

Experiment on Grafting of Virus-Free *Citrus reticulata* Hongmeiren onto Different Rootstocks

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Abstract [Objectives] To select the virus-free *Citrus reticulata* Hongmeiren as test material to select rootstocks suitable for local cultivation, and to carry out demonstration and popularization of suitable rootstocks for planting *C. reticulata* Hongmeiren in the south bank of Hangzhou Bay. [Methods] The effects of different rootstocks on the survival rate, biological characteristics and fruit quality were analyzed by grafting onto three kinds of rootstocks, namely, *C. unshiu* Marc. cv. Owari, *S. mandarin* cv. Miyagawa wase and *C. trifoliata* L. [Results] The grafting survival rate for *C. trifoliata* L. was the highest; from the index of scion growth, the scion diameter, new shoot length, new shoot thickness and leaf area of *C. unshiu* Marc. cv. Owari were the largest, and the tree height of *S. mandarin* cv. Miyagawa wase was the highest; from the fruit quality index, the fruit quality of *C. unshiu* Marc. cv. Owari was the best. [Conclusions] *C. unshiu* Marc. cv. Owari is suitable as the preferred rootstock for virus-free *C. reticulata* Hongmeiren on the south bank of Hangzhou Bay, and can be demonstrated and promoted.

Key words Rootstock, Virus-free *Citrus reticulata* Hongmeiren, Grafting

0 Introduction

Citrus reticulata Hongmeiren is a tangerine and orange hybrid variety with a strong orange surface, rich pulp, high sugar and high quality, and a sweet orange-like aroma. In recent years, *C. reticulata* Hongmeiren has become a characteristic industry in Zhejiang and even neighboring provinces and cities, especially in Ningbo, Taizhou, Quzhou, Huzhou and other places^[1–2]. However, during the development of *C. reticulata* Hongmeiren industry, the mild virus diseases originally occurring in *Satsuma mandarin* orchards have been increasing year by year. Viral diseases such as CTV, CTLV, SDV and CYSCV have been found in *C. reticulata* Hongmeiren orchards in Zhejiang Province^[3]. Some viral diseases have seriously affected the normal production of *C. reticulata* Hongmeiren orchards in the province. Viral disease is becoming one of the biggest obstacles affecting the sustainable development of *C. reticulata* Hongmeiren industry^[4]. Moreover, after fruiting, the tree vigor weakens rapidly, and it is easy to become a "small old tree". The problem of premature senility of *C. reticulata* Hongmeiren has become the technical bottleneck restricting the development of *C. reticulata* Hongmeiren industry^[5]. Therefore, in this study, virus-free seedlings^[6] were used to find rootstocks that are more suitable for the local environment and cultivation conditions through experiments, so as to enhance the growth ability of *C. reticulata* Hongmeiren, improve its adaptability and stress resistance, promote its healthy growth and improve fruit quality.

1 Materials and methods

1.1 Overview of the experimental area The test site was set in Chunwang Hongmeiren Base in Ziling Village, Henghe Town, with an altitude of 20 m. In 2023, the annual average temperature was 18.2 °C, the extreme maximum temperature during the year was 39.6 °C, the extreme minimum temperature was –5.7 °C, the total precipitation was 1 341.7 mm, and the total number of sunshine hours was 1 879.2. It was sandy loam soil with medium fertility.

1.2 Test materials The tested rootstocks are three varieties, namely, *Citrus unshiu* Marc. cv. Owari, *Satsuma mandarin* cv. Miyagawa wase, *Citrus trifoliata* L., with 2-year-old seedlings with consistent growth, 40 cm of headed trunk and 2–3 branches. In November, 2020, the rootstock was used for planting, and the row spacing was 2 m × 2 m. In March 4, 2021, the rootstock with good traits was selected and the scion of virus-free *C. reticulata* Hongmeiren was used for grafting. 20 plants were grafted with rootstock-scion combination in each plot, randomly arranged and repeated three times. Field management was carried out according to routine management measures.

