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Optimization and Application of High-Yield Cultivation Techniques for Yellow Pitaya (*Selenicereus megalanthus*)

Min Dong ✉

Jiaxing Realzen Ecological Agriculture Technology Co., Ltd, Jiaxing, 314200, Zhejiang, China

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Abstract The cultivation area of yellow pitaya (*Selenicereus megalanthus*) is expanding globally, but its production faces challenges such as sensitivity to environmental conditions, insufficient understanding of agronomic requirements, and high labor intensity. This study systematically analyzes the cultivation techniques and strategies for yellow pitaya, focusing on optimizing water and fertilizer management, artificial pollination, and evaluating the adaptability of these techniques under different climatic conditions. The results indicate that proper fertilization management, organic cultivation practices, and artificial pollination significantly enhance yield and fruit quality. Integrating various cultivation techniques, combining organic and inorganic fertilizers, improving pollination methods, and implementing breeding programs could further promote efficient production of yellow pitaya. This study provides valuable guidance for growers, researchers, and policymakers, contributing to the sustainable development of the yellow pitaya industry.

Keywords Yellow pitaya (*Selenicereus megalanthus*); Cultivation techniques; Yield improvement; Pest and disease management; Organic cultivation; Water and fertilizer management

1 Introduction

Selenicereus megalanthus, commonly known as yellow pitaya or yellow dragon fruit, is a species in the cactus family (Cactaceae) that has gained considerable attention for its exotic flavor, striking appearance, and nutritional benefits (Tel-Zur et al., 2004; Morillo et al., 2022). Originally classified under the genus *Hylocereus*, recent taxonomic revisions have placed this species more accurately in the genus *Selenicereus*, recognizing its distinct botanical characteristics. It is native to the regions of Central and South America, particularly Colombia, Ecuador, and Bolivia, where it has a long tradition of cultivation (Dag and Mizrahi, 2005; Goenaga et al., 2020). The cultivation of yellow pitaya has expanded globally, with commercial production mainly concentrated in Hainan, Guangdong, and Guangxi in China, as well as in countries like Thailand, Vietnam, Mexico, and Guatemala (Goenaga et al., 2020). This crop is highly adaptable, thriving in environments ranging from very arid regions to areas with annual rainfall exceeding 3500 mm.

Yellow pitaya (*Selenicereus megalanthus*) is rich in Vitamin C, dietary fiber, and antioxidants, and is widely praised for its health benefits, which has driven the demand for cultivation in new regions (Hua et al., 2018). Despite the expansion of cultivation, current farming practices face various challenges, including sensitivity to environmental conditions, limited understanding of specific agronomic requirements, and labor-intensive production methods (Rahman et al., 2015; Rabelo et al., 2020). These issues can negatively impact both the yield and quality of the fruit. Furthermore, variations in growth habits and fruiting patterns add to the difficulty of maintaining stable yields. In response to these challenges, integrated measures are necessary to develop standardized and adaptable cultivation techniques to meet the needs of different growing regions.

Increasing the yield of yellow pitaya is crucial for several reasons. Higher yields can significantly enhance the economic viability of yellow pitaya cultivation, making it a more attractive option for farmers and investors (Dag and Mizrahi, 2005). Additionally, improved yields can meet the growing consumer demand for healthy and

diverse food products (Goenaga et al., 2020). Effective cultivation techniques, such as optimal nitrogen fertilization and hand pollination, have been shown to improve yield and fruit quality in yellow pitaya (Alves et al., 2021; Li et al., 2022). For instance, nitrogen fertilization has been found to increase yield, fruit quality, and cladode nutrient content in yellow pitaya (*Selenicereus megalanthus*), with the highest yield obtained at 300 g N per plant (Alves et al., 2021). Similarly, hand pollination has been identified as a necessary method to achieve high yields, as it ensures better fruit set and quality compared to spontaneous self-pollination or bee pollination (Dag and Mizrahi, 2005; Li et al., 2022).

The study systematically explores the cultivation techniques and strategies of yellow pitaya (*Selenicereus megalanthus*) to enhance its yield and quality. It analyzes various aspects of yellow pitaya cultivation, such as nutrient optimization, irrigation management, and pest and disease control, while also evaluating the applicability of these techniques under different climatic conditions to provide adaptable and region-specific solutions for farmers. This study intends to offer valuable insights for yellow pitaya growers, researchers, and policymakers, contributing to efficient cultivation and promoting sustainable development of yellow pitaya production.

