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Growth Characteristics and High Sweetness Cultivation Management Plan of Thornless Yellow Dragon Fruit

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Abstract *Hylocereus undatus* (Haw.), also known as thornless yellow dragon fruit, is a yellow-skinned, white-fleshed dragon fruit that has garnered attention for its bright appearance and high vitamin content. However, its high acidity and short shelf life have limited its market acceptance, with the cultivation area gradually decreasing from 5,000 mu to less than 200 mu. This study focused on the growth characteristics and cultivation and management measures of *Hylocereus undatus* (Haw.). The study found that spraying the entire fruit with 100 ppm gibberellin + 10 ppm forchlorfenuron + 1,000 ppm slow-release nitrogen fertilizer during the first fruit expansion period can extend the fruit-bearing period to 40 days, the hanging period 30 days, and increase soluble solids by 21.5% Brix. The results indicate that the optimized cultivation management plan effectively improved the taste and shelf life of *Hylocereus undatus* (Haw.), enhancing its market competitiveness. The improved cultivation management techniques not only enhanced the fruit quality of *Hylocereus undatus* (Haw.) but also provided solid technical support for its commercial promotion. The findings of this study offer valuable insights for the cultivation of other high-acidity, short-shelf-life fruits, and have significant practical implications.
Keywords Dragon fruit; Thornless yellow dragon fruit (*Hylocereus undatus* (Haw.)); Cultivation technology; High sweetness; Shelf life

1 Introduction

Dragon fruit (*Hylocereus undatus* (Haw.) Britton & Rose) is a perennial climbing succulent plant of the genus *Hylocereus* in the Cactus family. It originates from the tropical rainforests of Brazil, Mexico, Ecuador, and other Central and South American regions, being a typical tropical plant. Dragon fruit has a unique appearance and is rich in nutrients, containing water-soluble dietary fiber, betalains, and the rarely found plant protein, making it highly favored by consumers (Goenaga et al., 2020). In recent years, the consumption of dragon fruit in China has been continuously rising, driving rapid growth in its cultivation area. As of 2020, the cultivation area of dragon fruit in China has exceeded 1 million mu (Luo et al., 2023), making it an important economic crop in the southern subtropical regions.

The varieties of dragon fruit cultivated in China are mainly red-skinned with red pulp (*Hylocereus costaricensis*) and red-skinned with white pulp (*Hylocereus undatus* (Haw.)), with the main cultivated varieties being 'Jindu No.1,' 'Dahong' and 'Guihonglong' among others (Lu et al., 2023). Although these varieties have significantly increased yield, there are minor differences in fruit appearance, quality, and yield, leading to a lack of diversity and serious homogenization, which weakens market consumption. To address market consumption upgrades, breeding new high-quality dragon fruit varieties has become an important solution to stimulate further industry development and meet market demand. Yellow-skinned dragon fruit, due to its novel appearance, unique taste, and high economic benefit, is considered a potential upgraded variety of dragon fruit.

Yellow-skinned dragon fruit is divided into thorny yellow dragon and thornless yellow dragon (Figure 1). The thorny yellow dragon, also known as the bird's nest fruit, has spines on the fruit's surface that gradually fall off as

the fruit ripens and turns yellow. It is native to the tropical highland regions of Ecuador, Colombia, and Peru (Espinoza-Lozano et al., 2022). These regions are rich in cactus family plant resources, and studies have shown that the bird's nest fruit is an allotetraploid hybrid naturally produced by *Hylocereus undatus* (Haw.) and Selenicereus (Setyowati et al., 2018). Thornless yellow dragon, also known as the Israel Dragon (*Hylocereus undatus* (Haw.)), was developed by Professor Yosef Mizrahi's team in Israel in the 1990s through hybrid breeding. It is a yellow-skinned, white-fleshed variety belonging to the white-fleshed dragon fruit (Abdi and Mizrahi, 2012). The thornless yellow dragon fruit is large, with bright yellow tender skin, smooth surface, white flesh, small seeds, delicate taste, and strong disease resistance, making it a high-quality dragon fruit variety.

