shock response in plants (Wang et al., 2009, Xue et al., 2021, Yamaguchi and Ito 2021). The transcription factors activate Heat Shock Proteins (HSPs) and ROS-scavenging enzymes, which protect against HS-induced protein unfolding and oxidative stress. The expression of histone deacetylases (HDACs) was upregulated in *Zea mays* during cold stress which leads to the deacetylation at lysine residues of histone subunits H3 and H4 (Hu et al., 2011). Low temperature usually deteriorate the physiology of plants which cause chilling injury, apoptosis, chlorosis, damage to the membranes and eventually leads to wilting of plants. Precocious flowering during autumn or winter is a floral regulatory process which prevent precocious flowering during autumn or winter. It is a memory response correlated with epigenetic regulation.

Conclusion

Epigenetics is important regulatory mechanism in plants influenced by environmental stimulus. The changes are inherited over generations which contribute significant role in providing stress tolerance to plants. Modern high-throughput techniques help us to identify epigenetic changes and knowledge on the effect of epigenetic changes in gene regulation. Manipulation of DNA at specific loci helps to regulate gene expression and neighbouring chromatin which leads to modification of cell physiology and biochemistry. One of the unexplored ways to improve stress tolerance is to enhance stress memory in plants by the modification of epigenome using biotechnological approaches. Hence epigenetic variation remains as an alternate solution for developing abiotic stress tolerant crop varieties.

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Beginner's Guide to Starting a Vegetable Garden at Home

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There is a unique sense of fulfilment in plucking a ripe tomato from a plant you have nurtured or adding crisp, home-grown lettuce to a freshly prepared salad. Beyond the pleasure of vibrant flavours, vegetable gardening has grown into a meaningful movement one that reconnects individuals with nature, lowers household food expenses, and supports sustainable living practices (Algert et al., 2016). As urbanization expands and food prices continue to rise, an increasing number of people are turning to their own yards, balconies, and even windowsills to cultivate fresh produce. The encouraging part is that successful gardening does not require vast land or specialized agricultural knowledge. With a bit of planning and care, anyone can begin growing nutritious vegetables at home. Whether you are an urban resident working with a few containers or a homeowner tending a backyard plot, this guide will equip you with essential knowledge from garden planning and planting techniques to harvesting and enjoying a thriving supply of home-grown produce.

Let's dig in.

Why Grow Your Own Vegetables?

Before you grab a trowel, it's worth understanding why vegetable gardening is such a powerful and rewarding pursuit. Store bought produce often travels long distances before it reaches your plate, losing nutrients and flavour along the way, while home-grown vegetables can be enjoyed at their nutritional peak bursting with vitamins, minerals, and natural sweetness. Growing your own food is also a meaningful step toward sustainability, reducing your carbon footprint by cutting transportation emissions and packaging waste, and encouraging eco-friendly practices such as composting and water conservation. Beyond environmental benefits, a home garden supports food security and helps lower household expenses, as even a small space can yield fresh vegetables throughout the season. Gardening also nurtures the mind and body; it offers gentle physical activity and serves as a therapeutic escape, with research showing that spending time in green spaces can reduce stress, improve mood, and enhance overall well-being (Soga et al., 2017). Simply put, growing your own vegetables is good for your health, your wallet and the planet.

Planning Your Garden: Start Small, Dream Big

Like any worthwhile project, success in gardening starts with careful planning. Choosing the right location is essential, as most vegetables require at least six hours of sunlight per day; take time to observe your yard, balcony, or patio to find a well-lit area that is also sheltered from strong winds. Even if outdoor space is limited, many vegetables can still thrive in containers or on sunny window ledges with the proper care. It is also wise to start small, since one of the most common beginner mistakes is planting too much too soon. Beginning with a modest plot—such as a 1×2 meter raised bed—or a few large containers for herbs and compact crops like lettuce or radishes allows you to learn what works in your environment before expanding. Additionally, knowing your growing zone will help you choose plants suited to your climate.