2 Biological Characteristics and Growth Requirements

2.1 Botanical characteristics of yellow pitaya (*Selenicereus megalanthus*)

Yellow pitaya (*Selenicereus megalanthus*) is a climbing cactus renowned for its vibrant yellow peel. The plant features long, triangular stems with prominent ridges and spiny structures on the surface. These stems typically have three pronounced ridges, along which small clusters of spines are distributed, providing the plant with a degree of protective functionality (Sorace et al., 2016). Yellow pitaya exhibits strong branching, forming an extensive stem network that is well-suited for climbing or spreading along support structures. Its aerial roots assist in anchoring the plant to surfaces, thereby stabilizing it and promoting vertical growth (Morillo-Coronado et al., 2022).

The flowers of yellow pitaya are large, highly fragrant, and typically bloom at night. They are white, trumpet-shaped, and can reach up to 30 cm in length. Classified as “ephemeral”, these flowers usually last for only one night. Yellow pitaya primarily relies on moths and bats for pollination. Although the plant is capable of self-pollination, cross-pollination significantly enhances fruit set and improves fruit quality (Paul et al., 2019; Rabelo et al., 2020). Upon successful pollination, the flowers develop into oval-shaped fruits with bright yellow scales covering the peel (Figure 1). The flesh is white, dotted with small black seeds, and is renowned for its sweet and refreshing flavor. The fruiting period varies depending on environmental conditions and cultivation practices. Research indicates that different cultivation systems can result in significant variations in fruit size and yield (Chu and Chang, 2020).

2.2 Environmental requirements for growth

The yellow pitaya (*S. megalanthus*) is highly adaptable and capable of growing under a wide range of environmental conditions. However, optimal growth is achieved under specific conditions. Its photosynthesis mechanism, similar to most cacti, follows Crassulacean Acid Metabolism (CAM), which minimizes water loss by opening stomata at night, making it well-suited to arid environments (Rabelo et al., 2020). For optimal growth, yellow pitaya requires ample sunlight, with studies showing that approximately 70% light transmittance is ideal. The species is photoperiod-sensitive, and the length of daylight influences its flowering and fruiting cycles. Under controlled light conditions, shade cultivation can improve certain growth parameters, such as the number of fruits per stem segment and stem segment length (Victor et al., 2021). Yellow pitaya thrives in warm tropical climates, with an optimal temperature range of 18 °C to 30 °C. It is sensitive to frost and prolonged cold, which can adversely affect its growth and fruit production.

Humidity also plays a critical role in its development, with a suitable range of 60%-80%. While the plant has some drought tolerance, regular watering during vigorous growth and flowering periods significantly promotes growth. However, overwatering can lead to root rot, making well-drained soil and controlled irrigation essential

(Morillo et al., 2023). Additionally, good air circulation is crucial for preventing fungal infections in humid conditions. Maintaining stable light, temperature, and humidity in controlled environments can enhance the plant's overall productivity (Victor et al., 2021; Morillo-Coronado et al., 2022).

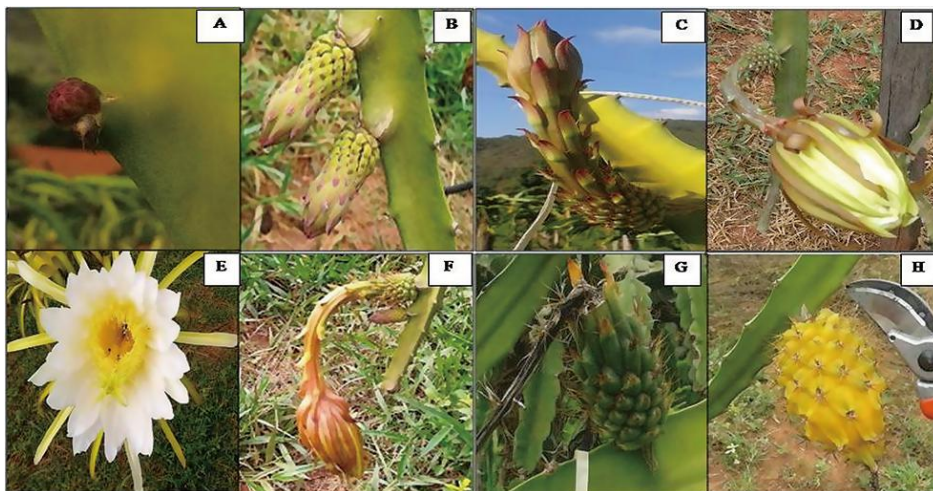


Figure 1 Phases of reproductive phenology of yellow pitaya: (A) appearance of the floral bud, (B, C) floral button elongation, (D) onset of sepal detachment, (E) before the flower, (F) pollinated flower, (G) growing fruit, and (H) maturation of the fruit of *S. megalanthus* in Couto de Magalhães de Minas, Minas Gerais State, Brazil (Adopted from Rabelo et al., 2020)