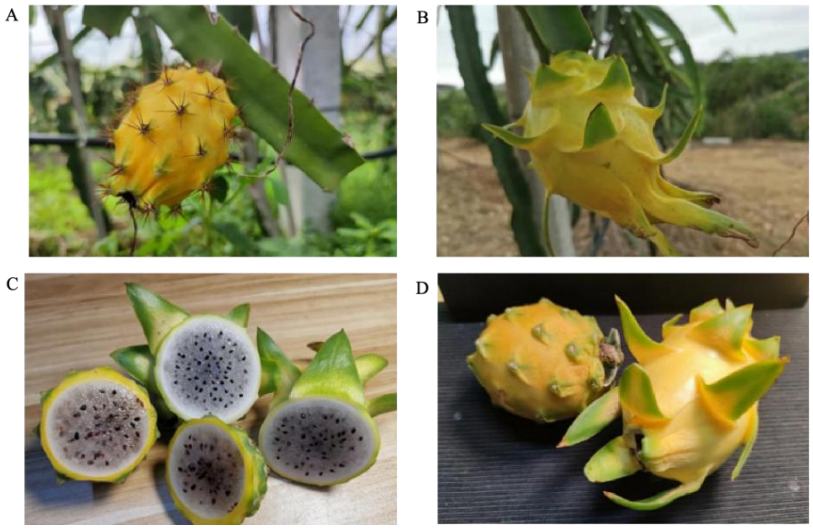

Figure 1 Differences in peel, flesh, and fruit size between thorny yellow dragon fruit and thornless yellow dragon fruit
Image caption: (A) Field photo of thorny yellow dragon fruit (Yanwoguo), showing fruit with thorny peel; (B) Field photo of thornless yellow dragon fruit, showing fruit with smooth peel; (C) Differences in flesh between thorny yellow dragon fruit (bottom) and thornless yellow dragon fruit (top), with the image showing whiter flesh, smaller seeds, and finer texture in thornless yellow dragon fruit; (D) Size differences between thorny yellow dragon fruit (top) and thornless yellow dragon fruit (bottom), with thornless yellow dragon fruit being larger, with a bright, tender yellow peel. Results indicate that there are significant differences in appearance and taste between thorny yellow dragon fruit (Yanwoguo) and thornless yellow dragon fruit (Israeli yellow dragon fruit)

The high sweetness of dragon fruit is one of the key factors that make it popular with consumers in the market. As living standards improve, consumers have higher demands for the sweetness, taste, and nutritional value of fruits. High-sweetness dragon fruit not only has a good taste, satisfying consumers' taste needs but also improves consumers' health through its rich nutritional content. Therefore, cultivating high-sweetness dragon fruit has significant market value and economic benefits. Although the thornless yellow dragon fruit has advantages such as large fruit size and strong disease resistance, its high acidity and low soluble solids content affect its market acceptance to some extent (Qin et al., 2022, Rural Science and Technology, 13(19): 67-69). Increasing the sweetness of the thornless yellow dragon to improve its taste and make it a more popular high-quality variety in the market is essential for promoting the development of the dragon fruit industry. By optimizing cultivation management techniques, such as using suitable fertilizers and reasonable water management measures, the sweetness of the thornless yellow dragon can be effectively increased, enhancing its market competitiveness.

This study focuses on the thornless yellow dragon, introducing its growth characteristics and cultivation management points. The research provides a detailed analysis of the growth environment, nutritional needs, water management, and pest and disease control characteristics of the thornless yellow dragon, proposing optimized cultivation management plans. Specifically, measures such as chemical spraying are suggested to increase the sweetness of the thornless yellow dragon, thus improving the cultivation technology system for yellow dragon fruit. By cultivating high-sweetness, high-quality thornless yellow dragon, the study aims to improve market supply quality, meet consumer demand, further stimulate market demand, and promote the sustainable

development of the dragon fruit industry. Additionally, the study hopes to summarize and promote the cultivation experience of the thornless yellow dragon, providing references for the cultivation of dragon fruit in other regions and varieties, thereby contributing to the prosperity and development of the dragon fruit industry globally.

2 Results and Analysis

2.1 Growth characteristics of thornless yellow dragon branches

Dragon fruit utilizes the Crassulacean Acid Metabolism (CAM) pathway, a mechanism that allows it to close its stomata during the day to maintain water balance and open them at night to absorb carbon dioxide. This adaptation improves carbon fixation efficiency under low carbon dioxide concentrations (Hultine et al., 2019). Due to this unique carbon fixation method, the branches of dragon fruit elongate during the day and exhibit minimal growth at night. The growth rate of the branches is also closely related to their growth stage.

In the early growth stage (typically referring to young branches less than 20 cm in length), the elongation rate of the branches is relatively slow, extending by about 1 cm per day. However, once the branches exceed 20 cm in length, the elongation rate significantly increases, with daily growth reaching approximately 2-3 cm (Figure 2). This variation indicates that the growth pattern of dragon fruit is closely tied to its physiological and metabolic characteristics, providing important guidance for the efficient cultivation of thornless yellow dragon.