Getting to Know Your Soil (or Creating It)

Healthy plants begin with healthy soil, making soil preparation one of the most important steps in gardening. If you have a backyard, start by testing your soil using an inexpensive kit to check pH and nutrient levels, as most vegetables grow best in slightly acidic to neutral soil (pH 6–7). Loosen compacted areas and mix in organic compost or well-rotted manure to improve fertility, drainage, and microbial activity. If your native soil is poor or you are gardening on a patio or paved area, raised beds or containers are excellent alternatives. Raised beds offer improved drainage and easier maintenance, while containers can support a wide range of crops, from tomatoes and peppers to greens and carrots. Just be sure that any pot has proper drainage and is filled with a high-quality potting mix rich in organic matter to support strong, productive plants.

Choosing the Right Vegetables

When starting out, it's best to focus on easy, fast-growing vegetables that offer quick rewards and help build your confidence as a gardener. Some of the best choices for beginners include tomatoes especially compact or cherry types for small spaces along with fast-growing greens like lettuce and spinach, crunchy radishes that can be ready in just 3–4 weeks, productive green beans and versatile herbs such as basil, mint and parsley, which thrive in containers and offer continuous harvests. Vigorous crops like cucumbers and zucchini also provide generous yields with minimal effort. As you plan, it's wise to grow what you genuinely enjoy eating, since the most satisfying garden is one that fills your plate with your favorite ingredients. You can also boost garden health and productivity through companion planting, such as pairing tomatoes with basil to repel pests, growing carrots alongside onions to deter insects, or planting marigolds to protect a variety of crops. A thoughtful mix not only improves yields but adds beauty and diversity to your garden.

The Art of Planting: Getting Your Hands Dirty

Now comes the fun part planting! Gardeners can begin either from seeds or by purchasing young seedlings from a nursery. Seeds are more affordable and offer a rewarding experience, while seedlings save time and often provide quicker results for beginners. When sowing seeds, always read the packet for correct spacing and planting depth, water gently but consistently and be patient, as germination may take anywhere from a few days to two weeks. Proper spacing is essential to avoid overcrowding, which can reduce airflow and increase the risk of disease; if a packet recommends 12 inches of space, it is best to follow that guidance for stronger plants and improved harvests. Watering is another key factor in plant success. Most vegetables need about one inch of water per week, though this can vary by climate and crop. Water deeply and less frequently to encourage strong root systems and aim to water in the morning so foliage can dry during the day, reducing the chances of mold or mildew development.

Feeding Your Plants Naturally

Fertilizers can certainly boost plant growth but using too much can harm both plants and long-term soil health, so it is best to focus on natural sources of nourishment. Compost is one of the most valuable soil amendments, providing a balanced supply of nutrients while improving soil structure and moisture retention. Organic fertilizers made from materials such as seaweed, bone meal or worm castings can also support healthy growth without the harsh effects of synthetic chemicals. In addition, applying mulch whether straw, dried leaves, or a layer of compost helps retain soil moisture, suppress weeds, and slowly enrich the soil as it breaks down. Ultimately, thriving gardens are built on living, biologically active soil, and when you feed the soil, it will continue to feed your plants in return.

Keeping Pests and Problems Under Control

Every gardener, no matter how experienced, faces occasional challenges from aphids and slugs to hungry birds but the key is to stay observant and act early. Instead of reaching for harsh chemical pesticides that may harm beneficial insects, eco-friendly methods can help maintain balance in the garden. Hand-picking pests may feel tedious, but it is effective for small spaces, while neem oil or insecticidal soap offers a safer option for most vegetables and pollinators. Companion planting can also provide natural pest protection, and attracting beneficial insects such as ladybugs, lacewings, and bees strengthens your garden's defenses (Gurr et al., 2012). Just as important, healthy plants are naturally more resistant to pests and diseases, so focus on keeping them strong through good soil nutrition, crop rotation, proper watering, and regular removal of weeds and dead leaves. A clean, well-maintained garden not only limits pest problems but also supports a thriving ecosystem where plants can grow their best.

