Technical bulletin No.2025/51

Package of Practices for Cultivation of Dragon Fruit in Multiple Stressed Areas






ICAR-National Institute of Abiotic Stress Management
Malegaon, Baramati- 413 115, Pune,
Maharashtra, India

Package of Practices for Cultivation of Dragon Fruit in Multiple Stressed Areas

Kakade V.D., Boraiah K.M., Salunkhe V.N., Morade A.S., Chavan S.B., Nangare D.D., Priyanka Jadhav, Rinku Dey and Reddy K.S.

2025

ICAR-National Institute of Abiotic Stress Management
Malegaon, Baramati- 413 115, Pune,
Maharashtra, India

भाकृअनुप
ICAR

राअस्ट्रैप्रसं
NIASM

Citation

Kakade V.D., Boraiah K.M., Salunkhe V.N., Morade A.S., Chavan S.B., Nangare D.D., Priyanka Jadhav, Rinku Dey and Reddy K.S., 2025. Package of Practices for Cultivation of Dragon Fruit in Multiple Stressed Areas. Technical bulletin No.2025/51, pages- 32.

Published by

Director, ICAR-National Institute of Abiotic Stress Management

ISBN No.: 978-81-985897-8-1

Contact

ICAR-National Institute of Abiotic Stress Management
Malegaon Kh., Baramati, Pune, Maharashtra 413 115, India
Phone: +91-2112-254055/57/58/59
Fax: +91-2112-254056
Email: k.sammireddy@icar.org.in

PREFACE

Dragon fruit, a member of the cactus family, holds great promise for diversifying fruit cultivation in India's semi-arid and degraded soil regions. With its high market demand, rich nutritional profile, and low water requirement, it is particularly well-suited to shallow basaltic light soils, provided that appropriate agronomic practices are followed.

This technical bulletin is designed to provide an integrated overview of dragon fruit cultivation under abiotic stress scenarios, particularly in regions affected by heat stress, water scarcity, and poor soil fertility. It covers key topics such as the importance of the crop, ideal soil and climatic conditions, propagation methods, recommended planting systems, training and pruning, expected yield levels, and pest and disease management strategies. The content is drawn from both research findings and practical field insights tailored for stressed ecosystems.

We believe that this publication will serve as a ready reference for progressive farmers, extension personnel, and young researchers who are exploring the potential of dragon fruit as a sustainable crop option in challenging environments.

We express our sincere gratitude to the past Directors of the ICAR-NIASM, Baramati for continuous encouragement and support during research work carried out on different aspects of dragon fruit and in bringing out this bulletin.

Authors

Importance

Dragon fruit or pitaya (*Selenicereus* spp., previously known as *Hylocereus*), are perennial semi-epiphytic vines from the Cactaceae family. These plants are native to the tropical and subtropical forests of Mexico, Central America, Northern South America, and the West Indies (Valiente-Banuet et al., 2007; Le Bellec et al., 2006). Recently, the fruit has surged in popularity due to its exceptional nutritional properties, potent antioxidant capabilities, minimal cultivation needs, and high profitability (Nangare et al., 2020, Kakade et al., 2020). Dragon fruit is packed with nutrients, including antioxidants like betalains and phenolic compounds, dietary fibres, vitamins, and minerals, while being low in sugar (Chatterjee et al., 2024, Perez et al., 2007, Khalili et al., 2009). Its consumption is linked to numerous health advantages, such as lowering blood cholesterol and reducing the risk of various diseases, including cancer, diabetes, cardiovascular issues, and infections of the respiratory, gastrointestinal, and urinary tracts (Chatterjee et al., 2024, Khalili et al., 2009). Furthermore, it promotes eye health and is often recommended for weight management due to its high fibre content and low-calorie nature (Tenore et al., 2012; Wichienchot et al., 2010). Dragon fruit can be enjoyed fresh or processed. Its eye-catching bracts, vibrant red-purple or white flesh, and small edible black seeds make it a popular choice in fruit salads. It is also extensively used to make juice, jam, jelly, candy, syrup, and wine (Islam et al., 2012). The peel is rich in pectin, betalains, phenols, dietary fibres, and natural food colorants. Its ability to thrive in various soils and climates, along with its excellent nutritional profile, commercial potential, and appeal to health-conscious consumers, has earned it the reputation of a super fruit. Despite this, dragon fruit cultivation in semi-arid regions faces several challenges including extreme weather events like heat waves and heavy rains during flowering reduce pollination, causing bud drop, misshapen fruits, and yield loss. High temperatures lead to heat stress and sunburn, affecting fruit quality. Waterlogging in heavy soils and moisture deficits in light soils also hinders root growth and plant health. Diseases such as stem canker and anthracnose, along with insect pests, pose serious threats. Poor canopy management worsens disease problems. Limited pollinators, complex pollination needs, and inadequate nursery practices further restrict fruit set and quality planting material.

Area and production

The rapid expansion of dragon fruit cultivation to over 30 countries within a relatively brief period highlights its increasing global popularity. Vietnam is the leading country in terms of both acreage and production of dragon fruit. Table 1 presents a comprehensive overview of the countries engaged in dragon fruit cultivation (Le Bellec et al., 2006; Mizrahi, 2014; Karunakaran and Arivalagan, 2019). Dragon fruit cultivation in India is rapidly expanding nationwide, with the primary regions include Maharashtra, Gujarat, Andhra Pradesh, and Telangana, with notable cultivation also occurring in Kerala, West Bengal, Karnataka, Tamil Nadu, Odisha, Arunachal Pradesh, Nagaland, Manipur, and Mizoram. Furthermore, sporadic cultivation has been documented in states such as Punjab, Chhattisgarh, Uttar Pradesh, Bihar, among others, highlighting its potential across diverse agro-climatic zones.

Table 1: Distribution of dragon fruit across the globe

Continents	Growing countries/states
Australia	Australia
Asia	China, India, Indonesia, Israel, Malaysia, Taiwan, Thailand, Sri Lanka, Bangladesh, Vietnam, Myanmar, Philippines, Japan, Cambodia, Singapore, South Korea,
Europe	Italy, Spain, Netherlands, Portugal
North America	Canada, Mexico, Guatemala, Costa Rica, Nicaragua
South America	Colombia, Brazil, Ecuador
Africa	Tanzania, Uganda, Zambia, Reunion Island
Oceania	Hawaii, New Zealand

Soil requirements

Dragon fruit demonstrates significant adaptability to a diverse array of soil types, including sandy, sandy loam, sandy clay loam, clay, and gravel soils (Chakma et al., 2014). Dragon fruit thrives in soils with a pH range of 5.5 to 8.5 (Chakma et al., 2014, Yuqing et al., 2015), with a preference for slightly acidic conditions, particularly in high-rainfall areas. It is also well-suited for cultivation on non-arable and degraded lands, such as rocky and barren terrains derived from basaltic parent material with minimal soil development, desert soils, and erosion-prone gully beds of ravine areas characterized by low water retention capacity-locations where options for fruit crop cultivation are typically limited (Nangare et al., 2020; Jinger et al., 2024a; Jinger et al., 2024b). In the context of deep Vertisols, ensuring adequate drainage is crucial to prevent waterlogging during the rainy season (Kakade et al., 2022). Waterlogged conditions impede plant growth and development, while promoting the proliferation of stem and root rot pathogens. Raised bed planting is a practical approach to maintain a well-aerated root zone free from excess moisture (Velmurugan et al., 2016). In semi-arid regions with light-textured soils and low water retention, smaller raised beds are generally sufficient (Fig. 1). Investigations into the root system of 8-year-old plants reveal that anchoring roots extend up to 1.5 m horizontally. The fibrous root structure, with 50% of root mass concentrated in the top 30-60 cm of soil, suggests that soil depth may not be a limiting factor for cultivation (Kakade et al., 2022). This characteristic renders dragon fruit an excellent candidate for expanding cultivation into shallow and degraded lands.

Figure 1: Dragon fruit plantation in rocky *murrum* soils at ICAR-NIASM, Baramati

Climate

These plants thrive in tropical climates characterized by warm, humid conditions and evenly distributed rainfall in open areas (Ortiz-Hernandez and Carrillo-Salazar, 2012). Optimal growth is observed in environments with average annual temperatures ranging from 20 to 30 ºC and relative humidity between 60 and 80% (Nerd et al., 2002). Dragon fruit flourishes within a temperature range of 13–35 °C and is highly vulnerable to extreme temperatures (<12 °C and >38 °C). The cultivation of dragon fruit has been successfully extended to regions with drier and warmer climates, such as India and Israel. Although the plants can withstand these conditions, their productive growth is often compromised without appropriate management strategies. In open-field conditions typical of such climates, heat stress presents a significant challenge, resulting in sunburn, increased susceptibility to diseases, stunted growth, flower drop, reduced fruit set, and overall plant vulnerability (Nerd et al., 2002; Patil et al., 2024).