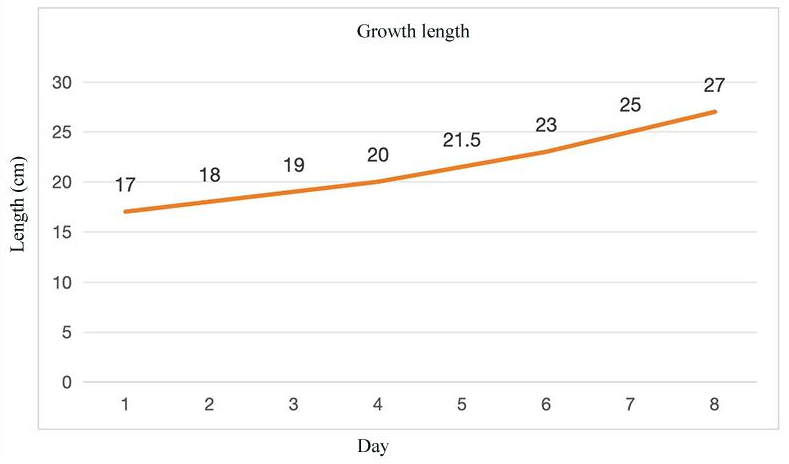

Figure 2 Daily measurement of thornless yellow dragon shoot growth

2.2 Root characteristics of thornless yellow dragon

The root system of thornless yellow dragon is more vigorous compared to the red-pulp dragon fruit. Its underground roots are not only well-developed but also possess a stronger resistance to nematodes, which contributes to the plant's excellent performance in resisting pests and diseases (Long et al., 2020). Additionally, the aerial stems of thornless yellow dragon are prone to developing aerial roots. Once these aerial roots reach the ground, they transform into underground roots, further enhancing the plant's stability and absorption capacity (Figure 3). This unique root structure provides thornless yellow dragon with a strong adaptability to various environments.

Figure 3 Vigorous root system of thornless yellow dragon

Thornless yellow dragon not only has strong pest and disease resistance but can also be used as a rootstock. By grafting varieties such as red-pulp dragon fruit or the bird's nest fruit onto thornless yellow dragon, the nematode resistance of these grafted varieties can be improved. This grafting method effectively leverages the robust root system of thornless yellow dragon, enhancing the growth performance and pest resistance of the grafted varieties. This approach not only improves the overall yield and quality of dragon fruit but also effectively reduces the impact of pests and diseases, promoting the sustainable development of the dragon fruit industry.

2.3 Flowering period and fruit development characteristics of thornless yellow dragon

The flowering period of thornless yellow dragon overlaps with that of Jindu Dragon Fruit. In Hainan, China, through supplementary lighting technology, it is possible to achieve over 20 flowering batches annually (Xiong et al., 2020). Thornless yellow dragon requires about 18 days from the initial appearance of flower buds to flowering, but this process can extend to 30 days during extremely cold winter periods. Starting from May each year, the interval between each batch of flowers is approximately 15 days. During extremely hot weather, a new batch of flowers can appear weekly. For example, in July, the flowering time for thornless yellow dragon is typically at 9 pm, which is half an hour later than Jindu Dragon Fruit, and the flowers close by 9 am the next day.

During the flowering of thornless yellow dragon, its stigma is noticeably higher than the stamens, characterizing it as a typical cross-pollination flower (Figure 4). This floral structure facilitates cross-pollination, enhancing the fruit set rate and quality (Cho and Ding, 2021). Through reasonable cultivation management and supplementary lighting technology, the flowering period of thornless yellow dragon can be effectively controlled, ensuring a stable and continuous yield and quality throughout the year. The application of this technology not only increases the market supply of thornless yellow dragon but also brings higher economic benefits to farmers.

2.4 Short fruit hanging period and re-greening phenomenon of thornless yellow dragon

Seven days after the flowers of thornless yellow dragon fade, the fruit begins its first enlargement phase. After 23 days, the peel starts to change color from green to yellow. This color change process lasts about a week, during which the fruit enters its second enlargement phase. On the 30th day after flowering, the peel begins to re-green, and the scales start to thin and soften, with the tips even showing signs of drying. By the 40th day, the fruit tips

further dry out, crack, and exhibit rot, losing their commercial value (Figure 5). This phenomenon indicates that the fruit hanging period of thornless yellow dragon is relatively short, making it prone to re-greening and quality degradation issues.

