

Research Report

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Effects of Different Cultivation Management Models on Yield and Commercial Traits of Changshan Huyou

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Abstract This study summarizes the effects of different management methods on the yield and quality of Changshan Huyou. It was found that conventional management could ensure stable yields, but it was prone to soil degradation and environmental pressure. Ecological and organic management can enhance fruit quality and also contribute to product differentiation, but it has higher requirements for environmental conditions and technical levels. Precise and integrated management, through intelligent irrigation, digital monitoring and nutrient regulation, has improved resource utilization and also made fruit quality more stable. The research also pointed out some problems, such as the trade-off between output and quality, differences in adaptability among different regions, and the lack of long-term comparative data. In the future, the development of Changshan Huyou should focus on the application of intelligent agriculture, the integration of breeding and management, as well as the promotion of sustainable cultivation models. This study aims to provide references for the efficient production, green development and brand building of Changshan Huyou.

Keywords Changshan Huyou; Cultivation management models; Yield and quality; Precision agriculture; Sustainable development

1 Introduction

Changshan Huyou (*Citrus changshan-huyou*) has an attractive fruit shape, mostly pear-shaped, spherical or flat-spherical, with a golden color. It is a characteristic product of Changshan County, Quzhou City, Zhejiang Province, and also a product with a geographical indication of China. It has received widespread attention due to its strong adaptability and high commercial value. At present, Changshan Huyou has been promoted and cultivated in Zhejiang, Hunan and other places, demonstrating good environmental adaptability and stable yield and flavor (Zhong, 2004; Tan et al., 2012; Yu et al., 2012).

The fruit of Changshan Huyou is rich in vitamins, 16 kinds of essential amino acids for the human body, as well as elements such as phosphorus, potassium, iron and calcium. It also contains flavonoids, coumarins and terpenoids. These substances not only enhance its nutritional value but also endow it with certain medicinal and health care functions. The unripe fruit dried product "Quzhou bitter orange pericarp" has been included in the Chinese Pharmacopoeia (Huang et al., 2025). In addition, the cultivation and processing of Changshan Huyou have played a significant role in promoting the local economy and increasing farmers' income (Zhong, 2004; Tan et al., 2012).

However, there are still many challenges in the production of Changshan Huyou. Factors such as climate, soil and management methods can affect output, causing fluctuations and thereby influencing the long-term stability of the industry (Yu et al., 2012). Fruits often vary in terms of flavor, nutrition and appearance, which limits the development of commercialization and branding (Huang et al., 2025). Meanwhile, with the increasingly fierce competition in the citrus market, Changshan Huyou needs new breakthroughs in variety improvement, cultivation techniques and deep processing and utilization (Zhong, 2004).

This study evaluated different cultivation and management models and compared their effects on the growth, yield and commercial traits of Changshan Huyou. The results show that optimizing management measures can enhance

the stability of yield and also improve the consistency of fruit quality. This research aims to provide theoretical basis and technical reference for the efficient cultivation of Changshan Huyou, industrial upgrading, and its sustainable development in modern fruit industry.

2 Biological and Commercial Characteristics of Changshan Huyou

2.1 Morphological and physiological traits of Huyou

Changshan Huyou (*Citrus changshan-huyou*) is a unique citrus fruit tree in China, mainly produced in Changshan County, Zhejiang Province and other places. It is a local specialty variety formed by the natural hybridization of pomelos and other citrus fruits, and belongs to evergreen subtropical fruit trees (Figure 1). Changshan Huyou grows fast, has strong adaptability, and is also cold-resistant and easy to store. The fruits enter the expansion period from June to July and September, and are ripe and harvested in November (Gao et al., 2022). In terms of morphology, the leaves of Changshan Huyou are relatively thick. The fruits are mostly spherical or flattened spherical, with golden peel and pale yellow flesh. It has a high yield and good stress resistance (Miao et al., 2024). In addition, polyploid Changshan Huyou (such as tetraploid) has larger fruits, larger leaves and flower organs, strong pollen viability and ovule viability, which is suitable for hybrid breeding (Huang et al., 2025).