Cladode sunburn typically occurs during summer when temperatures exceed 35 °C and photosynthetically active radiation (PAR) reaches 1480 µmol $m^{-2}s^{-1}$. Sunburn may also occur in early winter when the diurnal temperature variation reaches 20 °C, accompanied by similar PAR levels. The symptoms of sunburn include cladode bleaching, yellowing, browning, necrosis, and decay (Fig. 2) (Patil et al., 2024).

Figure 2: Sequential stages of sunburn injury in dragon fruit

To mitigate these issues, manipulation of the plant microclimate through shading during peak heat periods (April-May) is essential. Patil et al. (2024) found that 50% white and black shade nets were most effective in reducing heat stress and sunburn (>96%) in dragon fruit. Shading lowered canopy temperature by 3–7 °C, reduced solar radiation by 40–70%, and improved plant health by enhancing sprouting (28–84%), chlorophyll (28–79%), and yield (up to 67%). White 50% shading also boosted phenol and flavonoid content, while 35% white improved vitamin C levels. To use this shading technology for reduction of heat stress in dragon fruit during peak summer, install a shading structure 2.5 feet above the canopy using durable RCC poles or iron angles with a 'T', 'Y', or inverted 'V' top frame. Use a 50% shade net, preferably white or black, securely stretched to avoid sagging. Install shading from April–May or adjust based on weather, and remove once temperatures decline to avoid over-shading. Regular inspection and timely adjustments are essential for optimal performance. However, excessive shading either through use of shade nets having shade factor more than 50 % or keeping shade more that heat stress period should be avoided, as it can cause coiling of cladodes (Fig. 4 left), suppress flowering and fruiting by reducing photosynthetic activity and altering key physiological processes.

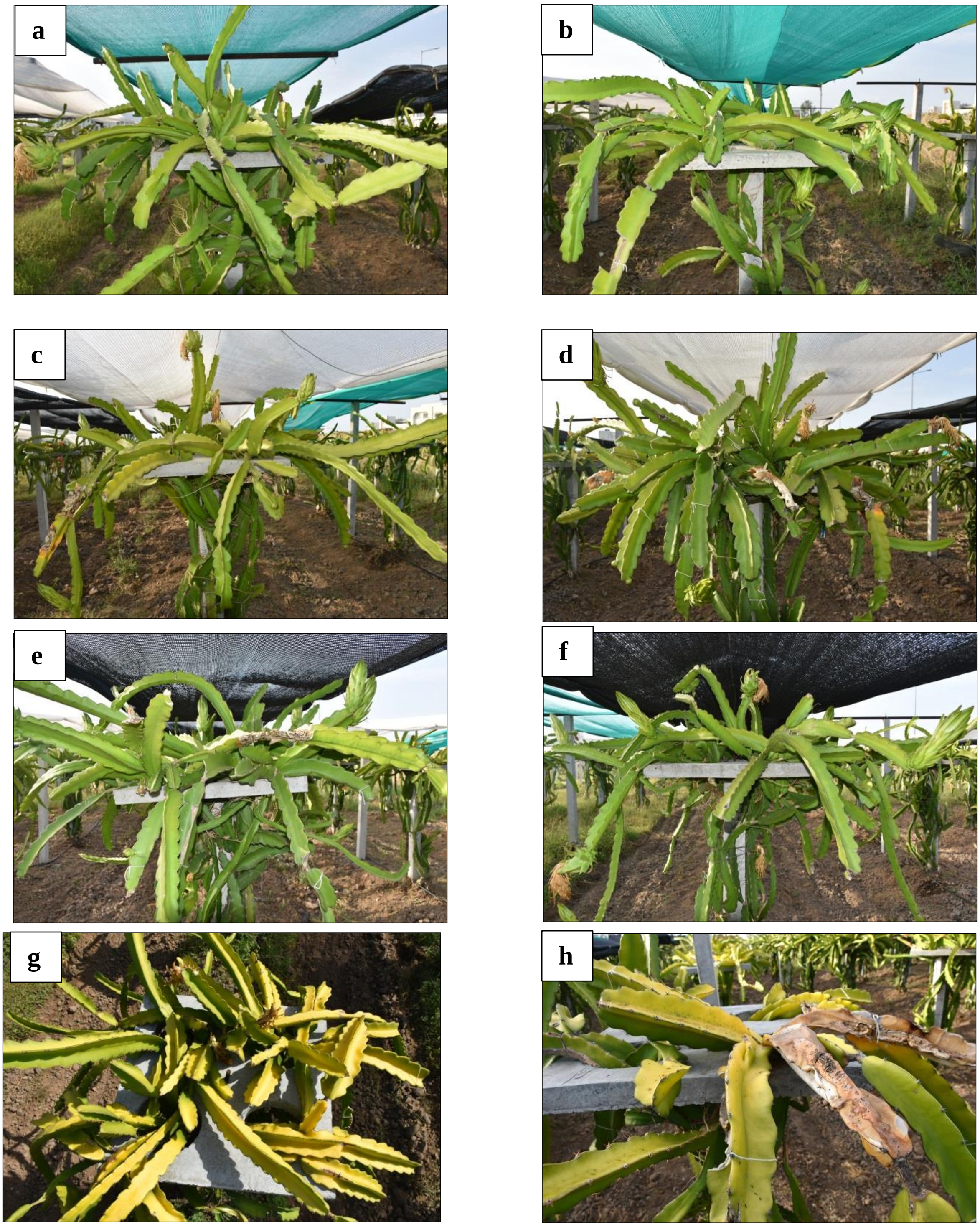

Figure 3. Comparison of plant growth and advanced flower buds in different shading treatments conducted at ICAR-NIASM, Baramati (a & b: Green 35% & 50%; c & d: White 35% & 50%; e & f: Black 35% & 50%; g & h: Control)

In addition to shading, sunburn can be mitigated through chemical interventions of anti-transpirants, such as the application of kaolin (**Coniberti et al., 2013**). Kaolin creates a reflective white coating on plant foliage, thereby effectively reducing canopy temperature. When applied at higher concentrations (8–10%), it can substantially decrease heat stress in dragon fruit from March to May (Fig. 4 right). Avoid applying kaolin sprays on cloudy or rainy days, as rainfall can wash it off, requiring repeat applications and increasing costs.

Figure 4: Effect of excess shading (left) and use of Kaolin to reflect sunlight (right)

Despite its sensitivity to temperature, dragon fruit demonstrates remarkable adaptability to a wide range of precipitation. It is cultivated commercially in regions with high rainfall, up to 3500 mm, as well as in arid and semi-arid areas with minimal rainfall, as low as 120 mm (Gunasena et al., 2007). This adaptability is primarily attributed to its exceptional drought tolerance and high water use efficiency (WUE), facilitated by significant internal water storage capacity (Mizrahi, 2014). The plant's unique morphological adaptations, including succulent stems, acicular leaves, water-rich fruits, sunken stomata, and Crassulacean Acid Metabolism (CAM) physiology, enable it to minimize transpiration and retain water under arid conditions. However, drought stress can negatively impact the development of new stems and hinder physiological processes such as water vapour conductance, CO_2 uptake, and photosynthesis (Ben-Asher et al., 2006; Nobel and De la Barrera, 2004; Nerd and Neumann, 2004). As a survival strategy during drought, the plant reallocates biomass towards root development, reducing aboveground growth, which can subsequently limit fruit production (Yuqing et al., 2015). Therefore, maintaining a consistent water supply during dry periods is crucial for optimal growth and yield. Conversely, excessive rainfall can adversely affect both vegetative and reproductive growth by causing waterlogging and soil saturation. Thus, ensuring proper drainage is essential to prevent waterlogging in orchards.

High precipitation levels can disrupt reproductive processes, particularly during flowering and pollination. Rainfall during this critical period can wash away pollen, resulting in reduced fruit set, smaller fruit size, and increased rates of premature fruit drop. Crop losses of up to 70% have been reported when rainfall coincides with flowering, and even light precipitation (1–2 mm) during this stage can negatively impact final fruit size due to poor pollination (Ortiz-Hernandez and Carrillo-Salazar, 2012; Boraiah et al., 2022). Prolonged moisture and frequent rainfall also create favourable conditions for the proliferation of fungal and bacterial diseases (Hieu et al., 2018). Therefore, preventing waterlogging and ensuring adequate air circulation are essential strategies to mitigate these risks and support healthy crop development. They demonstrate adaptability to a wide range of altitudes, from 2 to 2750 meters above sea level (Sudarjat et al., 2019). Flower bud induction is facilitated by day lengths exceeding 12 hours, in conjunction with rainfall, high humidity (>80%), and moderate temperatures.