Figure 4 Full bloom period of thornless yellow dragon

Figure 5 From flower emergence to fruit harvest and loss of commercial value in thornless yellow dragon

Moreover, the fruit hanging period and re-greening phenomenon are significantly influenced by environmental temperature. If the temperature is lower, the fruit hanging period and re-greening time will be correspondingly extended. Therefore, to ensure the quality and market value of thornless yellow dragon fruit, it is essential to reasonably schedule the harvest time according to local climate conditions to avoid excessive fruit hanging time that leads to a decline in commercial value. By timely harvesting and scientific management, the quality and economic benefits of thornless yellow dragon fruit can be effectively enhanced.

2.5 Low soluble solid content in thornless yellow dragon fruit

The soluble solid content of dragon fruit varies significantly across different regions. Typically, the sweetness is highest at the center of the fruit, followed by the top and bottom, and lowest at the edges (Wei et al., 2020; Junior et al., 2021). Compared to red-skinned dragon fruit, thornless yellow dragon has an overall lower sweetness. Research data indicates that the soluble solid content at the center of thornless yellow dragon fruit is about 16%-17% Brix, while at the edges it is about 12% Brix. In contrast, the corresponding values for red-skinned dragon fruit are 18%-24% Brix and 16% Brix, respectively. This indicates that thornless yellow dragon has higher acidity and lower sweetness, which is a major factor affecting its market acceptance.

Premature harvesting is one of the key reasons for the low sugar-to-acid ratio in thornless yellow dragon. To ensure the shelf life of thornless yellow dragon, farmers typically start harvesting 1-3 days after the fruit changes color, i.e., 23-25 days after flowering. At this point, the peel is golden yellow and the scales are thicker, making the fruit more resistant to transportation and extending its shelf life. However, at this harvest time, the soluble solid content at the center of the fruit is relatively low, around 15%-17% Brix, with a noticeable sour taste. Appropriately delaying the harvest time could be an important measure to increase the sweetness of thornless yellow dragon fruit, optimize the sugar-to-acid ratio, and thus improve its market acceptance.

3 Discussion

The sweetness and acidity of thornless yellow dragon fruit are two key factors affecting its market acceptance. The fruit's sweetness mainly depends on the content of soluble solids, while acidity affects the overall flavor of the fruit (Yu et al., 2021). Studies have shown that the soluble solid content at the center of thornless yellow dragon fruit is about 16%-17% Brix, while at the edges it is about 12% Brix. This difference is significantly lower than that of red-skinned dragon fruit, resulting in lower sweetness overall (Arivalagan et al., 2021). Additionally, the higher acidity of thornless yellow dragon gives it a more sour taste, which affects consumer preference. To improve market acceptance, effective methods must be found to increase the sweetness and reduce the acidity of thornless yellow dragon.

Varietal improvement is one important way to enhance the sweetness and reduce the acidity of thornless yellow dragon fruit. Through hybrid breeding, new varieties with higher sweetness and lower acidity can be developed (Subandi et al., 2018). Similar studies in apples (*Malus pumila*) and sweet peppers (*Capsicum annuum*) have found that hybridization and re-pollination can significantly increase fruit sweetness and yield, proving the importance of hybridization in fruit tree variety improvement (Rymenants et al., 2020; Pylypenko et al., 2021). Additionally, facility cultivation is an effective method. Growing in greenhouses or tunnels allows control over temperature, moisture, and light conditions, optimizing the fruit's growth environment and improving its quality (Matra et al., 2020). Harvesting time has a significant impact on the soluble solid content and acidity of thornless yellow dragon fruit. Farmers typically start harvesting 1-3 days after the fruit changes color, i.e., 23-25 days after flowering. At this time, the peel is golden yellow, the scales are thicker, making the fruit more resistant to transportation, and the shelf life is longer. However, fruit harvested at this time has a relatively low soluble solid content at the center, about 15%-17% Brix, with a noticeable sour taste. Premature harvesting is one of the main reasons for the low sugar-to-acid ratio in thornless yellow dragon.