2.3 Soil and climate requirements for cultivation

S. megalanthus prefers well-drained soils with a pH range of 5.5 to 7.5. The soil should be rich in organic matter and nutrients to support vigorous growth and high fruit yield. Organic cultivation practices, including the use of worm compost and other organic amendments, have been shown to significantly improve soil fertility and plant health (Fratoni et al., 2019). Nitrogen fertilization, in particular, has been identified as a critical factor in enhancing yield and fruit quality, with optimal rates varying depending on the specific growth cycle and environmental conditions (Alves et al., 2021; Victor et al., 2021).

In terms of climate, yellow pitaya is best suited for cultivation in subtropical to tropical regions. Its flowering and fruiting processes require a distinct dry period, making areas with alternating wet and dry seasons particularly favorable for its growth (Rabelo et al., 2020). Regarding precipitation, an annual rainfall range of 600 to 1,200 mm is ideal, but proper drainage is essential to prevent waterlogging. Planting sites should be sheltered from strong winds to avoid physical damage to the stems and flowers, which could adversely affect yields. In regions prone to heavy rainfall, it is recommended to use raised beds or ridge planting systems to enhance drainage efficiency.

3 Seedling and Planting Techniques of Yellow Pitaya

3.1 Selection and cultivation of quality seedlings

Selecting high-quality seedlings is crucial for establishing a healthy and high-yield yellow pitaya plantation. Key criteria for seedlings include vigor, disease resistance, and uniformity. Healthy seedlings should exhibit bright green stems, robust root systems, and no visible signs of pests or diseases (Zheng et al., 2018). Seedlings should be approximately 30 cm long and well-rooted, as these characteristics are indicative of healthy and vigorous plants capable of establishing quickly in the field (Victor et al., 2021). Additionally, seedlings should be selected based on their phenotypic traits, such as uniformity in size and absence of physical damage, to ensure consistent growth and yield (Morillo-Coronado et al., 2022).

Yellow pitaya can be efficiently propagated through stem cuttings, a simple and effective method for preserving the genetic traits of the parent plant. Cuttings should be rooted in a substrate composed of vegetable soil and worm compost, which provides essential nutrients and promotes healthy root development (Victor et al., 2021). The use of a protective cultivation system with horticultural shade cloth allowing 70% sunlight penetration can

enhance seedling growth by providing an optimal microenvironment. Regular monitoring and management of the nursery, including pest control and adequate watering, are crucial for maintaining seedling health and vigor (Li et al., 2022; Morillo-Coronado et al., 2022).

3.2 Appropriate planting density and methods

Planting density is a key factor affecting the yield of yellow pitaya, with its optimal level determined by soil fertility, climate, and cultivation practices. Goenaga et al. (2020) compared the yield and fruit quality of different pitaya varieties and highlighted that optimizing planting density can increase individual fruit weight and sugar content while reducing disease incidence. Proper planting density helps minimize competition for resources such as water and nutrients and lowers the risk of disease transmission. Studies have shown that high-density planting, with a spacing of 50 cm between plants, can effectively enhance fruit yield (Victor et al., 2021). This density facilitates efficient use of space and resources, thereby increasing productivity per unit area.

Planting design for yellow pitaya should account for its spatial requirements to ensure adequate sunlight and air circulation. Row arrangements should be optimized to maximize light exposure and can incorporate intercropping with other crops to enhance land use efficiency and potentially reduce pest and disease incidence (Loureiro et al., 2020). For example, alternating different pitaya varieties can help optimize space utilization. Additionally, due to the climbing nature of yellow pitaya, proper trellises and support structures are essential for managing plants and facilitating harvest. Vertical trellis systems are commonly employed to support the plants, encouraging upward growth and ensuring that fruits do not come into contact with the ground. This approach minimizes the risks of rot and pest infestations (Morillo-Coronado et al., 2022; Trindade et al., 2023).