Harvest Time: The Reward for Your Effort

There's no moment quite like your first harvest the pride of holding a vegetable you grew with your own hands is truly unforgettable. Each crop offers unique signs to let you know it's ready: tomatoes should be firm, evenly colored, and just slightly soft to the touch; lettuce can be harvested by cutting the outer leaves first to encourage continuous growth; beans and peas benefit from frequent picking, which stimulates more pod production; and for root vegetables, a gentle check of one plant can help you determine whether it has reached the right size. Regular harvesting keeps plants productive and prevents energy from being wasted on overripe produce. And remember, the cycle doesn't end once the vegetables leave the garden your kitchen scraps can go right into the compost bin, turning today's left overs into tomorrow's fertile, nutrient-rich soil.

Gardening Through the Seasons

With a bit of planning, you can enjoy homegrown vegetables throughout the entire year. In spring, it's time to start seeds indoors or sow early crops such as peas, lettuce, and radishes. Summer brings the peak of the growing season, when tomatoes, peppers, beans and zucchini flourish in the warm sun. As autumn arrives, gardeners can harvest root crops and plant cool-weather greens like kale, spinach, and carrots. Winter still holds opportunities: in mild climates, hardy vegetables may continue to grow, while in colder regions it becomes the perfect time to prepare soil, build compost, and plan the layout for the coming season. Each season carries its own rhythm and rewards, turning gardening into a continuous journey of learning, nourishment, and renewal.

Small Spaces? No Problem!

Even without a backyard, you can grow a surprising amount of fresh food by using creative gardening methods suited to small spaces. Container gardening allows you to use pots, window boxes, or hanging planters for herbs, lettuce, and cherry tomatoes, and lightweight containers can easily be moved to follow the sunlight throughout the day. Vertical gardening is another smart solution, making use of trellises, wall planters, or hanging baskets to grow crops like beans, cucumbers, and strawberries upward instead of outward. Indoor gardening is equally rewarding; with sufficient natural light or LED grow lights, you can cultivate herbs, microgreens, and even compact pepper varieties all year long. The key is creativity and adaptability no space is too small to grow something green and delicious.

Common Mistakes Beginners Make (and How to Avoid Them)

Even the best gardeners make mistakes, but most are easy to correct with a bit of awareness. One common issue is overwatering, which can drown roots in soggy soil, so it's always wise to check moisture levels before adding more water. Crowding plants is another frequent error, as adequate spacing is essential for healthy growth. Many gardeners also overlook sunlight requirements, yet most vegetables need about six hours of direct sun each day to thrive. Soil health is another key factor and neglecting to enrich it with compost can leave plants struggling for nutrients. Finally, it's important to remember that gardening rewards patience growth takes time, and expecting instant results can lead to disappointment. Every misstep is simply part of the learning process, bringing you one step closer to becoming a more confident and successful gardener.

The Joy of the Harvest Table

Perhaps the most magical part of gardening comes after the harvest when you turn your homegrown vegetables into delicious meals. Imagine a summer salad bursting with your own cucumbers and tomatoes, a comforting soup enriched with freshly picked herbs or a crisp carrot pulled from the soil just minutes before dinner. The flavor difference is undeniable and the sense of satisfaction is incomparable. Many gardeners find that growing their own food deepens their appreciation for cooking and encourages them to use ingredients more thoughtfully. Because each vegetable is the result of patience and care, very little goes to waste and every harvest becomes an opportunity to create something nourishing and memorable.

Conclusion: From Seeds to Satisfaction

Starting a vegetable garden at home isn't just about producing food it's about cultivating a lifestyle of mindfulness, sustainability, and joy. It reminds us that food doesn't begin on a supermarket shelf but in the soil beneath our feet. Whether your garden fills a backyard or sits within a single window box, every plant you grow connects you more deeply with nature and the rhythms of life. Along the way, you will make mistakes, learn, and grow much like the plants you nurture. So roll up your sleeves, feel the soil between your fingers, and plant the first seed. In just a few weeks, you'll taste the delicious reward of your efforts and discover that the real harvest is not only fresh vegetables, but also a profound sense of connection, pride, and peace.

