Effects of Different Rootstocks on the Growth and Fruit Quality of 'Huangjinmi' Grape in Hefei

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Abstract [**Objectives**] This study was conducted to enrich grape varieties. [**Methods**] The growth and fruit quality of grape with different rootstock and scion combinations were compared and analyzed taking CR2, CR3 and CR9 as rootstocks and 'Huangjinmi' as grafted seedlings and own-rooted seedlings as control. [**Results**] The comprehensive scores of 'Huangjinmi' grape with different rootstock and scion combinations showed an order of HJM/CR9, HJM/CR2 and HJM/CR3 from high to low. The three rootstock and scion combinations obviously promoted the growth and adaptability of grape trees, increased fruit size and improved fruit quality. Through the quality analysis of untreated and treated fruits, HJM/CR9 was superior to ZGM. Different fruit management measures can be adopted for 'Huangjinmi' grape to produce fruit with different quality according to market demand. [**Conclusions**] This study has a guiding significance for screening grape varieties suitable for adverse environments such as high soil viscosity, high temperature and high humidity.

Key words 'Huangjinmi'; Rootstock; Growth; Fruit quality; Effect

DOI:10.19759/j.cnki.2164-4993.2024.05.002

In recent years, the area of table grape in China has developed rapidly. At present, the cultivated area of grape in Anhui Province is about 27 000 hm^2, and the grape industry plays an important role in the southern producing areas. With the diversified development of grape varieties, varieties with high yield, large grains, no cracking, storage and transportation resistance and rose fragrance are more popular among growers and consumers[1]. The main varieties of aromatic grapes planted in Anhui Province are 'Jumeigui', 'Zuijinxiang' and 'Sunshine Rose'. 'Sunshine Rose' is an excellent late-maturing variety, and the rapid development of 'Sunshine Rose' has resulted in mixed regional quality, which has had a certain impact on the grape sales market[2-4]. Under the environment of high temperature and high humidity, early-maturing red varieties such as 'Xiahei' grape have high yield and difficult coloring, and shows affected flower bud differentiation. 'Victoria' grape is an early-maturing yellow-green variety, which is prone to softening and cracking after maturity, and not resistant to transportation after harvesting. At present, it is only planted sporadically. In the early stage, with the development trend of 'Sunshine Rose' going well, the planting area has been increasing, and the cultivation area of early-maturing varieties has been shrinking. The single variety structure in production areas hinders the healthy development of the grape industry. With the weakening of the benefits of 'Sunshine Rose' grape, the shortage of alternative grape varieties, especially the varieties with early maturity and good storage and transportation resistance, newly bred excellent varieties with independent property rights in China cannot meet the diverse needs of consumers. 'Huangjinmi' grape is a Eurasian early-maturing and fresh-eating grape variety selected by Changli Fruit Research Institute of China Academy of Agricultural Sciences. It is characterized by high yield, large grains, crisp flesh, rose fragrance and good storage and transportation resistance[5].

Between the Changjiang River and Huaihe River of Anhui Province, the rainy season is obvious, and the soil is sticky. The adaptability of grape in high temperature and high humidity environment has also become one of the factors limiting the industrial development. After grafting to rootstocks, it can not only improve the stress resistance of grapes, but also effectively regulate the vegetative growth and reproductive growth, which has a certain impact on phenology and yield. Meanwhile, rootstocks can also affect the appearance quality and internal quality of fruit ears[6-7]. In order to enrich grape varieties and popularize grape varieties with independent intellectual property rights in China, it is of guiding significance to evaluate grape growth and fruit quality of different rootstock and scion combinations and to screen grape varieties suitable for adverse environments such as high soil viscosity, high temperature and high humidity with own-rooted seedlings of 'Huangjinmi' as control.

Materials and Methods

General situation of experimental field

The experimental orchard was located in Tangliuqing Family Farm in Changfeng County between the Changjiang River and Huaihe River. It was a demonstration orchard of Hefei Experimental Station of the National Grape Industrial Technology System. The climate in the region is warm and humid, with obvious transition characteristics. There is sufficient light and a long frost-free

Received: June 9, 2024 Accepted: September 10, 2024

Supported by National Modern Agriculture Industry Technology System Construction Project (CARS-29-14); Chuzhou Science and Technology Planning Project (2022ZN004); Anhui Provincial Science and Technology Mission Project (2023tpt027); Special Project of Chief Expert Studio of Agricultural Industry in Hefei City, Anhui Province (2023).