Propagation and nursery management

Propagation through cuttings is a straightforward, efficient, and commercially viable method (Fig. 5) for dragon fruit cultivation (Le Bellec et al., 2006; Kakade et al., 2019). Alternative approaches include grafting, tissue culture, and occasionally seed propagation (Yassen, 2002; Vinas et al., 2012). Grafting is occasionally employed to utilize robust rootstocks or to enhance the vigour of scions with weak growth tendencies. *S. undatus* is a commonly used rootstock due to its accessibility and adaptability to local environments. This technique imparts vigour and resistance to the scion while promoting early bearing (Jiang et al., 2011). However, while cuttings offer a simple and cost-effective propagation method, grafting, although facilitating rapid varietal conversion, requires specialized skills. Conversely, tissue culture ensures disease-free plantlets but incurs higher costs and technical complexity. For cuttings, mature cladodes aged over 10-12 months and displaying a dark green colour, typically 15 to 60 cm in length, are ideal. Larger cuttings are generally preferred due to their greater food reserves, which support better rooting and shoot development (Kakade et al., 2019). Premature cuttings should be avoided as they lead to delayed rooting and poor plant growth and development. As cuttings contain 80–90% water, they are highly susceptible to soil-borne pathogens if planted directly. To reduce disease risk and promote healthy establishment, curing the cuttings before planting is essential. This involves placing the fresh cuttings in a shaded area for at least 4-5 days prior to nursery planting (Kakade et al., 2021). In addition to curing, pre-planting treatments with seed dressing fungicides can help prevent soft rot infections. The application of indole-3-butyric acid (IBA) has been shown to enhance rooting and shoot development in dragon fruit, similar to its effects in other fruit crops. For the quick dip method, an effective IBA concentration is 6000 ppm (Kakade et al., 2024; Rahbin et al., 2012; Seran and Thiresh, 2015).

Figure 5: Preparation, treatments and planting of dragon fruit cuttings in nursery

Intercultural operations

The initial and most critical task following transplantation in the main field is the tying of young shoots to support poles. For this purpose, nylon strips or repurposed sari strips, each approximately 2 cm in width, may be utilized (Fig. 6). In the absence of these materials, jute wire can serve as an alternative for tying. It is advisable to avoid using fine nylon strings, as they may damage the young growth by cutting young growth. This procedure of securing the main leader should be conducted in every three to four months until the lead branch comes out from the plate. Subsequently, the necessity for this operation diminishes.

Figure 6: Development of initial framework by tying main stems to support system

Pruning is the second critical operation in dragon fruit cultivation, essential for plant training, canopy management, improved air circulation and light penetration, reduced pest and disease incidence, and enhanced fruit yield and quality (Doke et al., 2024). The pruning approach depends on the plant's age and growth stage. In the first two years, corrective and structural pruning guide plant architecture and control vegetative growth. A single stem is allowed to grow around support, with lateral branches removed. Once stem surpasses support, pinching encourages side branching and canopy formation (Kakade et al., 2020). In mature orchards, pruning stimulates new growth, optimizes the cladode-to-fruit ratio, and reduces canopy competition and disease risk. Excessive cladodes hinder cultural operations and degrade fruit quality by competing for resources and increasing canopy density, which favours pests and pathogens. A balanced cladode-to-fruit ratio is critical for flowering, fruit set, and development; therefore, it is recommended to maintain 120-160 cladodes or 12 to 14 cladodes per square meter in mop-top training system through need-based light pruning (Fig. 7) in semi-arid regions (Hoe, 2017; Hieu et al., 2018; Alam et al., 2022; Doke et al., 2024). Spur pruning negatively affects new growth, while cane pruning enhances flowering and early yields by exposing more areoles and reducing apical dominance (Arredondo et al., 2022). In dense wire-trellis systems, intensive annual pruning is needed, unlike mop-top systems which require lighter biennial and major pruning every 4–5 years. The ideal pruning time in India is November–December, enabling strong sprouting and cane maturity before

June–July. Delayed pruning may reduce sprouting, expose young shoots to heat stress, and shorten the maturation period, ultimately lowering productivity.

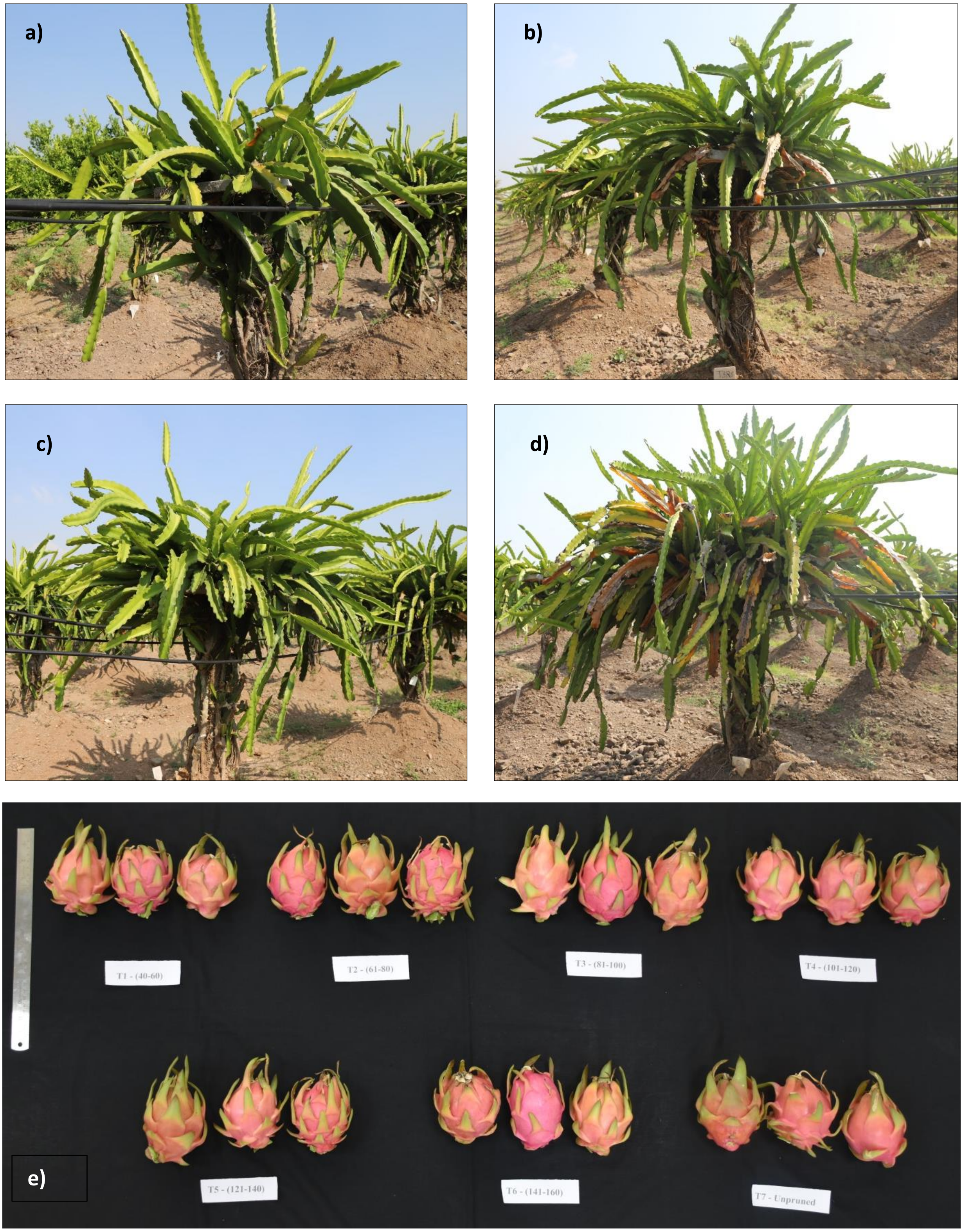

Figure 7: Comparison of plant canopies and disease incidence in different pruning treatments a) severe, b) moderate, c) light and d) un-pruned control. Comparison of fruit size in pruning treatments (e)

Bagging in dragon fruit can be a valuable practice that protects developing fruits from pests, diseases, and mechanical damage. It helps to improve fruit quality by promoting uniform coloration, reducing blemishes, and minimizing pesticide residue. Bagging can also create a favourable microenvironment around the fruit, which may enhance ripening and reduce postharvest losses (Nangare et al., 2020).