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Plant Tissue Culture Techniques of Tropical Tuber Crops Utilized For Developing Pest and Disease Free Plantlets

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Tissue culture is a technique which is used to produce plants in sterile nutrient rich controlled environment. This technique works based on the property of the plant cells called totipotency. The technique originated at 20th century by Gottlieb Haberlandt who proposed concept of *in vitro* cell culture and recognized as the father of plant tissue culture. It is now used for functional gene studies, for developing transgenic plants and also used with the emerging technologies such as the genome editing. The application of tissue culture with *Agrobacterium tumefaciens* infection play important role in genetic manipulation of plants with desirable traits. The first true plant tissue cultures were obtained by Gautheret from cambial tissue of *Acer pseudoplatanus*. The various techniques used in tissue culture were callus culture, anther culture, embryo culture, ovary culture, cell suspension culture and protoplast culture. The important tissue culture techniques used in tropical tuber crops are meristem culture, micropropagation, and somatic embryogenesis.

Meristem culture

It is a technique widely used in potato, cassava, yam and sweet potato for producing virus free plants. Meristems are the actively dividing tissues at the shoot tip. Meristem culture with thermotherapy is an effective method for producing virus free plants in cassava. Heat treatment (thermotherapy) is often done to cassava plants before meristem culture. This will helps to reduce viral load and increase the chances of successful virus elimination from the meristem. The meristematic tip with one or more leaves was cultured to the medium with growth regulators. The method is widely used in potato for producing virus free plants. The technique along can be used for eliminating the sweet potato virus complex from sweet potato.

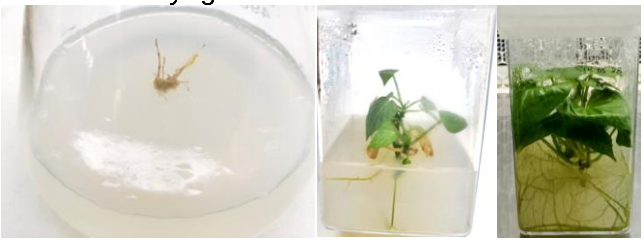
Micropropagation

A technique used to rapidly multiply plants from small tissue samples, including tuber crops like potatoes. Single node cuttings were used for the propagation of virus tested clones of cassava, yams and sweet potato. Single node cuttings were placed in liquid culture medium for one month to induce multiple shoot formation and subsequently sub culturing the node cuttings in solid media. Ng and Hahn 1985, Ng 1988b). The method is used for producing disease-free seed potatoes and for conserving germplasm. Micropropagation involves several stages, including the initiation and multiplication of shoots, rooting, and acclimatization of plantlets. The technique is used for the quick production of a large number of plants from a single explant, which can be used for meeting the producing disease free planting material on large scale. It is widely used for producing potato, cassava, and yam propagation, ensuring a consistent supply of high-quality planting material. It is also used for conserving the germplasm on large scale.

Somatic embryogenesis

The first report of somatic embryo from cultured cells of *Daucus carota* is reported by Reinert 1958 and Steward et al., 1958. Since then the somatic embryogenesis of a number of plant species were reported and the clonal propagation of many genotypes on large scale is possible through this method. The main four steps of embryogenesis is induction of embyogenesis, embryo development, embryo maturation and conversion. Among them the first two steps deals with inducing the cells for the formation and development of embryos. The third step is preparing the embryo for germination and fourth refers to formation of somatic seedlings and growth. The same technique where plant embryos are developed from somatic (non-reproductive) cells, is used for propagating tuber crops like potatoes, yams, and cassava. Emerging technique for cassava and other tuber crops. The regeneration of sweetpotato through somatic embryogenesis has been reported from 1980s in several cultivars (Karamian and Ebrahimzadeh

2001; Sivparsad and Gubba). Similarly in the case of cassava various explants sources like axillary buds, protoplasts, shoot apices, were used for somatic embryogenesis.