1.3 Test methods One month after grafting, the survival rate of each grafting combination was counted. On December 20, 2021, the survival rate and various physiological indexes of grafted seedlings were counted. In November 2023, the single fruit weight and fruit quality indicators were counted. A tape was used to measure the tree height and new shoot length, a vernier caliper was used to measure the scion thickness (2 cm above the graft union), new shoot thickness (2 cm above the sprouting point), fruit vertical and transverse diameter and peel thickness, a leaf area measuring instrument (Zhejiang Topu Technology Co., Ltd.) was used to measure the leaf area, an electronic scale was used to measure the single fruit weight, and the soluble solids were measured by a sugar meter (Japan Atago PAL-1). 10 biological replicates were set for each indicator.

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2 Results and analysis

2.1 Comparison of survival rate of virus-free *C. reticulata* Hongmeiren grafted onto different rootstock varieties From the analysis of the survival rate comparison results of virus-free *C. reticulata* Hongmeiren grafted onto different rootstock varieties (Table 1), the grafting onto the three rootstock varieties was compatible. From the survival rate after grafting, the survival rate was the highest for *C. trifoliata* L. (94.1%), the survival rate was at middle level for *C. unshiu* Marc. cv. Owari, and the survival rate was the lowest for *S. mandarin* cv. Miyagawa wase (89.4%). As far as the germination time of scion is concerned, the germination

time of scion was the earliest, starting on April 28, with a germination duration of 55 d, and the germination time of *S. mandarin* cv. Miyagawa wase and *C. trifoliata* L. started from May 3, with a germination duration of 60 d. From the point of view of preserving rate, the preserving rate was the highest for *C. trifoliata* L. (90.4%), followed by *C. unshiu* Marc. cv. Owari, and the preserving rate was the lowest. It can be seen that as rootstock, *C. trifoliata* L. had the best survival rate after grafting, followed by *C. unshiu* Marc. cv. Owari, and *S. mandarin* cv. Miyagawa wase was relatively poor.

Table 1 Comparison of survival rates of virus-free *Citrus reticulata* Hongmeiren grafted onto different rootstock varieties (2021)

Rootstock variety	Grafting number	Living number	Survival rate//%	Survival number	Preserving rate//%
<i>C. unshiu</i> Marc. cv. Owari	52	48	92.3	47	90.4
<i>S. mandarin</i> cv. Miyagawa wase	57	51	89.4	50	87.7
<i>C. trifoliata</i> L.	51	48	94.1	48	94.7

2.2 Comparison of the growth of virus-free *C. reticulata* Hongmeiren seedlings grafted onto different rootstocks Through the analysis of the growth of virus-free *C. reticulata* Hongmeiren seedlings grafted onto different rootstocks (Table 2), it was found that after grafting in March 2022 to the end of the year, the branch growth potential and resistance of virus-free scion of *C. reticulata* Hongmeiren were good. Comparing the growth of different rootstocks, the plant height of *S. mandarin* cv. Miyagawa wase was the highest (120.3 cm), and the plant height of *C. trifoliata* L. was the lowest (114.8 cm). The scion stem diameter and new shoot length and thickness of *C. unshiu* Marc. cv. Owari were all

greatest, reaching 15.2 mm, 25.2 cm and 5.2 mm, respectively; the graft union healing time was the fastest for *C. unshiu* Marc. cv. Owari (216 d), followed by *C. trifoliata* L., and it was the slowest for *S. mandarin* cv. Miyagawa wase (227 d); in terms of leaf growth, it was the largest for *C. unshiu* Marc. cv. Owari (3 158.2 mm²), and it was the smallest for *C. trifoliata* L. (2 684.4 mm²). From the growth of grafted seedlings, the indexes of plant height, scion and shoot growth, leaf area and branch resistance were the best for *C. unshiu* Marc. cv. Owari, followed by *S. mandarin* cv. Miyagawa wase, and various indexes of *C. trifoliata* L. were relatively low.