3.3 Planting substrate and soil management

The ideal planting substrate for yellow pitaya should have excellent drainage and be rich in organic matter. Commonly used substrates include a mixture of sand, perlite, and compost, which provide the necessary aeration and balanced nutrient supply. The substrate pH should range from slightly acidic to neutral (approximately 6.0 to 7.0) to ensure optimal nutrient absorption by the plant roots (Alves et al., 2021). Studies have found that mixing sandy soil with organic compost in a 3:2 ratio offers excellent aeration and a balanced nutrient supply. Adding vermicompost and mountain microorganisms to the substrate can further improve soil structure and enhance microbial activity, thereby promoting plant growth (Fratoni et al., 2019; Victor et al., 2021).

Soil preparation should incorporate the application of organic matter to improve soil fertility and structure. Applying compound fertilizers containing nitrogen, phosphorus, and potassium (e.g., N-P2O5-K2O at a ratio of 8-20-20) significantly enhances seedling growth and nutrient accumulation (Fratoni et al., 2019). The use of organic fertilizers such as cow, sheep, and horse manure is an effective way to provide sustainable nutrients and improve soil health (Victor et al., 2021). Regular soil testing is recommended to monitor nutrient levels and adjust fertilization practices accordingly. Mulching around the plant base helps retain soil moisture, regulate temperature, and reduce weed growth, thereby supporting overall plant health (Thakur, 2021).

4 Water and Fertilizer Management of Yellow Pitaya (*Selenicereus megalanthus*)

4.1 Water management and irrigation strategies

Effective irrigation scheduling is crucial for optimizing the growth and yield of yellow pitaya. Regular monitoring of soil moisture levels and adjusting irrigation frequency based on climatic conditions and plant needs can help maintain optimal hydration. Studies have shown that pitaya plants benefit from consistent moisture, particularly during flowering and fruiting stages, to ensure high-quality fruit production (Morillo-Coronado et al., 2022).

Implementing efficient irrigation techniques such as drip irrigation can significantly enhance water use efficiency and reduce wastage. Drip irrigation delivers water directly to the root zone, minimizing evaporation and runoff. This method is particularly beneficial in arid regions where water conservation is critical. Additionally, mulching around the base of the plants can help retain soil moisture and reduce the frequency of irrigation (Morillo-Coronado et al., 2022; Oltehua-Lopez et al., 2023).

4.2 Fertilizer requirements and application techniques

Yellow pitaya has specific nutritional requirements that vary across different growth stages. During the vegetative stage, a balanced supply of nitrogen (N), phosphorus (P), and potassium (K) is essential for promoting healthy cladode development. As the plant transitions to the flowering and fruiting stages, the demand for phosphorus and potassium increases to support flower formation and fruit set. Research indicates that applying 300 g of N per plant can significantly enhance yield and fruit quality in *Selenicereus megalanthus* (Fratoni et al., 2019; Alves et al., 2021).

To maximize nutrient uptake, fertilizers should be applied in a manner that ensures even distribution and minimizes leaching. Split applications of fertilizers, where nutrients are provided in smaller doses at regular intervals, can improve nutrient availability and uptake efficiency. Foliar feeding, where nutrients are sprayed directly onto the leaves, can also be an effective method to quickly address nutrient deficiencies (Fratoni et al., 2019).

4.3 Integration of organic and inorganic fertilizers

Organic fertilizers, such as compost and manure, offer several benefits for pitaya cultivation. They improve soil structure, enhance microbial activity, and provide a slow-release source of nutrients. The use of organic inputs has been shown to increase the fresh and dry weight of cladodes, indicating better overall plant health and productivity (Fratoni et al., 2019; Victor et al., 2021).

Combining organic and inorganic fertilizers can provide a balanced nutrient supply, leveraging the immediate availability of inorganic nutrients and the long-term benefits of organic matter. This integrated approach can enhance soil fertility and plant growth. For instance, using a mix of organic compost and NPK fertilizers has been found to support optimal growth and yield in yellow pitaya (Vilaplana et al., 2018a; Fratoni et al., 2019).

5 Growth Regulation Techniques of Yellow Pitaya

5.1 Pruning and plant management

Pruning is a crucial practice for maintaining the health and productivity of yellow pitaya plants. Different pruning methods significantly impact plant growth and yield. For example, vine pruning promotes more flowering and new branch growth, which is vital for future yield. In contrast, short-branch pruning aids plant rejuvenation but substantially reduces flowering and hinders robust vegetative growth (Arredondo et al., 2022). A combined pruning approach provides intermediate effects, while simple sanitary pruning is more effective during the early years of cultivation.