Sweetpotato plants developed from apical bud method

In vitro microtuberization

Tuberization is a physiological process that is influenced by various factors, such as concentration and carbohydrate source, light intensity and plant growth regulators (Kerbauy and Fisiologia 2019). In tuberous plants microtuberization can be induced by *in vitro* methods from explants originated from apical and nodal parts of plants (Ovono et al., 2010). Eventually these can be used as propagative materials for pest and disease free plant materials. Particularly useful for potatoes and other tuber crops especially yams, which allows the efficient storage and distribution of good quality planting materials. The vegetative propagation of yams has limitations such as low sprouting index, dormancy, contamination of pathogens and pest infestation. In order to overcome these challenges the alternative methods to improve production of yam seedlings is induction of *in vitro* tuberization and the microtubers obtained from this methods can be used for the propagation of this crop. It is also used as an effective method for the international distribution of virus tested clonal germplasm in yams.

Anther culture

Anther culture is practiced in cassava for producing haploid plants which will be subsequently used for producing homozygous diploids. It is one of the technique where immature haploid male gametophytes are developed to haploid or doubled-haploid embryos. It is cost effective method with minimum input requirements compared to other microspore culture techniques. Callus was obtained from the anther culture from B5 medium supplemented with sucrose, coconut water and gelrite. The calluses will be transferred to the MS medium with sucrose, kinetin, IAA and gelrite. The MS medium without growth hormones will develop into protocom like structures and roots (Ng 1992). The anther culture was reported in cassava for generating homozygous plants (Perera et al., 2014a; Perera et al., 2014b).

Embryo/ovule culture

Cassava being an allotetraploid (2n=4x=36) and is a highly heterozygous crop (Fregene et al., 1997). The hybridization between cassava and its related wild Manihot sp. is done for developing pest and disease resistant varieties. But the germination percentage of seeds from wild species plays an important role and was low in some cases. So embryo culture was used in cassava to germinate embryos isolated from wild seeds and first reported in cassava by (Biggs et al., 1986; Fregene et al., 1999). Even immature embryo culture is also a technique that can also be used to rescue the hybrids which are difficult to germinate by conventional methods. Various methods have been developed for the treatment of mature seeds and for culture of mature seeds in cassava (Ng 1989).

Conclusion

The biotechnological research for producing disease – pest free cassava, sweet potato and yam, tissue culture plants by invitro culture is important for the rapid multiplication. Since more research needs to be done with molecular markers is useful for the rapid identification of offtype plants.

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Mango Leaf Webber (*Orthaga exvinacea*): Biology, Damage and Integrated Pest Management

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The mango leaf webber, *Orthaga exvinacea* (family Pyralidae, order Lepidoptera), constitutes a major constraint to mango production, causing severe yield losses under unmanaged conditions. Infestations can result in 25-100% production loss and an average yield reduction of 61.51%, accompanied by increased fruit drop (from 38.51% to 50.58%) and a decline in fruit set (from 378 to 232 fruits per tree) (Polu et al., 2022). In India, where mango is cultivated over approximately 2.29 million hectares, such damage poses a substantial threat to grower livelihoods across South Asia. However, timely implementation of integrated pest management (IPM) strategies has been shown to restore yields to 61–66 quintals per hectare with benefit-cost ratios exceeding 4.0, indicating that economic gains markedly outweigh management costs (Polu et al., 2022). In the context of climate change-driven increases in pest pressure, the adoption of integrated and sustainable management approaches is therefore imperative for mango cultivation.

Biology

Egg Stage: Females deposit oval, flattened eggs 0.84mm × 0.56mm singly or in small groups near the midrib or along leaf veins. Eggs are initially pale yellowish to green, turning light pink before hatching. Females produce an average of 58 eggs during their reproductive lifespan (Kavitha et al., 2005).