Varieties

Varietal evaluation and breeding for new traits of Dragon fruit is under progress for Indian conditions. Presently, the available varieties which have been planted in farmers' field are imported from other countries. In India, mostly magenta pink fleshed dragon fruit have been planted by most of the growers. Under changing climate scenario and increasing biotic and abiotic stresses, there is an urgent need of collecting and identifying the varieties which are stress resilient without compromising yield and quality parameters.

Orchard establishment

Establishing a robust support structure prior to planting is essential due to the semi-epiphytic growth habit of dragon fruit. While ground-level training is an option, it is labour-intensive and increases the risk of fruit contamination. Two primary support systems are commonly employed: the vertical "mop-top" method and the horizontal trellis system. The vertical or mop-top system utilizes reinforced cement concrete (RCC) poles and top plates—sometimes incorporating rubber tires or iron rings—to support plant growth. Optimal support is achieved using RCC poles measuring 5–6 feet in height, topped with either square or circular plates (Karunakaran and Arivalagan, 2019). Typically, 3–4 plants are established around each pole (Fig. 8). As they grow, cladodes ascend the pole and eventually droop under their own weight. This system is cost-effective to establish; however, it presents several limitations, including lower planting density and challenges in crop management, disease control, and intercultural operations. Intercultural operations such as pruning, spraying, and harvesting require movement around individual poles, which can reduce efficiency (Truc et al., 2021). In contrast, the horizontal 'T'-bar wire trellis system allows for planting at 30–60 cm intervals in straight or staggered rows, with shoots trained along overhead wires. This configuration forms a fruiting "wall" with access on both sides, improving efficiency in management and harvesting operations. The trellis system supports higher planting densities, ranging from 6,000 to 10,000 plants per hectare, compared to the mop-top method. Although initial setup and maintenance costs are higher, these are often outweighed by increased yields and revenue (Le Bellec et al., 2006; Truc et al., 2021). Dragon fruit plants have a productive lifespan of 20–25 years and are capable of bearing heavy fruit loads, especially during peak seasons. Therefore, a strong, durable support system is vital for maintaining orchard productivity and longevity. Training on live trees is also possible (Ortiz-Hernandez and Carrillo-Salazar, 2012); however, excessive canopy shading can significantly suppress flowering and fruiting.

Figure 8: Stepwise installation of support system and planting in dragon fruit

Planting is optimally conducted during the rainy season, as the onset of the monsoon provides favourable conditions, including mild temperatures, increased soil moisture, and higher relative humidity. These factors facilitate robust root development, promote the emergence of new cladodes, and enhance overall plant vigour and orchard establishment. However, with the availability of irrigation, planting can be extended until early summer (March). Careful handling during transplanting is crucial to prevent transplant shock. Dragon fruit cuttings are typically rooted in nurseries under 50–90% shade net conditions. Upon transfer to open fields, these cuttings may experience heat stress due to sudden exposure to intense sunlight and elevated temperatures (Fig. 9). This stress can lead to sunburn, bleaching, cladode yellowing, and increased susceptibility to secondary fungal infections. To mitigate transplant shock, gradual acclimatization to outdoor conditions is recommended. During hot days, young plants should be temporarily covered and then left uncovered from evening until the following morning. This stepwise exposure aids the plants in adapting and building resilience to environmental fluctuations. Furthermore, during summer planting, young dragon fruit plantlets should be cultivated under the shade of seasonal crops such as *bajra*, sorghum, or *dhaincha* to shield them from heat stress.

Figure 9: Transplanting shock to young dragon fruit plants

Different countries employ varying planting geometries and spacing strategies for cultivation (Table 2 and Fig 10). However, suboptimal spacing can impede intercultural operations, complicate harvesting, and increase the risk of disease and pest outbreaks. Closer spacing causes intermingling of branches which results in to reduction of flowering and fruiting on those sides and also hinders movement while performing different intercultural operations. Therefore, selecting an appropriate planting layout is critical for efficient orchard management and sustained productivity.

Table 2: Dragon fruit spacing and plant population

Spacing (m×m)	Poles per hectare	Plant population per hectare		References
Mop top system		Three plants per pole	Four plants per pole	Nangare et al., 2020
2.5 × 3.0	1333	3999	5332	
3.0 × 3.5	952	2856	3808	
Wire trellis system with double row planting				
3.3 × 3.3 × 0.46	952	12820		Kakade et al., 2020
3.3 × 3.3 × 0.60	952	9642		

Irrigation and fertilizer management

The plant exhibits high water use efficiency and a lower water requirement compared to C3 and C4 crops. It develops aerial roots from the sides of the stem to collect water from the surroundings and for anchorage. It requires only 10% of the water needed by most other fruit crops such as pear, citrus, and peach. An irrigation level of 120 to 150 mm per year is recommended to meet its water needs. Dragon fruit is a very shallow-rooted crop, and its water requirement and frequency of irrigation are higher than those of other cacti. Therefore, to ensure commercial production, a sufficient amount of water is necessary. Small quantities of irrigation at shorter intervals are more effective in ensuring proper growth and higher fruit yields. The flowering and fruit enlargement stages are critical, as they coincide with the monsoon season, during which 50-60% of the water demand is fulfilled by rainwater. However, in the case of erratic rainfall, irrigation at 2-3 day intervals is essential. During the winter season, the plant produces new growth, necessitating irrigation every 2-3 days. In the summer season, to mitigate heat stress, watering can be reduced to once every 15 days. Micro-irrigation is recommended to avoid uneven and excessive watering. Utilizing mulching with weed mat or sugarcane trash or any other available crop residue can significantly diminish water loss through evaporation, thereby conserving water resources and inhibiting weed proliferation.

Dragon fruit, while not an exhaustive fruit crop, possesses a superficial root system that enables it to assimilate minimal quantities of nutrients. The judicious application of manures and fertilizers is essential for achieving higher fruit yields of superior quality. Various fertilizer regimens are observed in different countries. For instance, in Taiwan, 100 g of commercial 13-13-13 fertilizer per plant is applied alongside 4 kg of organic manure every four months. In Vietnam, the application consists of 540:720:300 g of NPK and 20 kg of manure per plant annually, divided into four splits (Tri et al., 2000). In India, the ICAR-NIASM, Pune (MS) has recommended a specific dosage for dragon fruit cultivated in rocky, degraded lands. During the first two years, 500 g of urea, 500 g of phosphorus, and 300 g of potassium are applied to each pole annually, divided into four splits at three-month intervals. After two years, each pole per year should receive 800 g of nitrogen, 900 g of phosphorus, and 550 g of potassium, distributed in six splits (Nangare et al., 2020). Fertilizer application can be done at the pre-flowering stage (May, as a basal dose), fortnightly during flowering (using water-soluble fertilizers with an emphasis on pottassic and phosphatic fertilizers), post-harvest (November/December, as a basal dose), and monthly during vegetative growth stage (using water-soluble fertilizers focusing on nitrogenous fertilizers).

Weed management

Weed management in dragon fruit is vital to minimize competition for nutrients, water, and light, thereby improving crop growth and yield. Common methods include manual weeding, mulching, and selective herbicide use. Integrated Weed Management (IWM) is recommended, combining cultural practices (like mulching with crop residues (Fig. 10), weed mats, or intercropping), mechanical tools (rotavator, cultivators), and chemical methods. Timely intervention, especially during early growth stages, is essential to ensure healthy orchard development.

Figure 10: Mulching with sugarcane trash to reduce weed load and moisture conservation in wire trellies system

Intercropping

Short-statured intercrops can be grown with dragon fruit during its juvenile phase and in the rabi and summer seasons of its productive phase. However, intercropping during the flowering and fruiting stages may hinder essential intercultural operations like spraying and harvesting. Suitable intercrops may include marigold, wheat, sorghum, and *dhaincha* in winter, and bajra, maize, *dhaincha*, and fodder sorghum in summer (Fig. 11).

Figure 11: Intercropping with seasonal crops during initial periods of orchard establishment

Since dragon fruit is a light-loving crop, tall intercrops such as *Melia dubia* and drumstick, teak should be avoided to prevent over shading, which can reduce flowering and fruiting (Fig. 12).

Figure 12: Intercropping with tall growing crops is to be avoided

Flowering and fruiting behaviour

The flower initiation in dragon fruit is mainly influenced by the photo period, which requires 12-13 h of light. The phenology of reproductive stages such as floral bud initiation, anthesis and fruit development varies from species to species. The flowering period starts from May and ends in September/October with 5-6 major cycles and 2-3 blooms with few sparse flowers. After bud initiation, it takes 14-15 days for anthesis from floral bud stage and fruit matures 30-35 days after anthesis (DAA). The anthesis starts at 6.30 PM in the evening, completely blooms between 9.00 PM-12.00 AM, starts closing 7.00 AM onwards, partially closes at 9.00 AM and starts withering in the next day evening.