Table 2 Growth of virus-free *Citrus reticulata* Hongmeiren seedlings grafted onto different rootstock varieties (2021)

Rootstock variety	Plant height//cm	Scion stem diameter//mm	New shoot length//cm	New shoot thickness//mm	Graft union healing time//d	Leaf area//mm ²	Branch resistance	Comprehensive evaluation
<i>C. unshiu</i> Marc. cv. Owari	118.5	15.2	25.2	5.2	216	3 158.2	A	A
<i>S. mandarin</i> cv. Miyagawa wase	120.3	13.3	21.8	4.7	227	2 874.1	A	B ⁺
<i>C. trifoliata</i> L.	114.8	11.8	19.5	4.1	221	2 684.4	A	B

2.3 Effects of different rootstock varieties on fruit quality of virus-free *C. reticulata* Hongmeiren Through the analysis of the effects of different rootstock varieties on the fruit quality of virus-free *C. reticulata* Hongmeiren (Table 3), it was found that the fruit shape of young trees with first fruits was generally large due to low yield. From the average single fruit weight, it was the largest for *C. unshiu* Marc. cv. Owari (258.3 g); from the vertical and transverse diameter and shape index, the fruit of *C. unshiu* Marc. cv. Owari was close to perfect round, while the fruit of *S. mandarin* cv. Miyagawa wase and *C. trifoliata* L. was oblate; the peel of the newly fruiting young trees of *C. reticulata* Hong-

meiren was relatively thick, and the fruit thickness of the three rootstock varieties was similar, at about 2.5 mm; in terms of soluble solids content, it was the highest for *C. unshiu* Marc. cv. Owari (12.7%), and it was 11.8% for *S. mandarin* cv. Miyagawa wase and 11.5% for *C. trifoliata* L.; the flavor of *C. unshiu* Marc. cv. Owari and *S. mandarin* cv. Miyagawa wase was excellent, and the flavor of *C. trifoliata* L. was above average. Through the comprehensive evaluation of single fruit weight, shape index, fruit thickness, soluble solids and flavor related to fruit quality, it was found that *C. unshiu* Marc. cv. Owari > *S. mandarin* cv. Miyagawa wase > *C. trifoliata* L.

Table 3 Effects of different rootstocks on fruit quality (2023)

Rootstock variety	Average single fruit weight//g	Vertical and transverse diameter//mm	Shape index	Peel thickness//mm	TSS//%	Flavor
<i>C. unshiu</i> Marc. cv. Owari	258.3	75.9 × 80.2	0.95	2.5	12.7	Excellent
<i>S. mandarin</i> cv. Miyagawa wase	242.1	70.2 × 83.5	0.84	2.4	11.8	Excellent
<i>C. trifoliata</i> L.	198.2	65.1 × 74.3	0.88	2.6	11.5	Above average

NOTE Shape index = Vertical diameter/Transverse diameter.

(To page 34)

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(From page 30)

3 Conclusions

Through the experiment of grafting of virus-free *C. reticulata* Hongmeiren onto different rootstocks, we can draw the following conclusions. In terms of survival rate and preserving rate, *C. trifoliata* L. rootstock performed the best; in terms of growth potential, *S. mandarin* cv. Miyagawa wase had the greatest tree height, while *C. unshiu* Marc. cv. Owari had the best performance in scion stem diameter, shoot length, shoot thickness and leaf area, showing the best growth potential; as for fruit quality, *C. unshiu* Marc. cv. Owari had the greatest single fruit weight, the highest soluble solid content, the best flavor and excellent overall fruit quality.

Considering the growth, development and fruit quality after grafting of *C. reticulata* Hongmeiren, among the three kinds of rootstocks selected in this experiment, *C. unshiu* Marc. cv. Owari showed the best comprehensive performance on virus-free *C. reticulata* Hongmeiren, followed by *S. mandarin* cv. Miyagawa wase.

When planting *C. reticulata* Hongmeiren in the south bank plain of Hangzhou Bay, *C. unshiu* Marc. cv. Owari was used as the rootstock for virus-free *C. reticulata* Hongmeiren. Because of its vigorous growth potential, excellent fruit quality and high yield, it got the highest comprehensive score and showed the

strongest local adaptability. Therefore, when building a new *C. reticulata* Hongmeiren orangery in the south bank plain of Hangzhou Bay, it is recommended to choose *C. unshiu* Marc. cv. Owari as high-quality seedling for rootstock.

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