To improve the sweetness and taste of the fruit, it is recommended that farmers slightly delay the harvest time. Harvesting 5-7 days after the fruit changes color may slightly shorten the shelf life but will significantly increase the sweetness and reduce the acidity, thereby enhancing market acceptance. During the cultivation of thornless

yellow dragon, farmers often use agricultural techniques such as grafting, thinning flowers and fruits, using regulators, and bagging to improve fruit quality. Grafting techniques can select superior rootstocks to enhance the disease resistance and adaptability of the fruit tree. Thinning flowers and fruits can reduce the number of fruits, concentrating nutrient supply to improve fruit size and quality. Using regulators can adjust the growth and maturation process of the fruit, while bagging can prevent fruit from pest damage, ensuring the appearance quality of the fruit. By selecting the appropriate formula and using these agricultural operations at the right time at critical points, the quality and marketability of thornless yellow dragon fruit can be significantly improved. For example, using growth regulators in the early stages of fruit growth can promote fruit development and increase soluble solid content (Dano et al., 2020). Bagging can prevent direct sunlight, reducing sunburn and maintaining peel smoothness (Hossain et al., 2021).

To enhance the market competitiveness of thornless yellow dragon, in addition to improving fruit sweetness and optimizing cultivation management, efforts should also focus on varietal improvement, post-harvest technology optimization, and market promotion. In terms of varietal improvement, introducing and cultivating high-quality new varieties can improve the overall quality of thornless yellow dragon. Post-harvest technology optimization can involve advanced preservation technologies, such as cold chain transportation and storage, to extend the fruit's freshness and shelf life (Ngoc et al., 2018; Subandi et al., 2018). Market promotion and consumer education are also important means to enhance the market competitiveness of thornless yellow dragon. Conducting market promotion activities can increase consumer awareness and acceptance of thornless yellow dragon. Additionally, scientific packaging and brand building can enhance the market image of thornless yellow dragon, increasing its added value.

Future research directions mainly focus on genetic research and molecular breeding, environmental adaptability studies, and the development of long-term preservation technologies. Genetic research and molecular breeding can use genome editing technology to cultivate more advantageous thornless yellow dragon varieties, enhancing their sweetness and disease resistance. Environmental adaptability studies can optimize cultivation management by studying the climate conditions of different regions, improving the adaptability and yield of thornless yellow dragon. Developing long-term preservation technologies can research different preservatives and packaging materials to extend the freshness and shelf life of thornless yellow dragon. These studies can not only improve the market competitiveness of thornless yellow dragon but also provide technical references for the introduction and improvement of other foreign varieties, promoting the development of the entire dragon fruit industry.

4 Materials and Methods

4.1 Research materials

This study focused on the thornless yellow dragon fruit (*Hylocereus undatus* (Haw.)) as the test subject, with the experiment conducted in Hainan, China. Thornless yellow dragon is characterized by its large fruit size, tender yellow peel, smooth fruit surface, white flesh, small seeds, delicate taste, and strong disease resistance.

The experiment involved systematic observation and recording of thornless yellow dragon's performance at different growth stages. The growth conditions were analyzed under various soil conditions, fertilizer ratios, and irrigation measures to determine the optimal cultivation management plan. Special attention was given to the effects of chemical spraying on improving fruit sweetness and quality.

4.2 Cultivation of thornless yellow dragon

4.2.1 Thinning flowers and fruits

Thinning flowers and fruits is a critical management measure in the cultivation of thornless yellow dragon (Li et al., 2023). The first flowering often results in deformed flowers, leading to an insufficient number of scales on the fruit surface, thin peel, and low fruit sweetness (Figure 6; Table 1). To avoid deformed flowers, it is recommended to start retaining fruits on trees with at least three mature fruit-bearing branches. For every additional three branches, one more fruit can be retained. This method meets the requirement for sugar accumulation in the fruit, prevents a decline in fruit quality, and ensures the thickness of the peel and scales.

Thinning flowers and fruits not only reduces competition among fruits, ensuring each fruit receives sufficient nutrients and water, but also promotes uniform growth. If thinning is not performed, an excessive number of fruits can lead to a reduction in sugar content, adversely affecting taste and market acceptance (Zhai et al., 2015; Costa et al., 2018). Specific practices include removing deformed flowers and excess buds during the flowering period, and eliminating excess young fruits based on the tree's bearing capacity during the fruit setting period. Through proper thinning management, the fruit quality of thornless yellow dragon can be effectively enhanced, increasing its market competitiveness and supporting the sustainable and healthy development of the dragon fruit industry.