The productivity and quality of dragon fruit are primarily affected by flower drop, early fruit drop (within 3–5 days after pollination or anthesis), and reduced fruit size or weight. To address these issues, ICAR-NIASM has developed a set of technologies, which are briefly summarized below.

I. Flower drop: Cause and solution

Flower drop and immature fruit drop in dragon fruit were identified as major causes of yield loss; with up to 70% reduction in fruit production observed during certain flowering cycles particularly if blooming coincides with rains. Upon investigation, it was found that rainfall during the anthesis period—when flowers open and are ready for pollination—was strongly associated with reduced fruit set. Even light rainfall of 1–2 mm during this critical window led to significant pollen washout, preventing successful pollination and resulting in smaller fruit size and lower yield (Fig. 13).

Figure 13: Yellowing of flower indicating failure of fertilization due to deficit or failure of pollination.

To investigate the impact of rainfall on fruit set in dragon fruit, an experiment was conducted during a flowering cycle expected to coincide with rain. Seven different pollination treatments were tested, with some flowers left exposed and others protected using various materials. Rainfall during the critical anthesis period led to poor fruit set in flowers that were not covered. However, flowers protected with coverings, especially muslin cloth/polythene bag, showed significantly higher fruit set, confirming that shielding flowers from rain during pollination can effectively reduce flower drop and improve yield.

Based on these findings, a simple yet effective technique was developed to reduce flower and immature fruit drop in dragon fruit. This technology aims to minimize flower and immature fruit drop in dragon fruit, which often results from rainfall during the critical anthesis period. It integrates three key methods: bagging or covering of flower buds, sheltering of plants, and supplementary hand pollination. These interventions help reduce yield loss by protecting the flowers from rain-induced pollen washout and enhancing pollination success. To ensure the effectiveness of this technology, it is essential for farmers to understand the correct methods, timing, and duration for implementing these practices. The three components of the technology are described below:

A. Bagging or Covering of Flower Buds

This method involves covering unopened pre-anthesis flower buds using waterproof materials such as polythene bags, butter paper, or suitable-sized water-resistant covers. The goal is to shield the flowers from direct rainfall and prevent pollen washout during the anthesis period.

- **Timing**: Bags should be placed *before anthesis* (flower opening) begins.
- **Material choice**: Depends on local availability, cost, and prevailing weather conditions.
- **Effectiveness**: This is a low-cost, practical method suitable for small to medium-scale farmers.

B. Sheltering of Plants

In this method, entire plant rows are covered using 2-meter-wide transparent polythene sheets or thin tarpaulin to prevent direct rainwater from falling on the plant canopy (Fig. 14). This helps maintain flower integrity during anthesis and protects pollen from being washed away.

- **Application period**: Shelters should be installed only during the 2–3 day anthesis period of each flowering cycle.
- **Height**: The cover should be installed at least 1 meter above the canopy to allow air circulation and prevent heat stress on flowers.
- **Suitability**: This method is particularly effective for large orchards, especially where labor availability is limited, though it is more expensive than other methods.

C. Supplementary Hand Pollination

This technique involves manually pollinating the stigma of flowers that were exposed to rain and may have suffered pollen loss (Fig. 14).

- **Timing**: Pollination should be done in the early morning hours, ideally the morning after rain.
- **Pollen source**: Maintain at least one protected flower for every 20 flowers (20:1 ratio) to serve as a pollen donor. These protected flowers should be bagged in advance to ensure pollen viability and protect from rains.
- **Procedure**: Use the collected pollen to hand-pollinate flowers that may not have been adequately pollinated due to rain exposure.

This three-pronged approach offers a practical, adaptable, and effective solution to mitigate flower and fruit drop in dragon fruit, especially under unpredictable weather conditions. Proper timing, material use, and labor planning are key to maximizing the benefits of this technology.

 

Figure 14: Sheltering the plants to protect from the rains and pollinating the rain flashed flowers

Benefits and Precautions of the Technology

This technology effectively mitigates the negative impact of rainfall on fruit set and fruit size in dragon fruit. By protecting flowers during the anthesis period through timely interventions, farmers can reduce flower and immature fruit drop, thereby improving overall yield. When adopted correctly, especially during unseasonal or aberrant rains, this technology can significantly enhance farmers' income. Economic analysis shows favourable benefit-cost (B:C) ratios compared to rain-affected, unprotected conditions—1:2.00 for bagging, 1:2.20 for sheltering, and 1:2.50 for supplementary hand pollination.

To ensure successful implementation, several precautions must be taken. Flowers should be covered *before* anthesis begins, and if using polythene bags, they must be removed by the following forenoon. Additionally, small pinholes should be made in the bags to allow for aeration and prevent the build-up of heat and humidity. Sheltering of plants should only be done during the short blooming period (typically 2–4 days per month), and covers must be positioned at a proper height to avoid heat build-up or sun scorching of flowers.

For optimal results, farmers should be familiar with the plant's flowering and fruiting stages, including the timing of anthesis, pollen viability, and stigma receptivity. They should also be trained in identifying viable pollen, recognizing receptive stigmas, and understanding the correct techniques for pollen collection, storage, pollination, and bagging. Hands-on training or demonstrations are recommended to ensure that these practices are carried out effectively, along with the use of high-quality pollen sources to maximize pollination success.

II. Under sized fruit formation: Cause and solution

The fruit size of certain dragon fruit varieties, particularly the white-fleshed types (*Selenicereus undatus*), is often smaller and sometimes considered unmarketable compared to the larger, more desirable red-fleshed types (*S. costaricensis/polyrhizus*). This issue is largely attributed to insufficient pollination, which is caused by several factors, including unfavourable floral morphology (such as the pinnate type, where the stigma and stamens are positioned apart), lack of effective insect pollinators, and pollen washout due to rainfall during anthesis and pollination periods. The marketing of undersized fruits poses a significant challenge for dragon fruit farmers and associated stakeholders.

A pollination study conducted by ICAR-NIASM, Baramati, revealed stark differences in fruit set between varieties. In *S. undatus*, all pollination methods (open, selfing, hand self-pollination, and cross-pollination) resulted in 100% fruit set. However, one clone of red-fleshed type named as NR-1 only showed fruit set under cross-pollination, while all other treatments failed to produce fruit indicating the self-incompatibility. These findings highlighted the critical role of cross-pollination in improving fruit set, especially for some red-fleshed types with self-incompatibility.

To address this issue and improve fruit size and quality, ICAR-NIASM developed a technology involving supplementary hand pollination. The method involves hand self-pollination or cross-pollination, depending on the availability of labour and suitable pollen sources.

A. Self-Pollination:

Self-pollination is done by transferring pollen to the stigma from the same flower or another flower on the same plant or clone. This can be performed in two ways:

1. **With emasculation**: Once anther dehiscence is confirmed in the evening (on the day of anthesis), the flower is emasculated, and the pollen from the removed floral parts is applied to the stigma. A single stamen column can be used to pollinate 8–10 flowers effectively (Fig. 15).

2. **Without emasculation**: In this method, self-pollination is done early the next morning (after anthesis), without removing any flower parts. This is a simpler method, suitable when quick and efficient pollination is needed.

B. Cross-Pollination:

Cross-pollination involves transferring pollen from one clone or variety to the flower of another, for example, using pollen from a red-fleshed variety to pollinate a white-fleshed flower. The process typically includes emasculating the female flower before anthesis, preferably during the forenoon or afternoon, to save time and cover more flowers. The emasculated flowers are then pollinated with fresh pollen from the selected donor variety.

If the weather is hot and sunny, the pollinated stigma can be covered with butter paper to protect it from desiccation. In some cases, emasculation and pollination can be done simultaneously. However, for successful cross-pollination, identification of a compatible and high-quality pollen source (male parent) is essential.

The right stage for emasculation to attempt cross pollination can be identified by visual observation (appearance of white coloured petals at tip as shown in Fig. 2a) and also by touching (up on gentle pressing feeling soft compared hard in immature buds).

Emasculation method: By slightly piercing both thumbs inside bulge part of the flowers and cut the flower longitudinally by bending the each half of corolla column parts opposite side without damaging the central gynoecium part (Fig. 2).

Benefits and Precautions of the Technology

The supplementary hand pollination technology developed by ICAR-NIASM offers several important benefits for dragon fruit cultivation. It significantly enhances fruit size and quality, especially in varieties prone to producing smaller fruits due to poor natural pollination. Notably, cross-pollination not only improves fruit set but also reduces the fruit maturity period by about one week compared to naturally pollinated fruits. This leads to earlier harvests and potentially higher market value. By increasing the proportion of marketable, large-sized fruits, farmers can maximize yield per unit area and earn premium prices, thereby contributing to higher profitability and improved income, even under challenging conditions such as aberrant rainfall during flowering or anthesis. The technology has shown favorable benefit-cost ratios: 2.0 for hand self-pollination with emasculation, 2.5 without emasculation, and 3.0 for hand cross-pollination, indicating strong economic returns when implemented properly.