Figure 1 Field view of Changshan Huyou trees laden with mature fruits

2.2 Commercial quality indicators: fruit size, weight, peel thickness, juice content, flavor, and storage ability

The fruit of Changshan Huyou is generally medium to large-sized, with a single fruit weighing about 300 grams. The peel is relatively thick but easy to peel off. The flesh is juicy and has a unique flavor, with a hint of sweetness, sourness and a touch of bitterness. The fruit contains rich active substances, such as naringin, hesperidin and limonin (Zhang et al., 2012). The peel also contains a large amount of volatile oil, flavonoids, coumarins and terpenoids, etc., which bring special aroma and certain medicinal value (Gao et al., 2022; Huang et al., 2025). Changshan Huyou is suitable for storage and can be preserved for a long time at room temperature, which is convenient for long-distance transportation and market sales (Miao et al., 2024). Furthermore, it has a high content of antioxidant activity and functional components, and its nutritional and health care value is prominent (Zhang et al., 2012; Gao et al., 2022).

2.3 Current cultivation practices in major producing regions

Changshan Huyou is mainly cultivated in places such as Quzhou, Kecheng and Longyou in Zhejiang Province, and has a cultivation history of over a hundred years (Gao et al., 2022; Miao et al., 2024). The current mainstream planting methods include high-density cultivation, scientific pruning, reasonable fertilization and integrated pest and disease management, emphasizing ecological and green production (Zhong, 2004). Changshan Huyou has strong adaptability. After being introduced to Hunan and other places, it has performed well, with stable growth, good yield and flavor maintenance, few diseases and pests and easy control. It has high economic and ecological value (Tan et al., 2012). In recent years, with the development of deep processing and functional foods, the industrial chain of Changshan Huyou has been continuously extended, promoting the process of commercialization and branding (Gao et al., 2022; Miao et al., 2024).

3 Cultivation Management Models

3.1 Conventional management: high-input practices, strengths, and drawbacks

Conventional management mainly relies on a large amount of chemical fertilizers, pesticides and water management, with the aim of pursuing high yields and stable fruit quality. Under this model, Changshan Huyou grows well in a suitable environment, with relatively stable yield and flavor, few pests and diseases, and easy control. Therefore, it has good economic and ecological value (Tan et al., 2012). However, this high-investment approach will also bring environmental pressure, consume resources and may even lead to soil degradation. Excessive reliance on chemical inputs may also affect the safety and market competitiveness of fruits.

3.2 Ecological and organic management: sustainability and product differentiation

Ecological and organic management places greater emphasis on reducing the use of chemicals, focusing on soil health, biodiversity and ecological balance. In suitable regions, Changshan Huyou can also achieve high yields and quality through ecological management, and enhance the ecological value and market differentiation advantages of the fruit (Tan et al., 2012). Organic management can reduce the occurrence of pests and diseases, increase the safety and added value of fruits, and make them more competitive in the high-end market. However, this model has high technical requirements, is more sensitive to environmental adaptability, may have a slightly lower output, and is easily affected by climate and soil conditions (Yu et al., 2012).

3.3 Integrated and precision management: technology-driven approaches (smart irrigation, nutrient management, digital monitoring)

Integrated and precision management combines new technologies such as intelligent irrigation, nutrient regulation and digital monitoring. By collecting data on meteorology, soil and crop growth in real time, irrigation and fertilization schemes can be optimized, resource utilization can be improved, and adaptability to extreme climates can be enhanced, thereby maintaining the stability of yield and quality (Yu et al., 2012; Yan et al., 2021). This approach can achieve efficient and sustainable production, but it requires a high level of technology and management, and is more suitable for large-scale and modern planting.

4 Effects on Yield Performance

4.1 Yield comparison among different cultivation models

Different cultivation and management methods will significantly affect the yield of Changshan Huyou. Research has found that reasonable management measures, such as dense planting, pruning, integrated water and fertilizer management, and comprehensive pest and disease control, can significantly increase the yield and commercial quality of citrus fruit trees. In the introduction adaptability test, Changshan Huyou showed good growth momentum, high yield, stable fruit flavor, few and easy-to-control diseases and pests under suitable climate and management conditions, demonstrating strong adaptability and promotion value. Among them, dense planting and scientific pruning can increase the yield per unit area, while precise water and fertilizer management can further enhance fruit quality and yield stability (Tan et al., 2012). Compared with the traditional extensive management, the efficient and integrated management model can simultaneously increase output and quality.