Figure 6 Fruit of deformed flowers of thornless yellow dragon

Table 1 Characteristics of different batches of thornless yellow dragon fruits

No.	Peel thickness	Central sugar content (% Brix)	Weight (g)	Number of scales
First batch	Uneven	16.2	311.2	14.2
Second batch	Thick	17.75	324.25	18

Note: The first batch comes from new shoots, while the second batch comes from mature old branches

4.2.2 Rational fertilization

In the cultivation of thornless yellow dragon, rational fertilization is crucial for ensuring healthy growth and high yield. One day before flowering, applying 3-5 kg of calcium-magnesium fertilizer per mu helps promote the closure of the pistils, preventing bacterial invasion of the fruit and reducing the occurrence of fruit rot. During the first fruit enlargement phase, which is three days after the flowers fall, applying 3-5 kg per mu of a 15:9:30 NPK (nitrogen, phosphorus, potassium) water-soluble fertilizer promotes rapid fruit enlargement. Seven to ten days later, using a balanced fertilizer replenishes the tree's phosphorus, aiding the next flowering.

When the fruit begins to change color, applying a 0:30:40 NPK water-soluble fertilizer encourages sugar accumulation, increasing sweetness. After harvesting, applying a 20:20:20 NPK balanced fertilizer at 3-5 kg per mu replenishes the tree's nutrients, preparing it for the next batch of flowers and fruits. By using different types and ratios of fertilizers at various growth stages, the nutritional needs of thornless yellow dragon are met, promoting healthy growth and improving fruit quality and sweetness, thereby enhancing market competitiveness.

4.2.3 Chemical spraying

To increase fruit sweetness and maintain scale integrity, a specific chemical spraying regimen is employed. Seven days after the flowers fall, a water-soluble solution containing 100 ppm gibberellin, 10 ppm forchlorfenuron, and 1,000 ppm slow-release nitrogen fertilizer is sprayed on the entire fruit. Subsequently, 20 days after flowering, during the fruit coloring stage, the fruit is bagged. Fruits treated this way reach peak sweetness 35 days after

flowering, with the soluble solid content reaching up to 21% Brix (Table 2). Although sweetness gradually decreases afterward, the soluble solid content remains around 18% Brix 50 days after flowering, demonstrating a good level of sweetness.

Additionally, the scales of thornless yellow dragon fruit treated with chemical spraying remain relatively intact 60 days after flowering. In contrast, untreated fruit scales begin to dry out at the tips 30 days after flowering, with the scale quality gradually declining until they completely wither 40 days after flowering (Table 2). This chemical spraying method not only enhances the sweetness of thornless yellow dragon but also significantly extends the fruit's shelf life, ensuring its competitiveness and economic benefits in the market.

Table 2 Evaluation of appearance and soluble solids content after tree treatment

Group	Indicators	Days after flowering					
		20 d	25 d	30 d	35 d	40 d	45 d
Treatment Group	Weight (g)	370	424	487	510	515	517
	Sweetness (% Brix)	11	15	17	21	20.5	20
	Scale integrity	Intact	Intact	Intact	Intact	Intact	Intact
	Fruit surface color	Green	Yellow	Yellow	Yellow-green	Green	Green
Control group	Weight (g)	359	410	458	472	480	473
	Sweetness (% Brix)	11	15	17	18	17	15
	Scale integrity	Intact	Intact	Dry tips	Withered	Withered	Cracked
	Fruit surface color	Green	Yellow	Yellow	Yellow-green	Yellow-green	Yellow-green

4.2.4 Grafting method

Studies on various horticultural crops have shown that grafting can significantly improve fruit quality, as seen in melons, cucumbers, and tomatoes (Turhan et al., 2018; Noor et al., 2019). In the cultivation of thornless yellow dragon, either direct seedlings or grafted seedlings can be used. Typically, red-pulp dragon fruit is used as the rootstock for grafting. To analyze the impact of grafting on the sweetness of thornless yellow dragon, we measured the soluble solid content in the fruits of both direct seedlings and grafted seedlings. The results showed that the soluble solid content in different parts of the grafted seedling fruits was higher than that of the direct seedlings, with an increase ranging from 0.4% to 1.4% Brix (Figure 7). This indicates that grafting is an effective method for enhancing the sweetness of thornless yellow dragon.