Additionally, proper canopy management enhances photosynthetic efficiency by guiding branches to grow into a more open structure, optimizing light exposure. Maintaining an open canopy not only maximizes light interception but also improves air circulation, reducing the risk of fungal infections (Morillo-Coronado et al., 2022). Furthermore, minimizing branch overcrowding and improving ventilation can lower the incidence of pests and diseases (Vilaplana et al., 2018a).

5.2 Trellis construction and growth direction control

Trellises and support structures are crucial for supporting the climbing nature of yellow pitaya plants. Various types of trellises, such as vertical poles, horizontal wires, and T-shaped structures, can be used. These structures help in managing the plant's growth direction and prevent the branches from breaking under the weight of the fruit (Morillo-Coronado et al., 2022). Vertical poles are the most common support structure, offering a simple and effective way to allow plants to climb (Setyowati et al., 2018). T-shaped structures enable branches to spread horizontally, promoting better light exposure and easier harvesting. Wire trellis systems provide a more comprehensive support framework, accommodating multiple branches and enhancing stability, especially in windy conditions (Soffiatti et al., 2022). The choice of support system can be adjusted based on specific cultivation conditions and spatial requirements.

Growth direction control and plant training are crucial for maximizing the efficiency of the support system and ensuring that yellow pitaya plants grow in an organized manner. Techniques such as tying the branches to the trellis, using clips or ties, and regularly adjusting the plant's position can help in directing growth (Shah et al., 2023). This practice ensures that the plants grow in a manageable and productive manner, facilitating better light exposure and air circulation.

5.3 Hormone regulation and flowering period management

The use of plant growth regulators (PGRs) can significantly enhance the flowering and fruiting of yellow pitaya. PGRs such as auxins, gibberellins, and cytokinins can be applied to stimulate flower bud formation and improve fruit set. These hormones help in synchronizing the flowering period, leading to a more uniform and predictable harvest (Oltehua-Lopez et al., 2023; Erazo-Lara et al., 2024). However, careful management is required when using plant growth regulators (PGRs), as improper application may result in excessive vegetative growth, adversely affecting fruit development. By applying appropriate amounts of growth regulators at the right stages, farmers can ensure an increased number of flowers, thereby enhancing fruit set and ultimately boosting yield.

Flowering management is equally important for achieving synchronized fruit production, which simplifies harvest management and improves marketability. Techniques such as adjusting irrigation schedules, applying PGRs, and manipulating light exposure can help in controlling the timing of flowering. For instance, ensuring that the plants receive consistent and adequate water during the flowering period can promote uniform flowering and fruit set (Li et al., 2022). Additionally, hand pollination within a specific time frame after flowering can optimize fruit setting and size.

6 Pest and Disease Control of Yellow Pitaya

6.1 Common diseases and control measures

Yellow pitaya (*Selenicereus megalanthus*) is susceptible to several diseases, including black rot, anthracnose, stem brown spot, and stem canker. Black rot, caused by *Alternaria alternata*, manifests as dark lesions on the fruit, leading to significant postharvest losses (Vilaplana et al., 2018a; b). Anthracnose, caused by *Colletotrichum gloeosporioides*, presents as reddish-orange spots that turn dark brown and can lead to significant crop damage (Bello et al., 2022). Stem brown spot, caused by *Nigrospora sphaerica*, appears as reddish-brown necrotic lesions on the stems, which can merge into larger dark brown areas (Khoo et al., 2022a). Stem canker, caused by *Neoscytalidium dimidiatum*, is characterized by black pycnidia on the stem surface, leading to rotting and significant plant damage (Khoo et al., 2022b).

Effective control of these diseases involves both chemical and non-chemical methods. Sodium bicarbonate (SBC) treatments have shown efficacy in controlling black rot, reducing weight loss, and maintaining fruit quality during storage (Vilaplana et al., 2018a). Hot water treatments at 50 °C for 2 minutes have also been effective in reducing black rot lesions without affecting fruit quality (Vilaplana et al., 2018b). For anthracnose, biological fungicides like Serenade ASO, containing *Bacillus amyloliquefaciens*, have demonstrated complete inhibition of the pathogen's mycelial growth (Bello et al., 2022). Regular monitoring and early detection are crucial for managing stem brown spot and stem canker, with molecular and morphological characterization aiding in accurate pathogen identification (Khoo et al., 2022a;b).