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period. The annual average sunshine hours are 2 035 h, and the sunshine percentage is 48.1% on average. The annual average temperature is 14.8 – 15.9 ℃. The extreme maximum temperature is 41.3 ℃, and the extreme minimum temperature is – 23.8 ℃. The annual accumulated temperature ≥10 ℃ is between 4 700 – 5 100 ℃, and the annual accumulated temperature ≥0 ℃ is between 5 400 – 5 800 ℃. The frost-free period is over 227 d. The rainfall is moderate, and the rainy season is obvious. The average annual precipitation is 982.6 mm, and the summer precipitation accounts for 42% of the annual precipitation. The precipitation is the highest in July, with an average of 173.9 mm. The soil is clay loam.

Experimental materials

The experimental materials were grafted seedlings of 'Huangjinmi' (*Vitis vinifera* cv. Huang jinmi) (hereinafter referred to as HJM), and the rootstocks were CR2, CR3 and CR9. The growth, fruiting and fruit quality of grafted seedlings were investigated. The rootstock and scion combinations of 'Huangjinmi' were represented as HJM/CR2, HJM/CR3 and HJM/CR9 respectively. Own-rooted seedlings (denoted as ZGM) were used as control. All the seedlings used in the experiment were provided by Research Institute of Changli Fruit Tree, China Academy of Agricultural Sciences. The seedlings were planted in a single row, with a row spacing of 2 m × 3 m. They were planted in a rain-proof way, and the frames were "T-shaped" hedge frames, under which the trees were V-shaped. Irrigation was carried out in a manner of drip irrigation, and unified management was adopted.

Experimental methods

Phenological observation The criteria for judging grape phenology referred to Descriptors and Data Standard of *Grape Germplasm Resources*[8] and Liu Chonghuai's evaluation on the diversity of maturity time of grape cultivars and its classification[9].

Determination of quality traits The indexes such as single ear weight, grain weight, longitudinal diameter of fruit grain, transverse diameter of fruit grain and peel thickness were measured by conventional methods. Ear density, the difficulty of separating fruit stalk from fruit grain, fruit shape and fruit color were visually evaluated. Soluble solid content was measured by a hand-held refractometer. Titratable acid content was determined by NaOH titration[10].

Investigation on grape disease resistance The types and incidence of grape diseases in different growth periods were investigated according to the standards of the International Plant Germplasm Committee (IBPUR). The occurrence of powdery mildew was serious under sheltered cultivation conditions in the south, and the occurrence of powdery mildew was manly observed.

Results and Analysis

Effects of different rootstocks on the growth of grafted 'Huangjinmi' seedlings

It can be seen from Table 1 that the survival rate of rootstock-grafted seedlings was higher than that of own-rooted seedlings, and the survival rate of HJM/CR9 was 100%, followed by HJM/CR3 and HJM/CR2 in sequence. All three rootstocks increased the length of mature branch, the length of immature branch and the number of mature internodes. The annual growth of HJM/CR9 was the largest, followed by HJM/CR2 and HJM/CR3 in sequence. Compared with owned-rooted seedlings, HJM/CR2 had more mature internodes, followed by HJM/CR9 and HJM/CR3 in sequence. The three rootstocks also increased the thickness of scion, and the diameter ratio of scion to rootstock was greater than 1, resulting in the phenomenon of 'top-heavy'. Comprehensive evaluation showed that HJM/CR9 grew more vigorously than other combinations.

Table 1 Effects of different rootstocks on the growth of grafted 'Huangjinmi' seedlings

Rootstock and scion combination	Survival rate//%	Length of mature branch//cm	Number of mature internodes	Length of immature branch//cm	Scion diameter//mm	Rootstock diameter//mm	Diameter ratio of scion to rootstock
HJM/CR2	80	404.25	46	135.13	26.31	17.94	1.47
HJM/CR3	90	348.44	40	144.89	23.28	18.72	1.24
HJM/CR9	100	372.40	43	186.80	26.25	19.15	1.37
ZGM	40	228.75	30	125.00	21.13		

Effects of different rootstocks on phenology of grafted 'Huangjinmi' seedlings

According to the data in Table 2 and the comprehensive observation and analysis of phenology, the germination period of all combinations was in mid-March; the flowering period was in early May; the veraison period was in mid-June; and the maturation period was in late August. The phenology of grafted seedlings was delayed compared with that of own-rooted seedlings, and the maturation of HJM/CR9 was the latest, 2 – 3 d later than other rootstock combinations and 5 d later than own-rooted seedlings.