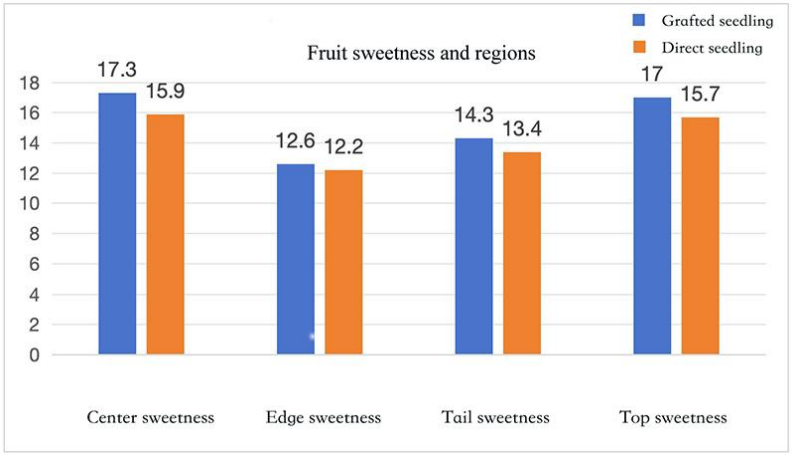

Figure 7 Content of soluble solids in different parts of thornless yellow dragon fruit

Research has found that using different varieties of red-pulp dragon fruit as rootstock for grafting thornless yellow dragon can have varying impacts on fruit quality. For example, when using Xiangmi Dragon as the rootstock, the grafted thornless yellow dragon fruit has a dense texture with a certain degree of sandiness. In contrast, when using Fugui Red as the rootstock, this texture difference is not observed. These findings provide valuable

technical references for the cultivation of thornless yellow dragon. Depending on market demand, appropriate grafting rootstocks can be selected to optimize fruit quality and enhance economic benefits.

4.3 Disease management of thornless yellow dragon

4.3.1 Control of canker disease

Similar to red-pulp dragon fruit, thornless yellow dragon is also susceptible to canker disease (Figure 8). Canker disease can cause spots on the stems and fruit surfaces, significantly affecting fruit quality and yield in severe cases (Kazerooni et al., 2020). It is crucial to take effective control measures promptly at the onset of infection. Studies have shown that spraying with a 1,500-fold solution of kasugamycin and quinoline copper and an 800-fold solution of potassium phosphite can effectively control canker disease. The specific method involves spraying twice in succession, with a one-week interval. During the spraying process, the canker spots gradually scab over and fall off, achieving the desired control effect.

Figure 8 Branches of thornless yellow dragon infected with canker disease

This control method is not only simple and feasible but also offers significant protection for the production of thornless yellow dragon. By implementing scientific disease management, the disease resistance of thornless yellow dragon can be improved, ensuring fruit yield and quality, thereby enhancing market competitiveness. Therefore, effective control of canker disease is an important aspect of the cultivation management of thornless yellow dragon and is worth promoting and applying.

4.3.2 Control of heart rot disease

Compared to red-pulp dragon fruit, thornless yellow dragon has a more severe problem with heart rot disease, which manifests as rotting in the center of the fruit (Figure 9). Pathogen isolation tests have revealed that this issue is caused by the infection of *Fusarium* spp. inside the fruit (Mahmud et al., 2020; Zhao and Huang, 2023). The pistil of thornless yellow dragon is hollow and directly connected to the fruit cavity, allowing pathogens to enter the fruit through the pistil and go dormant (Figure 10). As the sugar content in the fruit accumulates, the internal environment becomes suitable for the proliferation of *Fusarium*, leading to internal fruit rot. By the 23rd day after flowering, when the fruit enters the color-changing stage, the internal rot begins in the infected fruit, though the surface shows no abnormal signs, making it difficult to distinguish between healthy and diseased fruit by appearance. The incidence of heart rot disease in thornless yellow dragon is higher in summer and lower in winter.

Research shows that calcium and magnesium ions play a crucial role in the development of the pistil, promoting rapid expansion of pistil cells, thereby closing the hollow cavity of the pistil and preventing pathogen invasion (Wang et al., 2019). To address the heart rot disease of thornless yellow dragon, we attempted to apply

calcium-magnesium fertilizer one day before flowering, at a dosage of 3-5 kg per mu. The results indicated that this measure significantly reduced the incidence of heart rot disease in thornless yellow dragon. In practical applications, pre-application of calcium-magnesium fertilizer effectively prevents *Fusarium* from entering the fruit through the pistil, reducing the occurrence of heart rot disease, thus ensuring the fruit quality, increasing yield, and improving economic benefits.