Larval Stage: First and second instars are pinkish to light green with brown heads, scraping chlorophyll and causing patchy damage in 4.80±0.92 and 4.65±0.90 days. Third and fourth instars are dark greenish, consuming webbed leaves from margins inward, leaving major veins intact in 4.65±0.90 and 4.16±0.87 days. Fifth and sixth instars are dark greenish-black to greyish-green with brown prothoracic spots, developing in 4.52±0.51 and 5.20±0.42 days. Seventh instar is stouter, lighter-colored, with reduced feeding during 6.50±0.53 days pre-pupal phase; larvae reach 2-3cm. (Shrestha et al., 2022).

Pupal stage: Mature larvae enter a non-feeding pre-pupal phase, becoming cream-colored and constructing silken cocoons. Pupation occurs within webbed leaves, producing a dark brown, obtect pupa. Female pupae were significantly larger (13.69 × 5.60 mm) and developed more slowly (14.30 ± 1.43 days) than males (12.14 × 4.25 mm; 11.80 ± 0.63 days) (Kavitha et al., 2005).

Adult stage: Adult moths are sexually dimorphic, medium sized grey-brown insects with brown forewings and dirty white hindwings. Females are larger 13.22±0.20mm and longer-lived up to 5.80±0.42 days than males 11.54±0.33mm; 4.10±0.74 days (Kavitha et al., 2005).

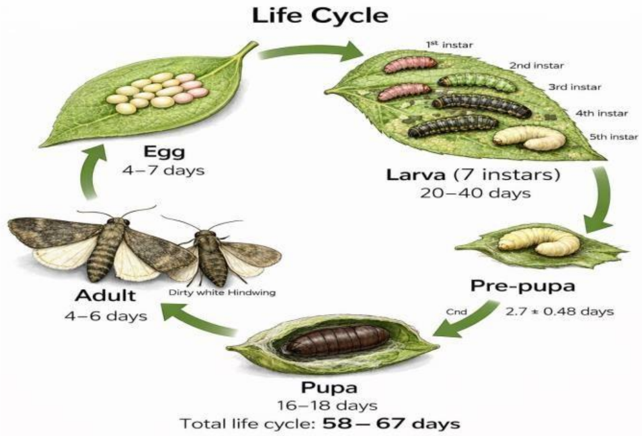

Fig 1. Life stages of mango leaf webber

Damage Symptoms

The primary damage occurs on leaves, where larvae are the economically damaging stage, feeding gregariously on soft leaf tissue by scraping the lamina while leaving midribs and vein networks intact, creating a skeletal appearance. They construct silken webs made from proteins secreted by the insect's silk glands (Gamit et al., 2022) to bind multiple leaves into cluster-like nests, within which several caterpillars feed voraciously. Infested leaves dry but remain attached due to webbing entanglement. Severe infestations cause terminal shoot webbing, giving trees a burnt appearance and prevents flowering and fruiting causing complete reproductive failure. Young trees (less than 5 years) show lower infestation levels, while mature trees with 15+ years exhibit significantly higher populations (121.61 larvae/ tree, 18.26 webs/ tree, 348.75 webbed leaves/tree).

Fig 2. Damage caused by leaf webber in mango plant

Ecology and Occurrence

Peak populations of mango leaf webber occur in early-to-mid November during the August-December active season (Kasar et al., 2017). High humidity and rainfall favor pest proliferation, while host cultivar susceptibility significantly influences infestation severity. Minimum temperature negatively correlates with pest abundance in resistant varieties, though susceptible varieties maintain high populations regardless of temperature. Populations collapse after late December as conditions become unfavorable, and from January through April, no webber populations are observed on foliage, providing a predictable ecological pattern for targeted management strategies. (Parameshwar et al., 2024). Two Orthaga species i.e. Orthaga exvinacea and O. euadrusalis are major mango pests in South and Southeast Asia. O. exvinacea is primarily distributed in southern India including Tamil Nadu, Andaman Islands, Kerala and has been recorded in West Bengal and Odisha.