6.2 Types of pests and integrated control strategies

Yellow pitaya is affected by various pests, including the guava root-knot nematode (*Meloidogyne enterolobii*) and fruit flies like *Bactrocera correcta*. The guava root-knot nematode causes plant stunting, reduced yields, and galled roots, significantly impacting plant health and productivity (Wu et al., 2023). *Bactrocera correcta*, a significant pest of pitaya, affects the fruit quality and yield, with the 3rd instar larvae being the most tolerant to control measures (Shan et al., 2023).

Integrated Pest Management (IPM) for yellow pitaya involves a combination of chemical, biological, and cultural practices. For nematode control, regular soil health monitoring and the use of resistant plant varieties are

recommended (Wu et al., 2023). For fruit fly management, combining methyl bromide (MB) and phosphine (PH₃) treatments has shown higher efficacy and reduced MB requirements, protecting fruit quality better than MB alone. Implementing these strategies in a coordinated manner can effectively manage pest populations and minimize crop damage.

6.3 Application of eco-friendly control methods

Biological control agents offer an eco-friendly alternative to synthetic chemicals. *Bacillus amyloliquefaciens*, used in Serenade ASO, has proven effective against *Colletotrichum gloeosporioides*, completely inhibiting its growth (Bello et al., 2022). These biological agents can be integrated into disease management programs to reduce reliance on synthetic fungicides and minimize environmental impact.

Natural pesticides and cultural practices play a vital role in sustainable pest and disease management. Sodium bicarbonate (SBC) treatments have been effective in controlling postharvest black rot without harming the fruit's sensory quality (Vilaplana et al., 2018a). Hot water treatments provide a residue-free method for controlling black rot, aligning with eco-friendly practices (Vilaplana et al., 2018b). Additionally, maintaining proper field hygiene, crop rotation, and using disease-free planting material are essential cultural practices that help prevent the spread of pathogens and pests.

7 Case Studies

7.1 Practices and outcomes of organic cultivation models

Studies have shown that conventional pitaya cultivation methods, relying heavily on chemical fertilizers and pesticides, negatively impact the environment and fruit quality, leading to increased interest in organic farming practices. One study explored the organic cultivation of two pitaya species (*Selenicereus megalanthus* and *Selenicereus undatus*) in southeastern Mexico (Victor et al., 2021). The research utilized organic substrates, including vermicompost and mountain microorganisms, combined with manual pollination techniques. It incorporated various organic fertilizers (e.g., biochar, wood ash, and animal manure) and natural pesticides derived from plant extracts such as garlic, onion, chili, and neem leaves (Table 1). The results demonstrated a remarkable yield breakthrough within the first year, achieving a total yield of 300 kg, with *S. undatus* and *S. megalanthus* contributing 179.4 kg and 119.6 kg, respectively. The maximum individual fruit weight reached 960 g, significantly exceeding the regional average. Furthermore, organic management improved fruit quality, delivering superior flavor and texture.

Table 1 Program of application of organic products in pitahaya production area (Adopted from Victor et al., 2021)

Date	Products
August 5th, 2019	Mountain microorganisms
August 12th, 2019	Biol (fermented liquid organic fertilizer) + ormus
August 19th, 2019	CaldoSulfocálsico (organic fungicide)
August 26th, 2019	Biol (fermented liquid organic fertilizer) + ormus
September 2nd, 2019	Biochar
September 9th, 2019	Organic Insecticide (potassium soap)
September 16th, 2019	Biol (fermented liquid organic fertilizer) + ormus
September 23rd, 2019	Caldo de cenizas (organic insecticide)
September 30th, 2019	Biol (fermented liquid organic fertilizer) + ormus
October 7th, 2019	Organic Insecticide (potassium soap)
October 14th, 2019	Biol (fermented liquid organic fertilizer) + ormus
October 21st, 2019	CaldoSulfocálsico (organic fungicide)

These findings highlight that organic cultivation significantly enhanced the yield and quality of both *Selenicereus megalanthus* and *Selenicereus undatus* while also reducing the fruit maturation cycle. This provides a successful model for sustainable pitaya farming, demonstrating the potential of organic agricultural techniques to improve economic returns and environmental sustainability. Such a model could be widely promoted in other tropical regions, creating greater value for pitaya growers.

7.2 Study on the effects of inducer treatments on yellow pitaya yield

Pre-treatment inducers, such as salicylic acid (SA), methyl salicylate (MeSa), methyl jasmonate (MeJa), and oxalic acid (OA), are known to regulate plant growth, enhance stress resistance, and optimize fruit quality. Erazo-Lara et al. (2024) investigated the effects of these four inducers applied at different concentrations on yellow pitaya. The study revealed that these inducers significantly improved crop yield and fruit quality, although the effects varied depending on the type and concentration of the inducer.