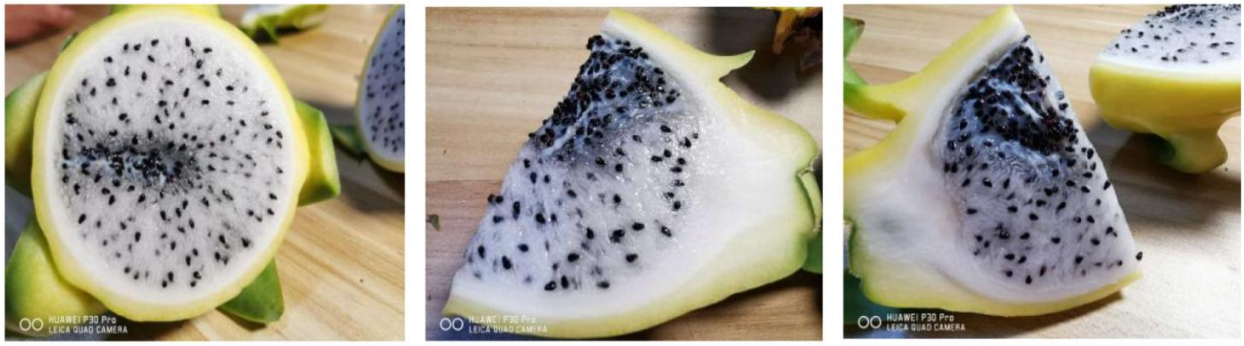

Figure 9 Thornless yellow dragon infected with heart rot disease

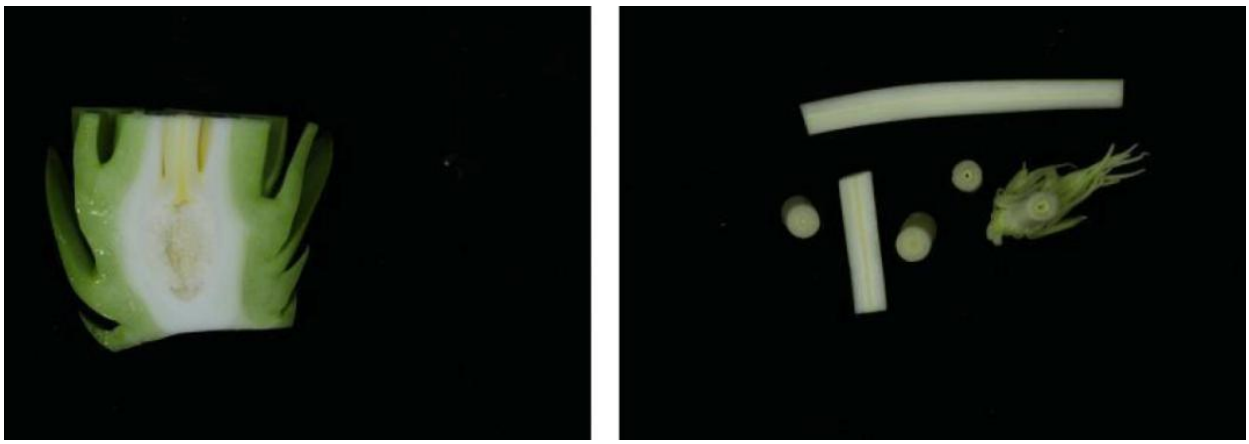

Figure 10 Anatomical details of the flower base (left) and style (right) of the thornless yellow dragon fruit

4.4 Post-harvest handling

Post-harvest handling of thornless yellow dragon fruit is crucial for maintaining its quality and extending its shelf life. During harvesting, it is essential to use a triangular pruning method to avoid damaging the flesh, as the base of the fruit is relatively wide, preventing fruit rot. Additionally, it is best to use horticultural shears and retain a broad fruit stem, shaping it into a rectangle, which helps protect the fruit during subsequent handling.

After harvesting, the fruit needs to be sorted and cleaned. In the washing pool, a solution with a certain concentration of prochloraz, iprodione, and 2,4-D is used to effectively remove surface impurities and pathogens. After washing, the fruit should be blow-dried to avoid excess moisture affecting fruit quality. Once sorting is complete, the fruit needs to be quickly transferred to a pre-cooling room to reduce the core temperature to 4 °C. Pre-cooling rapidly lowers the internal temperature of the fruit, slowing physiological activities and extending shelf life.

Subsequently, the fruit should be stored in a cold storage room. Using this method, yellow dragon fruit can be preserved for a month without rotting. Moreover, thornless yellow dragon fruit has an exceptionally long shelf life; when stored at room temperature or in a cold room for 20 days, the fruit still maintains good quality and freshness. This efficient post-harvest handling method ensures that the yellow dragon fruit remains in optimal condition during transportation and sales, providing consumers with high-quality produce.

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Conflict of Interest Disclosure

The authors affirm 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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