Our study revealed that the low yields of white-fleshed dragon fruit variety is due to a high proportion of small fruits and the fruit size can be improved via manual pollination. Supplementary manual pollination—both self and cross—significantly improved fruit size by up to 30% (321 g) and 82% (452 g), respectively, compared to natural pollination (247 g). This led to an additional yield of 3 tons/acre (33%) with self-pollination and 9 tons/acre (100%) with cross-pollination, over the natural yield of 8–10 tons/acre. As a result, total yield can potentially reach up to 18 tons/acre, while also enhancing fruit quality. These findings offer a promising solution for farmers growing white dragon fruit, with the potential to double their income and improve livelihoods (Boraiah et al., 2024).

To achieve optimal results, certain precautions are essential. Farmers and practitioners should be well-versed in the phenological stages of flowering and fruiting, particularly the timing of anthesis, pollen viability, and stigma receptivity. A sound understanding of emasculation and pollination techniques is also important. Only healthy, pest- and disease-free flowers should be selected for pollination, and choosing the best pollen donor (parent) is crucial to ensure better fruit set, improved size, and overall quality. Training or hands-on experience in these procedures can greatly enhance the success of the technology in field conditions.

Overall, to enhance the productivity and profitability of dragon fruit cultivation, a combined strategy involving prevention of flower and immature fruit drop along with supplementary manual pollination has proven highly effective. Protecting flowers during the anthesis period through bagging, sheltering, and timely hand pollination significantly reduces flower drop caused by rainfall and ensures better fruit set. Additionally, implementing manual self- and cross-pollination improves fruit size, quality, and overall yield—particularly in white-fleshed varieties, which naturally produce smaller fruits (Fig. 15). Together, these technologies can potentially double the yield (up to 18 tons/acre) and income of farmers by addressing both major limitations: flower drop and poor natural pollination. This integrated approach offers a reliable and practical solution to sustainably boost dragon fruit production, even under erratic weather conditions.

Emasculation **Pollination**

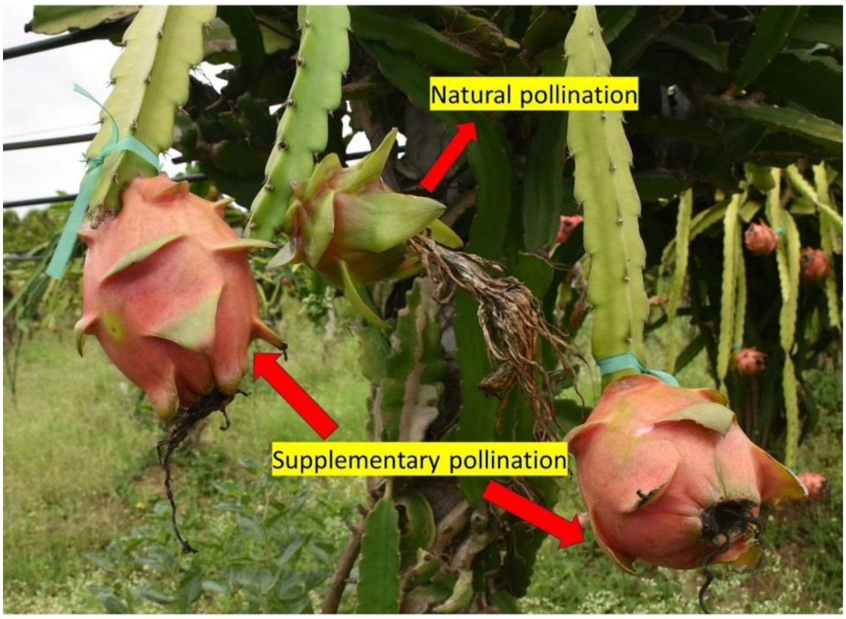

Figure 15: Process of manual pollination in dragon fruit. Manually pollinated flowers and resulted fruits showing early maturity, bigger and bright red coloured fruits

Harvesting and Yield

In India, dragon fruit harvesting typically begins in June and continues until November or December. The period from flowering to harvest spans approximately 45 days. To ensure optimal fruit quality, specifically in terms of size, it is recommended to maintain one or two fruits per cladode. Exceeding this number may result in a reduction in fruit size. Fruits showing the initial signs of colour development are suitable for distant markets due to their longer shelf life, while fully coloured fruits are ideal for immediate sale in local markets. Dragon fruit is well known for its vigorous vegetative growth and early fruiting potential. Traditionally, substantial yields are achieved within two to three years of planting, with full production capacity reached by the fifth year (Kakade et al., 2022). However, improvements in agronomic practices and increased farmer expertise have enabled higher yields even by the third year. In well-managed orchards across India, yields of 15 to 25 t/ha have been reported from the third year onwards. In Israel, *Selenicereus polyrhizus* has shown yields of around 16 t/ha as early as the second year (Raveh et al., 1998). In comparison, plantations in Nicaragua report yields of 10 to 12 t/ha by the fifth year (Thomson, 2002), and in Sri Lanka, yields of approximately 8 t/ha have been recorded from the fourth year onwards (Gunasena et al., 2007). This variability in yield across regions can be attributed to differences in soil and climatic conditions, pruning and training systems, and technical proficiency (Patil et al., 2024; Doke et al., 2024). Although establishing a dragon fruit orchard entails a high initial investment-estimated at US$ 9,000 to 10,000 per hectare-it becomes economically viable once established. Compared to other high-value crops such as grapes and pomegranates, dragon fruit requires fewer inputs after the initial years. Economic analyses indicate that a benefit-cost ratio of 1:3.42 can be achieved from the third year onwards, highlighting the crop’s potential as a profitable and sustainable option for growers (Sathe et al., 2024).

Pests and diseases

Dragon fruit is vulnerable to a variety of pests, including ants, termites, snails, aphids, thrips, mealy bugs, fruit flies, scale insects, rats, and birds (Carrillo et al., 2021). Among these, fruit flies (*Bactrocera* spp.), ants, thrips, aphids, and tachinid flies are the most prevalent (Fig. 22) during both vegetative and reproductive stages (Estigoy and Estigoy, 2019). To protect dragon fruit from fruit fly infestation, maintain field sanitation by regularly collecting and destroying fallen or infested fruits. Bagging of developing fruits with paper or cloth bags prevents egg laying by adult flies. Install methyl eugenol traps (10 per acre) to attract and kill male fruit flies, thereby reducing the population. In severe cases, imidacloprid 30 EC 1 ml/l, two sprayings at 2 weeks interval before ripening of fruits may be used with proper pre-harvest intervals. Additionally, timely harvesting of mature fruits minimizes exposure and risk of infestation. Nematode infections pose a serious threat to dragon fruit. In Brazil, *Meloidogyne javanica* and *M. incognita* caused root galls and stunted growth in *S. megalanthus* and *S. undatus*, respectively (Nascimento et al., 2020; De Souza et al., 2022). In India, *M. incognita* has been linked to root galling regardless of inoculum levels (Holajjer et al., 2022).

Figure 22: Fruit fly, Snail and Ants damage in dragon fruit

Major Diseases and Integrated Management Strategies

Dragon fruit is still unfamiliar to many growers regarding its pests, diseases, and effective management. The crop is affected by 25 species of pathogens belonging to 17 genera, with fungal pathogens posing the greatest threat (Baledres & Bengoa, 2019; Evallo et al., 2021). Vegetative propagation through cladodes facilitates the rapid spread of pathogens across orchards and regions.

1. **Stem Canker** (*Neoscytalidium dimidiatum*)

Most destructive disease; reported widely across countries.

Symptoms: Begin as depressed chlorotic spots with red flecks, developing into raised, hard brown scabs with pycnidia. Advanced stages show tissue necrosis, shot holes, yellowing, and fruit rot.

Favourable Conditions: Optimal growth at 35–37°C; most severe during wet seasons due to rain-splash dispersal of pycnidiospores (Salunkhe et al., 2023a).

2. **Anthracnose:** *Colletotrichum spp. (C. gloeosporioides, C. siamense, C. aenigma, C. truncatum)*

Symptoms: Reddish to dark-brown sunken lesions with chlorotic halos; black concentric rings of acervuli on fruit.

Favourable Conditions: High humidity, warm temperatures, frequent rains, especially during flowering and fruiting stages (Salunkhe et al., 2023b).

3. **Bacterial Soft Rot**: *Enterobacter cloacae*

Symptoms: Yellowish to brown, watery soft lesions on stems and fruits, rapid decay of fruit.