Table 2 Effects of different rootstocks on phenology of grafted 'Huangjinmi' seedlings

Rootstock and scion combination	Germination stage	Early flowering stage	Full-bloom stage	Veraison stage	Maturation stage
HJM/CR2	Mar. 16 – 18	May 2 – 3	May 5 – 6	Jun. 20 – 21	Aug. 19 – 22
HJM/CR3	Mar. 15 – 17	May 1 – 3	May 4 – 7	Jun. 16 – 18	Aug. 17 – 21
HJM/CR9	Mar. 17 – 19	May 2 – 3	May 5 – 7	Jun. 21 – 22	Aug. 20 – 24
ZGM	Mar. 15 – 17	May 1 – 2	May 3 – 5	Jun. 15 – 17	Aug. 15 – 20

Effects of different rootstocks on fruiting and adaptability of 'Huangjinmi'

All the introduced varieties began to bear fruit in the second year after planting. Compared with own-rooted seedlings, 'Huangjinmi' plants grafted to the three rootstocks all showed strong growth vigor, moderate ear shape density, uniform fruit uniformity and no dropping. Own-rooted seedlings and grafted seedlings both grew out flowers easily and had high fruit setting rate (Table 3). Color is one of the indexes to evaluate the appearance quality of colored varieties. The fruit of HJM/CR2 and HJM/CR9 was green, while the fruit of HJM/CR3 and ZGM was yellow green (Fig. 1).

Fig. 1 Effects of different rootstocks on fruiting of 'Huangjinmi'

'Huangjinmi' is a Eurasian grape variety with weak disease resistance, and the incidence of powdery mildew of HJM/CR9 was higher than others, which might be related to the closure of the orchard caused by vigorous growth. Fruit cracking is one of the factors affecting the quality in rainy areas in southern China, but it was not observed in own-rooted seedlings and grafted seedlings (Table 3).

Table 3 Effects of different rootstocks on fruiting and adaptability of 'Huangjinmi'

Variety	Growth vigor	Fruit setting rate	Fruit color	Powdery mildew	Fruit cracking
HJM/CR2	Strong	High	Green	Mild	No cracking
HJM/CR3	Strong	High	Yellow green	No	No cracking
HJM/CR9	Strong	High	Green	Moderate	No cracking
ZGM	Moderate	High	Yellow green	No	No cracking

Effects of different rootstocks on fruit quality of 'Huangjinmi' grape

The single ear weights of HJM/CR2 and HJM/CR9 free of fruit treatment (only thinning flowers and fruits, but no fruit keeping and expanding) were greater than that of ZGM, and the single ear weight of HJM/CR9 was the largest. The single grain weights of HJM/CR2 and HJM/CR3 were larger than that of ZGM, while the single grain weights of HJM/CR3 and HJM/CR9 were not different from that of ZGM. The fruit shape index of grafted seedlings and self-rooted seedlings ranged from 0.92 to 1.06, and the fruit was nearly round. Compared with own-rooted seedlings, the content of soluble solids in the fruit of grafted 'Huangjinmi' grape at the same period was low, and the titratable acid content ranked as HJM/CR9 > HJM/CR3 > HJM/CR2 from high to low, and the

overall taste was sweet and sour.

The single ear weights of HJM/CR2 and HJM/CR9 with fruit treatments (thinning flowers and fruits, keeping fruits and expanding) were greater than that of ZGM, and the single ear weight of HJM/CR9 was the largest. The single grain weights of HJM/CR2, HJM/CR3 and HJM/CR9 were larger than that of ZGM, and the single grain weight of HJM/CR9 was the largest. The fruit shape index of grafted seedlings and own-rooted seedlings ranged from 1.00 to 1.07, and the fruit was nearly round. Compared with own-rooted seedlings, the soluble solid content in fruit of grafted grape at the same period ranked as HJM/CR9 > HJM/CR2 > HJM/CR3, and the titratable acid content showed an order of HJM/CR3 > HJM/CR2 > HJM/CR9 from high to low, and the overall taste was sweet and sour.

Table 4 Effects of different rootstocks on fruit quality of 'Huangjinmi' grape

	Rootstock and scion combination	Single ear weight//g	Single grain weight//g	Longitudinal diameter of fruit grain//mm	Longitudinal diameter of fruit grain//mm	Fruit shape index	Soluble solid content//%	Soluble solid content//%
Free of treatment	HJM/CR2	490	12.4	25.14	27.23	0.92	17.61	0.32
	HJM/CR3	403	10.8	24.13	25.97	0.93	17.70	0.34
	HJM/CR9	599	10.4	26.15	24.67	1.06	18.16	0.35
	ZGM	431	10.7	25.31	25.54	0.99	19.15	0.28
Treatment	HJM/CR2	640	9.5	24.34	23.91	1.02	17.54	0.41
	HJM/CR3	596	10.3	26.25	24.57	1.07	16.96	0.43
	HJM/CR9	682	11.7	27.16	25.88	1.05	17.82	0.39
	ZGM	652	7.8	21.87	21.78	1.00	17.95	0.34