The experimental results demonstrated that all treatments increased fruit yield, size, and weight, but with differing levels of effectiveness based on inducer type and application concentration. Among the treatments, methyl jasmonate at a concentration of 10 mM showed the most pronounced effect on yield, achieving approximately 20 kg per plant. Oxalic acid at 5 mM was particularly effective in increasing fruit weight, reaching about 388 g per fruit (Figure 2). In terms of quality, the application of methyl jasmonate and oxalic acid significantly enhanced fruit firmness, while methyl salicylate at 10 mM accelerated fruit maturation. The study underscores the potential of pre-treatment inducers to enhance yellow pitaya yield and quality, with their effectiveness appearing to be concentration-dependent. Further research on the role of inducers during postharvest storage could lead to the development of more efficient fruit preservation strategies.

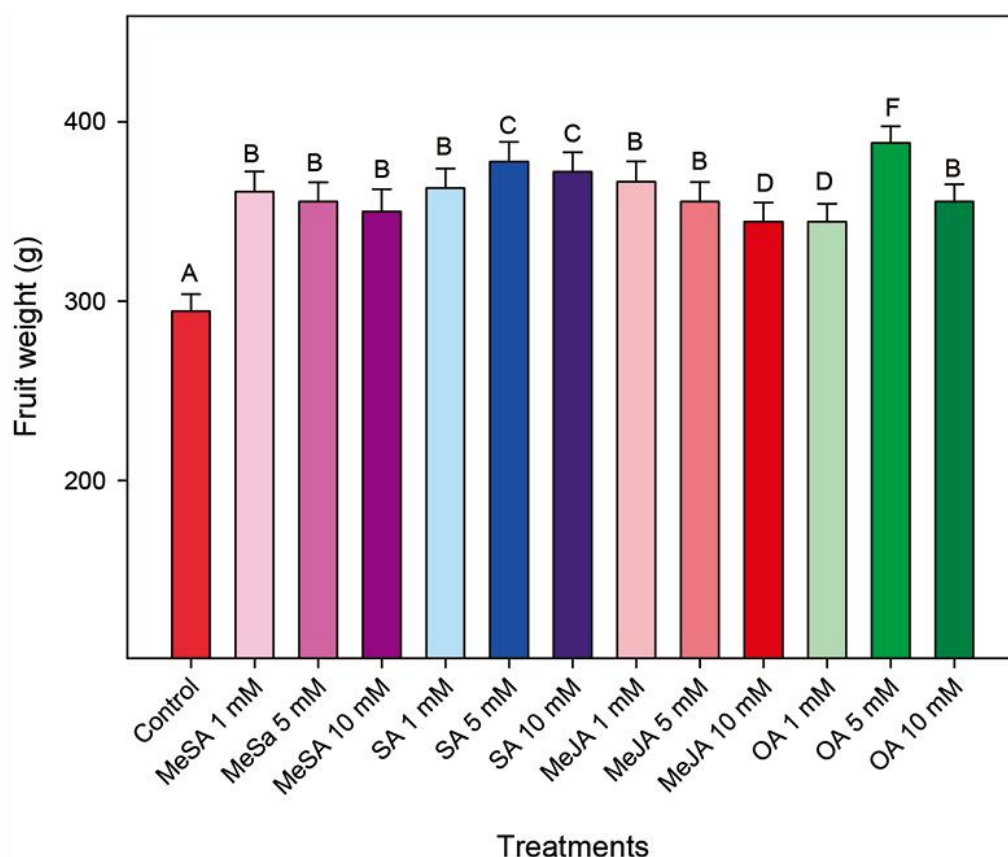


Figure 2 Fruit weight (g) at harvest time of pitahayas from control and treated with methyl salicylate (MeSa), salicylic acid (SA), methyl jasmonate (MeJa), and oxalic acid (OA) at concentrations of 1, 5, and 10 mM. Data are the mean $\pm$ SE (n=9). Bars with different letters denote significant differences at $p < 0.05$ after the Tukey's test (Adopted from Erazo-Lara et al., 2024)

8 Harvesting and Post-Harvest Handling of Yellow Pitaya

8.1 Determining the optimal harvesting time

The optimal harvesting time for yellow pitaya is crucial to ensure maximum fruit quality and yield. Indicators of maturity include changes in skin color, firmness, and the development of soluble solids. For instance, the soluble solids content, which is a measure of sweetness, tends to be slightly higher in open-field systems compared to covered systems, with values around 15.20 °Brix and 14.66 °Brix, respectively (Morillo-Coronado et al., 2022).