Integrated Pest Management

Cultural Control

- ***Orchard Management:*** Mango leaf webber infestations are more severe in old, unmanaged orchards with dense canopies thus; replace older plantings with dwarf, resistant varieties that are easier to manage. Infestation intensity is significantly higher on the western and southern tree aspects, so prioritize surveillance and management on these sides. Prune overcrowded and overlapping branches to reduce webber habitat, improve air circulation, and facilitate pest monitoring.
- ***Sanitation and Field Hygiene***: Regularly collect and burn fallen leaves to remove protective microhabitats where pupae overwinter. Deep ploughing during November-December disrupts soil pupae and exposes them to direct sunlight, thermal stress, and predatory natural enemies, significantly reducing survival rates.
- *O. exvinacea* being an oligophagous pest, is primarily specific to mango, with cashew recorded as a secondary host. Remove nearby cashew and Anacardiaceae plants from orchards to eliminate pest reservoirs.

Mechanical Control

- Web Removal and Destruction: Manually break and remove webbed leaf clusters to expose larvae and caterpillars to lethal desiccation and heat. Throughout the growing season, regularly prune and burn infested shoots to eliminate all developmental stages and prevent population buildup.
- ***Trunk Banding:*** Wrap tree trunks with alkathene sheets (400 gauge) at 30 cm above ground level with 25 cm width and apply grease barriers to prevent larvae from crawling up the trunk and establishing new feeding sites on canopy foliage.

Biological Control

Entomopathogenic Fungal Application: Spray *Beauveria bassiana* at 5 ml/liter of water two to three times during high humidity periods to suppress webber larvae effectively. Apply during early morning or late evening when environmental conditions favor fungal spore germination and infection.

Botanical Pesticides: Apply nimbicidine at 0.2% concentration 2 ml/liter of water as a safe botanical pesticide to effectively manage webber populations without harming beneficial organisms. Use at the initial stage of infestation for optimal results (Shrestha et al., 2022).

Legal and Regulatory Control: Enforce strict quarantine on movement of mango plant parts, propagules, fruits, and fodder to prevent pest dispersal to new regions. Monitor intra-national mango plant movement for early detection and rapid response. Originally from India, this pest has invaded Sri Lanka, Indonesia, and Japan, necessitating urgent preventive measures across mango-growing nations (Shrestha et al., 2022).

Table 1: Natural enemies for management of mango leaf webber populations

Natural Enemy	Type	Dose/ha	Life Stage Attacked
Brachymeria lasus	Parasite	5,000-10,000 pupae	Larvae
Hormius sp.	Parasite	5,000-8,000 individuals	Larvae
Pediobius bruchicida	Parasite	4,000-6,000 individuals	Larvae
Tetrastichus sp.	Parasite	4,000-6,000 individuals	Larvae
Hormiusa sp.	Parasitoid	3,000-5,000 individuals	Larvae
Goniozus sp.	Parasitoid	3,000-5,000 individuals	Larvae
Parena lacticincta	Predator	----	Larvae
Oecama sp.	Predator	---	Larvae
Beauveria bassiana	EPF	10%WP 5000 ml	Larvae
Serratia marcescens	EPB	--	Larvae
Bacillus thuringiensis	EPB	5%WP 1500 ml	
Aspergillus flavus	EPF	--	General suppression

Source: Adapted from Shrestha et al., 2022

Chemical Control

Chemical control of mango leaf webber should be undertaken only after crossing the economic threshold level following CIBRC guidelines, applied at the prescribed dose and timing. Sprays should be need-based, well-targeted to early larval stages, and rotated among different modes of action to avoid resistance development. Care must be taken to observe pre-harvest intervals, ensure proper coverage, and protect natural enemies, thereby promoting judicious and sustainable pesticide use.

Conclusion

Mango leaf webber causes severe damage to mango orchards by feeding gregariously on leaf tissue and constructing silken webs that bind multiple leaves, resulting in 25-100% production loss if unmanaged. Effective management of this pest requires combining multiple strategies in a coordinated manner. Integrated management combining cultural practices, biological controls, quarantine, mechanical removal, and selective pesticides outperforms individual methods for leaf webber control while minimizing pesticide dependence and maintaining economic productivity and environmental sustainability.

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