Conclusions and Discussion

The rapid development of excellent late-maturing variety 'Sunshine Rose' has caused the area of early-maturing grape varieties such as 'Xiahei' to shrink, and single variety structure cannot meet the diverse needs of consumers and markets. The soil is sticky, and the adaptability of grape in high temperature and high humidity environment also limits its industrial development. Rootstocks can improve the stress resistance of grapes, and thus increase the survival rate and nutritional growth[6-7]. The results showed that the survival rates of rootstock-grafted seedlings were all higher than that of own-rooted seedlings, and the survival rate of HJM/CR9 was 100%.

The compatibility of rootstock and scion combinations can also directly affect the vegetative growth and reproductive growth of grafted seedlings. The diameter ratio of scion to rootstock is one of the important indexes to measure the affinity[7], and the three rootstocks also increased the thickness of scion, and the diameter ratios of scion to rootstock were all greater than 1. There was a slight 'top-heavy' phenomenon, and the grafting affinity was good. Further analysis is needed. All three rootstocks increased the length of mature branch, the length of immature branch and the number of mature internodes. The annual growth of HJM/CR9 was the largest, and HJM/CR2 showed more mature internodes, followed by HJM/CR9 and HJM/CR3 in sequence. Weak tree vigor is not conducive to flower bud differentiation, and it is easy to lead to large and small fruits under facility cultivation. Generally, strong trees can produce good results when using plant growth regulators[11]. Both HJM/CR2 and HJM/CR9 grew vigorously. They obviously promoted tree growth and tree shape, and showed good adaptability to poor soil conditions.

Single ear weights of HJM/CR2 and HJM/CR9 with and without fruit treatment were higher than that of ZGM, and HJM/CR9 showed a single grain weight higher than that of ZGM. As a result, grape yield was improved after rootstock grafting[6-7]. Fruit color is one of the important indicators of appearance[12]. 'Huangjinmi' grape is a yellow-green variety, and different rootstocks have little effect on fruit color. Flavor is the most important intrinsic quality of table grapes, and the content and proportion of sugar and acid are the main influencing factors[13-14]. Compared with own-rooted seedlings, grafted 'Huangjinmi' grape fruit had a lower soluble solid content and a higher titratable acid content at the same time. The grape flavor of untreated fruit in grafted seedlings was sweet and sour, and that of expanded fruit in grafted seedlings was sweet and sour.

Comprehensive evaluation results showed that the comprehensive performance of 'Huangjinmi' grape with different rootstock and scion combinations was HJM/CR9, HJM/CR2 and HJM/CR3 from high to low in sequence, which all could obviously promote the growth and adaptability of trees, increase fruit size and improve fruit quality. The untreated and treated fruit of HJM/CR9 were better than those of ZGM. Different fruit management measures can be adopted for to produce different fruits, such as seedless, green and yellowish green 'Huangjinmi' grapes, according to market demand. The growth and fruit quality of 'Huangjinmi' grape with different rootstock and scion combinations need to be further comprehensively evaluated in combination with the environment.

Introduction and cultivation is one of the important measures to optimize the variety structure. In order to screen and introduce excellent varieties, it is necessary to find suitable cultivation methods and models through comprehensive evaluation. According to the experimental results, the cultivation points of 'Huangjinmi' grape in Hefei were summarized. (1) The growth and survival rate of rootstock-grafted seedling are better than that of own-rooted seedlings. Grafted seedlings can be selected for plots with poor drainage such as sticky soil, and own-rooted seedlings can be selected for plots with good soil structure such as sandy loam. (2) To produce yellow-colored 'Huangjinmi' grapes, own-rooted seedlings can be selected. HJM/CR9 grafted seedlings can be selected to produce green 'Huangjinmi' grapes while attention is paid to yield. Cultivating strong trees in the production process is beneficial

to early yielding and high yield. (3) To produce seedless 'Huangjinmi' grapes, plant growth regulators such as gibberellin can be used, but attention should be paid to the influence of concentration on fruit quality. High concentrations of plant growth regulators will increase acidity, which is not conducive to the accumulation of flavor substances.

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Editor: Yingzhi GUANG Proofreader: Xinxiu ZHU

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Editor: Yingzhi GUANG Proofreader: Xinxiu ZHU