Figure 23: Stem canker symptoms in dragon fruit

Favourable Conditions: Common from October to January during fluctuating day–night temperatures.

Other Pathogens: Apart from fungal and bacterial pathogens, rare cases of viral and nematode infections have also been observed.

IDM strategies:

1. Planting Material Selection and Preparation: Use only healthy, disease-free cladodes. Harden cladodes under shade for one week before planting. Treat cladodes with any one of the following fungicides: Carbendazim (0.1%), Copper Oxychloride (0.25%), Mancozeb (0.25%)

2. Orchard Establishment and Cultural Practices: Ensure well-drained soil and avoid waterlogging. Maintain proper spacing, provide partial shading using nets in summer to prevent sunburn, and prune regularly for good air circulation.

3. Pruning and Sanitation: Conduct regular pruning during winter to remove diseased or dead plant parts. Disinfect tools with 0.25% Copper Oxychloride before/after use. Apply 1%

Bordeaux mixture on pruning wounds to prevent infections. Immediately discard infected plant debris.

4. Fungicidal Spray Schedule: Apply fungicides every 15–21 days, depends on weather and disease intensity. Use following fungicides rotation; Carbendazim (12%) + Mancozeb (63%) @ 2–2.5 g/L; Tebuconazole (50%) + Trifloxystrobin (25%) @ 0.5–1 g/L; Zineb (68%) + Hexaconazole (4%) @ 2–2.5 g/L; Difenoconazole + Azoxystrobin @ 0.1%. Avoid sole reliance on chemical fungicides to prevent resistance build-up. Effective management of dragon fruit diseases requires an integrated approach that combines preventive cultural practices, routine sanitation, judicious fungicide use, and biological alternatives. Continuous monitoring and adaptive strategies based on environmental conditions will help minimize crop losses and ensure sustainable production.

References

Alam, M., Hasan, M.D.A., Mondal, T., Rathod, K.H., and Chhetri, S. (2022). Studies on the intensity of cladode pruning on vegetative and reproductive behaviour of dragon fruit (*Hylocereus costaricensis*). Journal of Crop and Weed, 18, 104-110.

Arredondo, E., Chiamolera, F.M., Casas, M., and Cuevas, J. (2022). Comparing Different Methods for Pruning Pitaya (*Hylocereus undatus*). Horticulturae, 8, 661.

Ben-Asher, J., Nobel, P.S., Yossov, E., and Mizrahi, Y. (2006). Net CO2 uptake rates for *Hylocereus undatus* and *Selenicereus megalanthus* under field conditions: Drought influence and a novel method for analyzing temperature dependence. Photosynthetica 44 (2), 181-186.

Boraiah, K.M., Basavaraj, P.S., Kakade, V. Harisha, C.B., Kate, P., Wakchaure, G.C., Rane, J., and Pathak, H. (2022). Prevention of Flower Drop in Dragon Fruit through Bagging, Sheltering and Supplementary Pollination. Technical folder no. 51. ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, Maharashtra, India.

Carrillo, D., Duncan, R., and Peña, J.E. (2021). Pitaya (Dragon Fruit) (*Hylocereus undatus*) Pests and Beneficial Insects. Article in EDIS · DOI: 10.32473/edis-in1292-2020

Chakma, S.P., Harunor Rashid, A.S.M., Roy, S., and Islam, M. (2014). Effect of NPK doses on the yield of dragon fruit (*Hylocereus costaricensis* (FAC Weber) Britton and Rose) in Chittagong Hill Tracts. American-Eurasian Journal of Agricultural and Environmental Sciences, (AEJAES) 14(6), 521-526.

Chatterjee, D., Mansuri, S., Poonia, N., Kesharwani, P., Lather, V., and Pandita, D. (2024). Therapeutic potential of various functional components presents within dragon fruit: A review. Hybrid Advances, 100185.

Coniberti, A., Ferrari, V., Dellacassa, E., Boido, E., Carrau, F., Gepp, V., and Disegna, E. (2013). Kaolin over sun-exposed fruit affects berry temperature, must composition and wine sensory attributes of Sauvignon blanc. European Journal of Agronomy, 50, 75-81, ISSN 1161-0301, .

De Souza, V.H.M., Inomoto, M.M., Silva, A.M.G.B., and Souto, T.G. (2022). First report of Meloidogyne incognita infecting white Pitahaya plants. Revista Brasileira de Fruticultura. 44, e822.

Doke, A., Kakade, V.D., Patil, R.A., Morade, A.S., Chavan, S.B., Salunkhe, V.N., Nangare, D.D., Boraiah, K.M., Thorat, K.S., Reddy, K.S. (2024). Enhancing plant growth and yield in dragon fruit (*Hylocereus undatus*) through strategic pruning: A comprehensive approach for sunburn and disease management, Scientia Horticulturae, 337, 113562, ISSN 0304-4238

Estigoy, J.H., and Estigoy, M.A.S. (2019). Population Dynamics of Insects Associated with Dragon Fruit (*Hylocereus* sp.). Philippine Entomologist (Philippines).

Gunasena, H.P.M., Pushpakumara, D.K.N.G., and Kariyawasam, M. (2007). Dragon fruit: Hylocereus undatus (Haw.) Britton and Rose. In Underutilized Fruit Trees in Sri Lanka, Pushpakumara, D.K.N.G., Gunasena, H.P.M., Singh, V.P., Eds.,World Agroforestry Centre, South Asia Office: New Delhi, India, 1, 110–141.

Hieu, N.T., Thu, N.N.A., Linh, D.T., Thanh, N.T.K.,Van Hoa, N., and Rangaswamy, M. (2018). Effect of various degree of canopy pruning on plant growth, yield, and control of canker disease of dragon fruit crop. In Proceedings of the International Conference on Tropical Fruit Pests and Diseases, Kota Kinabalu, Sabah, Malaysia, 25–27 September 2018.

Hoe, K.T. (2017). Planting Density of Red Pitaya (*Hylocereus Polyrhizus*) to Achieve Optimum Yield Under Malaysia Weather Condition. International journal of agriculture innovations and research, 6:2 ISSN (Online) 2319-1473.

Holajjer, P., Bajaru, B., Parameswari, B., Sivaraj, N., Srinivas Rao, M. and Anitha, K. (2022). Pathogenicity and Reproductive Potential of Root-knot nematode, Meloidogyne incognita on Dragon Fruit (*Hylocereus* spp.). Biological Forum – An International Journal 14(1): 1606-1609.

Islam, M.Z., Khan, M.T.H., Hoque, M.M., and Rahman M.M. (2012) Studies on the Processing and Preservation of Dragon Fruit (*Hylocereus undatus*) Jelly. The Agriculturists 10(2), 29-35.

Jiang, Y.L., Lin, T.S., and Lee, C.L. (2011). Phenology, Canopy Composition, and Fruit Quality of Yellow Pitaya in Tropical Taiwan. HortScience 46(11), 1497-1502.

Jinger, D., Kakade, V., Bhatnagar, P., Paramesh, V., Dinesh, D., Singh, G., N, N.K., Kaushal, R., Singhal, V., Rathore, A.C., Tomar, J., Singh, C., Yadav, L.P., Jat, R., Kaledhonkar, M.J., & Madhu, M. (2024b). Enhancing productivity and sustainability of ravine lands through horti-silviculture and soil moisture conservation: A pathway to land degradation neutrality. *Journal of environmental management, 364*, 121425.

Jinger, D., Kakade,V., Bhatnagar, P. R., Nandha Kumar, N., Dinesh, D., Singh, G., Partap, R., Sukhwal, A., Kumar, A., Singh, A.K., Kaledhonkar, M.J., Madhu, M. (2024a). Dragon fruit: A Remunerative Fruit under Rainfed Conditions for Ravine Lands of Central Gujarat, pp 18 and ISBN- 978-93-94687-87-5.

Kakade V., Jinger D., Dayal V., Chavan S., Nangare, D.D., Wakchaure, G.C., Dinesh D., (2020). Dragon fruit wholesome and remunerative fruit crop for India. Food and Scientific Reports, 1(12): 44-48.

Kakade, V., Dinesh, D., Singh, D., Bhatnagar, P.R., and Kadam, D. (2019). Influence of length of cutting on root and shoot growth in dragon fruit (*Hylocereus undatus*) Indian Journal of Agricultural Sciences, 89(11), 1895-99.

Kakade, V., Morade, A., and Kadam, D. (2022). Dragon Fruit (*Hylocereus undatus*) In Tropical Fruit Crops: Theory to Practical, Ghosh, S.N., Sharma, R.R., Eds., Jaya Publishing House: Delhi, India, 240–257.