Additionally, the physical size and weight of the fruit can serve as maturity indicators, with larger fruits typically found in open-field systems.

Harvest timing significantly impacts the quality and yield of yellow pitaya. Early or late harvesting can affect the fruit's firmness, color, and overall marketability. For example, nitrogen fertilization studies have shown that optimal nutrient management can enhance yield and fruit quality, with the highest yields observed at specific nitrogen rates (Alves et al., 2021). Proper timing ensures that the fruit retains its desirable characteristics, such as firmness and sweetness, which are essential for consumer acceptance (Alves et al., 2021; Morillo-Coronado et al., 2022).

8.2 Post-harvest handling and storage management

To minimize post-harvest losses, it is essential to implement effective disease management strategies. Treatment with 298 mM SBC has been shown to reduce weight loss, retain color and firmness, and slow changes in total soluble solids and titratable acid content during storage (Vilaplana et al., 2018). This treatment is superior to synthetic fungicides and helps maintain the sensory quality of the fruit.

Maintaining optimal storage conditions is critical for preserving the freshness of yellow pitaya. The ideal storage temperature is around 12 °C, with a shelf-life extension at 20 °C for up to 5 days (Cruz et al., 2021). These conditions help retain the fruit's firmness, color, and overall appearance, ensuring it remains marketable for a longer period. Proper storage conditions also help in slowing down the physiological changes that can lead to quality degradation.

8.3 Strategies to improve fruit quality

Post-harvest treatments play a vital role in enhancing the shelf life of yellow pitaya. Sodium bicarbonate (SBC) treatments are effective in controlling postharvest diseases and maintaining fruit quality. These treatments help in reducing weight loss and preserving the fruit's sensory attributes, making them a viable alternative to synthetic fungicides (Vilaplana et al., 2018). Additionally, organic cultivation practices, including the use of natural fertilizers and pest control methods, can contribute to improved fruit quality and extended shelf life (Victor et al., 2021).

Quality assessment and grading are essential for ensuring that only the best fruits reach the market. Key parameters for quality assessment include fruit size, weight, color, firmness, and soluble solids content. For instance, fruits grown in open-field systems tend to be larger and have higher soluble solids content, making them more desirable for consumers (Morillo-Coronado et al., 2022). Grading techniques should focus on these parameters to ensure consistency and high quality in the market supply (Morillo-Coronado et al., 2022; Morillo et al., 2023).

9 Concluding Remarks

The cultivation of yellow pitaya (*Selenicereus megalanthus*) involves several key techniques aimed at optimizing yield and fruit quality. Nitrogen fertilization has been shown to significantly enhance yield, fruit quality, and cladode nutrient content, with the highest yield for *S. megalanthus* achieved at 300 g N per plant. Organic cultivation methods, including the use of worm-compost and mountain microorganisms, have also demonstrated favorable results, significantly increasing production and fruit size compared to conventional methods. Hand pollination is another critical technique, with optimal results achieved when pollination occurs within 6 hours after flowering, ensuring high fruit setting rates and larger fruit sizes. Additionally, morphoagronomic evaluations have identified specific genotypes with superior agronomic traits, which can be targeted in breeding programs to further enhance yield.

Future research should focus on refining and integrating these cultivation techniques to further boost yield. This includes optimizing nitrogen fertilization rates and exploring the synergistic effects of combining organic and

inorganic fertilizers. Advances in pollination techniques, such as improving pollen storage methods, could also enhance fruit set and yield. Additionally, breeding programs should continue to identify and propagate high-yielding genotypes, leveraging molecular tools and genomic data to accelerate the development of superior cultivars. Addressing disease management, particularly postharvest diseases like black rot, through integrated pest management strategies, including the use of sodium bicarbonate treatments, will also be crucial.

The yellow pitaya industry is poised for significant growth, driven by increasing global demand and advancements in cultivation techniques. The adoption of optimized fertilization practices, organic farming methods, and efficient pollination strategies will likely lead to higher yields and better fruit quality, enhancing market competitiveness. Continued investment in breeding programs and the development of disease-resistant and high-yielding genotypes will further strengthen the industry's foundation. Moreover, sustainable practices, such as the use of organic inputs and integrated pest management, will appeal to environmentally conscious consumers and contribute to the long-term viability of dragon fruit cultivation. Overall, the future of the dragon fruit industry looks promising, with ample opportunities for innovation and expansion.

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Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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