4.2 Factors influencing fruit set, maturation, and stability of annual production

The main factors influencing the fruit setting rate, maturity and annual yield stability of Changshan Huyou include: climatic conditions (temperature, precipitation, light), soil fertility, variety characteristics, cultivation density, pruning methods, water and fertilizer management and pest and disease control. Suitable climate and soil are conducive to flower bud differentiation and fruit development. Scientific water and fertilizer management can promote fruit enlargement and improve quality. Reasonable pruning can improve the structure of the tree, enhance ventilation and light penetration, reduce the occurrence of pests and diseases, and thereby increase the fruit setting rate and fruit uniformity. Integrated pest and disease control can also ensure the normal development and stable yield of fruits (Tan et al., 2012). In addition, the genetic characteristics of the variety itself can also affect its adaptability to environmental stress and yield stability.

4.3 Long-term yield sustainability and orchard productivity trends

In the long term, scientific management methods are conducive to enhancing the sustained output and overall productivity of Changshan Huyou orchards. Continuous optimization of water and fertilizer management,

reasonable planting density and pruning, and green prevention and control of diseases and pests can not only increase the current season's yield, but also maintain soil fertility and ecological environment, reduce yield fluctuations, and extend the high-yield and stable production period of orchards. In suitable ecological areas, Changshan Huyou demonstrates advantages such as strong adaptability and stable yield, with high economic and ecological value, making it suitable for large-scale promotion (Tan et al., 2012). However, if management is lax or soil and ecological protection is neglected, the yield and fruit quality may gradually decline, which requires attention.

5 Effects on Commercial Traits

5.1 Influence on fruit size, shape, and external appearance

Different cultivation and management methods will directly affect the size, shape and appearance of Changshan Huyou. Reasonable water and fertilizer management, appropriate dense planting and pruning can make the fruits grow more evenly, increase the weight of individual fruits, make the fruit shape more regular, and also reduce deformed and small fruits, thereby increasing the commercial fruit rate. Under suitable climate and soil conditions, scientific management can make the fruit skin color brighter, the fruit surface smoother, the fruit dots finer, the fruit look more beautiful and more market-attractive. Meanwhile, the integrated prevention and control of pests and diseases can reduce the spots and damage on the fruit surface and make the fruit appearance better. However, if the planting is overly dense or the management is lax, it is easy to have fruits of uneven size and irregular shape, which will affect the commercial traits (Tan et al., 2012).

5.2 Effects on flavor, sugar-acid ratio, nutritional content, and consumer preference

Cultivation management also plays a crucial role in terms of flavor and nutrition. Scientific fertilization, especially the reasonable combination of nitrogen, phosphorus and potassium, along with water regulation, can help accumulate sugar, adjust acidity, and make the sugar-acid ratio of fruits moderate, resulting in a better taste. The use of organic or bio-fertilizers can increase the content of vitamin C and soluble solids, making fruits more nutritious. Meanwhile, the harvest time and post-harvest treatment are also very important, directly affecting the retention of flavor and nutrition. Consumers usually prefer Changshan Huyou with a well-shaped fruit, bright color, rich flavor and a well-balanced sugar-acid ratio. Scientific management can effectively enhance these characteristics (Tan et al., 2012).

5.3 Postharvest traits: shelf life, storage, and transportability

In terms of postharvest traits, the differences among various management methods are also quite obvious. Moderate water control, reasonable fertilization and pest and disease prevention can enhance the toughness and thickness of the fruit peel, reduce post-harvest rot and mechanical damage, and thereby extend the storage time and shelf life. Seizing the right timing during harvest, along with post-harvest pre-cooling, grading and packaging, helps maintain the freshness and appearance of the fruits and enhance their adaptability during transportation. In addition, the use of biological preservatives or the proper control of storage temperature and humidity can also delay fruit senescence, reduce weight loss and rot, and increase the commercial fruit rate. Therefore, scientific post-harvest management is particularly important for the long-distance transportation and market sales of Changshan Huyou (Tan et al., 2012).

6 Economic and Environmental Considerations

6.1 Production cost and profitability analysis for each model

Different cultivation methods vary greatly in terms of input, output and returns. The input of traditional management is low, but the yield and fruit quality fluctuate greatly and the profit-making ability is limited (Ren et al., 2020; Abisheva and Mussin, 2023). Modern intensive management, such as high-density planting, precise fertilization and intelligent irrigation, can increase the yield per unit area and make the fruits more uniform. However, this approach is more costly and requires more fertilizers, pesticides, labor and equipment. Modern management can increase the yield of citrus and pomelo trees by 30% to 60%, but the cost often rises by 40% to 70%. The final revenue ratio should also be calculated in combination with market prices and policy subsidies (Chandra et al., 2024). Studies have found that if reasonable optimization is carried out, such as moderate planting

density, scientific fertilization, and pest and disease control, the yield and commercial fruit rate can be increased without significantly increasing the cost (Ren et al., 2020; Chandra et al., 2024). Although organic and ecological management has a slightly lower yield per unit area, they are still competitive in the long term because the products can be sold at a higher price and some input is saved (Szeląg-Sikora et al., 2019; Boschiero et al., 2023).

6.2 Environmental impacts: soil fertility, biodiversity, pesticide/fertilizer use

While intensive management increases production, it also brings about some environmental problems, such as the decline of soil fertility, the reduction of biodiversity, and the excessive use of chemical fertilizers and pesticides (Huang et al., 2024). Relatively speaking, organic and ecological management can improve the soil, increase organic matter and microorganisms, make the soil healthier and have better ecological functions (Martinez et al., 2024). Some systematic reviews and life cycle analyses have shown that organic/ecological management is significantly superior to conventional intensive models in terms of greenhouse gas emissions, nutrient loss and water pollution (Boschiero et al., 2023). In addition, hybrid management, such as precise fertilization, integrated pest and disease control, and crop cover, can balance yield and environmental protection. This type of approach can reduce the usage of chemical fertilizers and pesticides by 20% to 40%, while increasing soil organic matter and biodiversity (Martinez et al., 2024; Peng et al., 2024). However, some ecological measures may lead to a decrease in output in the short term, and the relationship between the economy and the environment needs to be balanced through technological improvements and policy subsidies (Szeląg-Sikora et al., 2019; Boschiero et al., 2023; Huang et al., 2024).

6.3 Farmer adoption, labor requirements, and policy support

Whether farmers are willing to adopt new management methods is influenced by multiple aspects such as income, labor force, technical threshold and policy environment (Huang et al., 2024). The intensive approach has high requirements for labor and technology and is more suitable for large-scale operation. The demand for ecologically-managed labor force is high, but it can be shared through cooperatives or socialized services (Chandra et al., 2024). Policy support is also important, such as green subsidies, technology promotion, insurance, etc., all of which will affect farmers' choices. At present, the main difficulties for farmers to adopt the new model are large initial investment, insufficient technical services and high market risk. Therefore, to promote the sustainable development of characteristic fruit trees such as Changshan Huyou, it is necessary to strengthen training, increase policy support, and improve the market system (Szeląg-Sikora et al., 2019; Chandra et al., 2024; Huang et al., 2024).

7 Case Study: Cultivation Management of Changshan Huyou

7.1 Background: study location, orchard characteristics, and climatic conditions

Changshan Huyou is a geographical indication fruit tree in Quzhou City, Zhejiang Province, with high ecological and economic value (Tan et al., 2012). Quzhou has a subtropical monsoon climate. The annual average temperature is about 17 °C, the precipitation is about 1 500 millimeters, the light conditions are good, and the soil is mainly red soil and yellow soil, which is very suitable for the growth of citrus fruit trees (Yu et al., 2012). Most orchards are located in hilly areas with undulating terrain and smooth drainage. The management methods of local orchards vary greatly. Some are still using the traditional extensive mode, while others have adopted modern and precise methods (Tan et al., 2012). In recent years, industrial upgrading has promoted the application of some new technologies and new varieties, such as natural tetraploids and superior grafted strains, to increase yield and fruit quality (Figure 2) (Du, 2001; Huang et al., 2025).

7.2 Methods: cultivation management treatments, monitoring, and data collection

This case study selected typical Changshan Huyou orchards in Quzhou City and designed multiple cultivation and management models, including: conventional management (control), optimized fertilization (controlled-release fertilizer or organic fertilizer combination), dense planting and sparse planting, scientific pruning, irrigation regulation, and the introduction of superior varieties (such as natural tetraploid, preferred grafted strains) (Tan et al., 2012). The experiment adopted a random block design, with duplicate cells set for each mode. The monitoring contents include yield per plant, yield per unit area, fruit size, color, shape, soluble solids, acidity, commercial

fruit rate and incidence of pests and diseases, etc. (Du, 2001). The data covers the entire growing season, and some indicators even extend to the post-harvest storage period. Some studies also combined meteorological data, soil properties, fruit metabolomics and transcriptomics to analyze the effects of management measures on fruit quality and stress resistance (Huang et al., 2025).

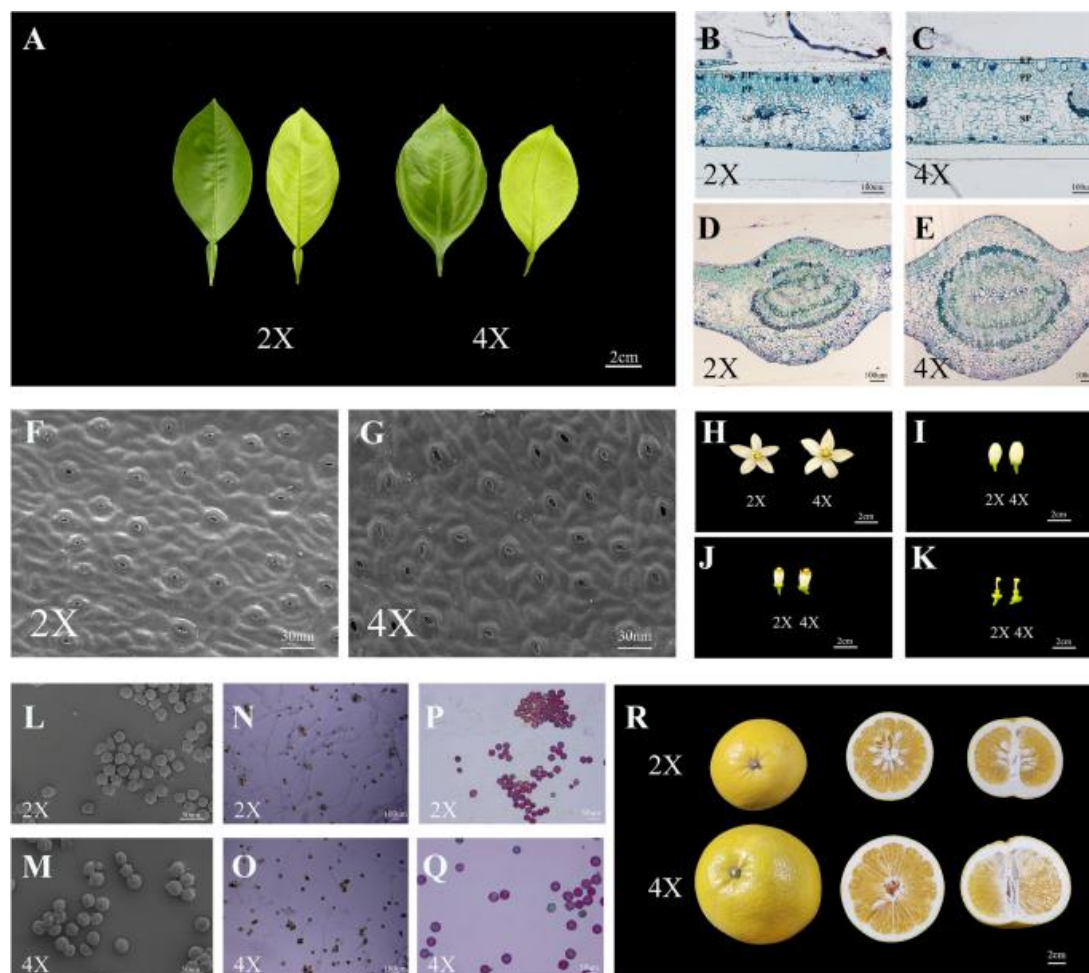


Figure 2 A Morphology of the leaves of the diploid (2X) and the tetraploid (4X) (Bar = 2 cm) (Adopted from Huang et al., 2025)
Image caption: The leaf was shown in both adaxial (upper) (left) and abaxial (lower) (right) surfaces. B-E Transversal sections of leaves (B-C) and midribs (D-E) of the diploid (2X) and the tetraploid (4X) (Bar = 100 μ m). F-G Scanning electron micrographs of stoma of the diploid (2X) and the tetraploid (4X) (Bar = 30 nm). EP: Epidermis, PP: Palisade parenchyma, SP: Spongy parenchyma. H-K Morphology of blooming flowers (H), floral buds (I), stamens (J), and pistils (K) of the diploid (2X) and the tetraploid (4X) (Bar = 2 cm). L, M Scanning electron micrographs of pollen grains of the diploid (2X) and the tetraploid (4X) (Bar = 50 nm). (N, O) The pollen germination of the diploid (2X) and the tetraploid (4X) (Bar = 100 μ m). P, Q Pollen staining activity of the diploid (2X) and the tetraploid (4X) (Bar = 50 μ m). R Morphological characteristics of fruits in the diploid (2X) and the tetraploid (4X) (Bar = 2 cm) (Adopted from Huang et al., 2025)

7.3 Results: yield outcomes, fruit quality improvements, and market acceptance

The results indicated that optimized fertilization and scientific irrigation could significantly increase the yield per plant and per unit area by 10% to 25% compared with conventional management (Huang et al., 2025). Dense planting can achieve early high yields in young orchards, but as the tree age increases, timely thinning is necessary; otherwise, it is prone to clogging, leading to a decrease in yield (Tan et al., 2012). Superior varieties such as natural tetraploid and preferred grafted lines have stronger growth vigor and higher yield potential (Du, 2001). Scientific pruning, reasonable fertilization and irrigation also make the fruit size more uniform, the fruit skin color brighter, the content of soluble solids higher and the flavor more stable (Tan et al., 2012). The fruit of the natural tetraploid is larger, the peel is thicker, and the contents of some metabolites such as flavonoids, terpenoids and amino acids are higher, with enhanced medicinal and processing values (Huang et al., 2025).

Under optimized management, the commercial fruit rate has increased, the fruit storage capacity has improved, and the incidence of pests and diseases has decreased. After the introduction of superior varieties and efficient management, both the appearance and internal quality of the fruits have improved, and the market acceptance has significantly increased. In some orchards, the commercial fruit rate exceeds 90%, and the economic benefits have significantly increased (Du, 2001; Tan et al., 2012). In addition, the development of the medicinal value of fruits has also expanded the industrial chain and increased the added value (Huang et al., 2025).

8 Challenges and Research Gaps

8.1 Lack of long-term comparative data across cultivation models

At present, research on different cultivation and management models of Changshan Huyou (such as organic, intensive, conventional, intelligent, etc.) is mostly short-term experiments or regional cases. Most studies only last for one quarter or 2 to 3 years, lacking systematic, long-term and multi-point comparative data. This leaves us with limited understanding of the sustained effects of management measures, interannual fluctuations, and their interactions with environmental factors such as climate and soil (Tan et al., 2012; Ren et al., 2020; Zhang et al., 2020; Li and Tao, 2023; Luo et al., 2023). For instance, some experiments have shown that optimizing dense planting, fertilization and water management can significantly increase yield and commercial traits. However, due to the short cycle, it is impossible to reflect the long-term cumulative effect and it is also difficult to assess the long-term changes in the orchard ecosystem.

8.2 Trade-offs between yield maximization and quality traits

In production, there is often a contradiction between “high yield” and “good quality”. For instance, intensive high-density planting and high nitrogen fertilizer input can increase the yield per unit area, but the fruits tend to be too large, the sugar-acid ratio decreases, the flavor becomes weak, and the risk of pests and diseases may also increase (Ren et al., 2020; Chen et al., 2023). In contrast, organic or ecological management can improve fruit quality and safety, but the increase in yield is limited and the management cost is higher. How to find the balance point between output and commercial traits under different modes is a difficult problem in current research and production. In addition, there are often complex interactions among varieties, environment and management measures, which makes the trade-off between yield and quality even more complicated (Zhang et al., 2020; Li and Tao, 2022; Li and Tao, 2023).

8.3 Insufficient region-specific optimization strategies

The ecological conditions in the main production areas of Changshan Huyou vary greatly, with different climates, soils and terrains. The responses of different regions to management models also differ significantly. However, most of the existing research focuses on a single region or unified management standards, lacking localized optimization plans for different ecological zones. For instance, there are significant differences in demands such as water and fertilizer management, pest and disease control, and fruit ripening regulation between the humid southern region and the subtropical northern region. A unified model is difficult to take into account the actual situation (Tan et al., 2012). In the context of frequent extreme climate events (such as high temperatures, heavy rain, and droughts), it is even more urgent to develop and promote adaptable regional management measures (Huang et al., 2020; Zhang et al., 2020; Yan et al., 2021; Li and Tao, 2023). At present, research on management optimization for different ecological zones, screening of adaptive varieties, and the synergy between management and varieties is still insufficient.

9 Future Perspectives

9.1 Application of smart agriculture and digital technologies in Huyou orchards

With the development of the Internet of Things, remote sensing, artificial intelligence and big data, smart agriculture is becoming an important method to increase the yield and quality of citrus fruits, including Changshan Huyou. Deep learning models can combine various types of data and perform well in aspects such as yield prediction, pest and disease monitoring, precise irrigation and fertilization. They can handle the complex relationships among the environment, plants and management, significantly improving prediction accuracy and management efficiency (Li et al., 2022a; Sun et al., 2022; Lu et al., 2024). Remote sensing and satellite data

combined with meteorological, soil and topographic information can achieve real-time monitoring of orchards, providing support for precise management and decision-making (Zhang et al., 2021; Li et al., 2022b; Ishaq et al., 2023). The prediction models based on machine learning have been verified in both large and small orchards, and can effectively improve the prediction accuracy and management scientificity (Guo et al., 2021; Li et al., 2022a; Liu et al., 2023; Sun et al., 2025). In the future, with the popularization of sensors, drones and automated equipment, the Changshan Huyou orchards will gradually achieve full-process digitalization and intelligence in planting, management and harvesting, promoting the industry to develop in the direction of high efficiency, greenness and sustainability.

9.2 Integration of breeding and management to improve both yield and quality

The yield and quality of Changshan Huyou are jointly influenced by multiple factors such as genetics, environment and management. The latest research indicates that the combination of molecular breeding and precise management is a key path to enhance the yield and quality of citrus fruits (Zhong, 2004; Huang et al., 2025). Through multi-environmental trials (METs), phenomics and genomic selection, high-yield, high-quality and stress-resistant varieties can be screened out. Combined with local climate and soil conditions, a reasonable match between varieties and management can be achieved (Guo et al., 2022; Li and Tao, 2022; Lee et al., 2023). Polyploid breeding, such as natural tetraploidization, can also enhance stress resistance, enrich secondary metabolites of fruits, and contribute to the development of diversified products such as seedless, medicinal and deep processing (Huang et al., 2025). Meanwhile, machine learning-based models can combine phenotypic, environmental and management data to provide decision support for breeding and cultivation, and promote the combination of variety innovation and efficient management (Zhong, 2004; Parmley et al., 2019; Yoosefzadeh-Najafabadi et al., 2021).

9.3 Scaling sustainable cultivation models for wider adoption and global competitiveness

Sustainable agriculture and large-scale management have been proven to significantly increase the yield, quality and ecological benefits of citrus crops (Tan et al., 2012; Yu et al., 2012; Yang et al., 2024). Crop rotation can increase soil fertility, reduce pests and diseases, increase the average yield by more than 20%, and adapt to various climatic and soil conditions (Zhao et al., 2020). Intercropping and diversified planting contribute to resource utilization and risk dispersion, and improve overall economic benefits and ecological stability (Yang et al., 2024). In the Changshan Huyou industry, regional suitability assessment and big data analysis can help achieve precise matching of varieties, management and environment, and promote the large-scale development of high-quality orchards (Yu et al., 2012). Meanwhile, promoting measures such as green prevention and control, water-saving irrigation and organic fertilizer substitution can also enhance the international competitiveness and brand influence of Changshan Huyou (Zhong, 2004; Tan et al., 2012).

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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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