Kakade, V.D., Jinger, D., Dinesh, D. Singh, G., Bhatnagar, P. R., Pande, R.A., Jat, Singh, A. K., Singh, C., and Makwana, B. C. (2021). Nursery and propagation techniques of Dragon fruit. Extension folder, ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Vasad, Anand, Gujarat, India

Kakade, V.D., Nangare, D.D., Chavan, S.B., Babar, R.R., Morade, A., Jadhav, S.,, Salunkhe, V.N. and Jinger, D. (2024). Influence of indole butyric acid on root and shoot growth in dragon fruit (*Selenicereus undatus*) stem cuttings. International Journal of Minor Fruits, Medicinal and Aromatic Plants. 10(1): 125-133.

Karunakaran, G. and Arivalagan M. (2019). Dragon Fruit - A New introduction crop with promising market. Indian Horticulture, 63(1), 8-11.

Khalili, M. A., Norhayati, A. H., Rokiah, M. Y., Asmah, R., Siti Muskinah, M., and Abdul Manaf, A. (2009). Hypocholesterolemic effect of red pitaya (*Hylocereus* sp.) on hypercholesterolemia induced rats. International Food Research Jornal, 16, 431- 440.

Le Bellec, F., Vaillant, F., and Imbert, E. (2006). Pitahaya (*Hylocereus* spp.): A new fruit crop, a market with a future. Fruits, 61, 237–250.

Mizrahi, Y., (2014). Vine-cacti pitayas - the new crops of the world. Revista Brasileira de Fruticultura- SP, 36(1), 124-138.

Nangare, D.D., Taware, P.B., Singh, Y., Kumar, P.S., Bal, S.K., Ali, S., and Pathak, H. (2020). Dragon Fruit: A Potential Crop for Abiotic Stressed Areas. Technical Bulletin No. 46. ICAR-NIASM, Baramati (India), 1-24.

Nascimento, D.D., Lopes, A.P.M., Ferreira, R.J., Carvalho, V.R., Bombonato, L.T., Diniz, D.B., Silva, J.A.A., Wilcker, E., and Soares, P.L.M. (2020). First report

of *Meloidogyne javanica* infecting *Hylocereus megalanthus* in Brazil. Plant Disease, 104, 2526. PDIS-02-20-0437-PDN–. doi:10.1094/PDIS-02-20-0437-PDN
Nerd, A., and Neumann, P.M. (2004). Phloem water transport maintains stem growth in a drought stressed crop cactus (*Hylocereus undatus*). Journal of the American Society for Horticultural Science, 129, 486–490. doi:10.21273/JASHS.129.4.0486
Nerd, A., Sitrit, Y., Kaushik, R.A., and Mizrahi, Y. (2002). High summer temperatures inhibit flowering in vine pitaya crops (*Hylocereus* spp.). Scientia Horticulturae, 96, 343–350.
Nobel, P.S., and De la Barrera E. (2004). CO2 uptake by the cultivated hemi epiphytic cactus, *Hylocereus undatus*, Annals of Applied Biology, 144, 1-18.
Ortiz-Hernandez, Y.D. and Carrillo-Salazar, J.A., 2012. Pitahaya (Hylocereus spp.): a short review. Comunicata Scientiae, 3(4), 220–37.
Patil, A., Kakade, V.D., Kalalbandi, B.M. et al. (2024). Mitigating heat stress in dragon fruit in semi-arid climates: the strategic role of shade nets in enhancing fruit yield and quality. Environ Dev Sustain.
Perez, G.R.M., Vargas, S.R., Garcia, A.B., and Mota, J.M.F. (2007). Microvascular protective activity in rabbits of triterpenes from *Hylocereus undatus*. Journal of natural medicines, 61, 296-301.
Rahbin, A., Aboutalebi, A., and Hasanzadeh, H. (2012). Study on the effect of cutting location on shoot and IBA on rooting of 'Night Jessamine' (*Cestrum nocturnum*) stem cuttings. International research journal of applied and basic sciences, 3(11), 2345-2348.
Raveh, E., Nerd, A., and Mizrahi, Y. (1998). Responses of two hemiepiphytic fruit-crop cacti to different degrees of shade. Scientia Horticulturae, 73(2, 3), 151-164.
Salunkhe V.N., Bhagat Y.S., Chavan S.B., Lonkar S.G., Kakade V.D. (2023a) First report of *Neoscytalidium dimidiatum* causing Dragon fruit stem canker in India. Plant Dis 107(4):1222. https://doi.org/10.1094/PDIS-04-22-0909-PDN
Salunkhe, V.N., Bhagat, Y.S., Lonkar, S.G., Kakade, V.D., Chavan, S.B., Kochewad, S.A., and Nangare, D.D. (2023b). First report of *Colletotrichum truncatum* causing anthracnose of dragon fruit (*Hylocereus* spp.) in India. Plant Disease, 107(3): 945. https://doi.org/10.1094/PDIS-04-22-0809-PDN
Sathe S., Jadhav M.S., Deshmukh B.J., Barve A.,, Ayare P.N., and Lajurkar M. (2024) Economic analysis of production of dragon fruit in Solapur district of Maharashtra. International Journal of Statistics and Applied Mathematics 2024; SP-9(5): 231-235. DOI: https://doi.org/10.22271/maths.2024.v9.i5Sd.1842
Seran, T.H. and Thiresh, A. (2015). Root and Shoot Growth of Dragon Fruit (*Hylocereus undatus*) Stem Cutting as Influenced by Indole Butytic Acid. Journal of agriculture and biological sciences, 1(2), 27-30.
Sudarjat, Leovika, A., Suminar E., Isnaniawardhani, V., Qanit, M.A.H., Fauzi A. A., and Mubarok, S. (2019). Morphological Characterization and Adaptation of Four Dragon Fruit Genotypes in Pangandaran Regency of Indonesia. Asian Journal of Plant Sciences, 18(1), 21-25.
Tenore, G.C., Novellino, E., and Basile, A. (2012). Nutraceutical potential and antioxidant benefits of red pitaya (*Hylocereus polyrhizus*) extracts. Journal of Functional Foods, 4 (1), 129-136.
Thomson, P. (2002). Pitahaya (*Hylocereus* species) A Promising New Fruit Crop for Southern California. Bonsall Publications, Bonsall, CA.
Tri, T.M., Hong B.T.M. and Chau, N.M. (2000). Effect of N, P and K on yield and quality of Dragon fruit. *Annual Report of Fruits Research, Southern Fruit Research Institute.* Agriculture Publishers, Ho Chi Minh City, Vietnam. (In Vietnamese).

Truc, L.T.H., Son, N.V., Long, N.N., Hoa, N.V., Campbell, J.M., Fullerton, R.A. (2021). Novel trellising and plant management techniques for dragon fruits in Vietnam. In Dragon Fruit—From Production to Market, 1st ed., Fullerton, R.A., Lee, W.-L., Eds., Food and Fertilizer Technology Center for the Asian and Pacific Region: Taipei, Taiwan, 183–194.

Valiente-Banuet, A., Santos Gally, R., Arizmendi, M.C., and Casas, A. (2007). Pollination biology of the hemiepiphytic cactus *Hylocereus undatus* in the Tehuacán Valley, Mexico. *Journal of Arid Environments*, 68, 1-8.

Velmurugan, A., Swarnam, T.P., Ambast, S.K., and Kumar N. (2016). Managing waterlogging and soil salinity with a permanent raised bed and furrow system in coastal lowlands of humid tropics, Agricultural Water Management, 168, 56-67, ISSN 0378-3774, .

Vinas, M., Fernández-Brenes, M., Azofeifa, A., and Jimenez, V.M. (2012). In vitro propagation of purple pithaya (*Hylocereus costaricensis* (F.A.C. Weber) Britton and Rose) cv. Cebra. In Vitro Cellular and Developmental Biology, 48(5), 469–77.

Wichienchot, S., Jatupornpipat, M., and Rastall, R.A. (2010). Oligosaccharides of pitaya (dragon fruit) fresh and their prebiotic properties. Food Chemistry, 120, 850-857.

Yassen, M. Y. (2002). Micropropagation of pitaya (*Hylocereus undatus* Britton and Rose). In Vitro Cellular and Developmental Biology, 38, 427-429.

Yuqing, H., Weiyuan,Y., Ling, M.O., Guangping, X.U., Zhongfeng, Z., Danjuan, Z., Chengxin, H.E., and Daxing, G.U. (2015). Physiological Effect on Hylocereus undulatus and Hylocereus undatus under Simulated Karst Soil Water Deficiency. Journal of Resources and Ecology, 6(4), 269-275. DOI:10.5814/j.issn.1674-764x.2015.04.011

भाकृअनुप
ICAR

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch