

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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