Effects of Different Dwarfing Rootstocks on Growth, Yield and Fruit Quality of 'Tianhong 2' Apple Trees

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Abstract [**Objectives**] The paper was to provide a reference for screening dwarfing rootstock suitable for main spur-type Fuji cultivars in central and southern Hebei Province. [**Methods**] With spur-type Fuji 'Tianhong 2' as the material, the vegetative growth, yield and fruit quality of 8 different rootstock-scion combinations were compared. [**Results**] 'Tianhong 2'/SH6 as self-rooted rootstock had large average single fruit weight (256.33 g), large number of fruits per plant (188.68), the highest yield [(3 250.08 ±23.42) kg/667 m^2] and the highest colored area (93.5%), and the soluble solid content reached the requirement of high quality fruit (15.78%). [**Conclusions**] In central and southern Hebei Province, 'Tianhong 2' grafted on SH6 self-rooted rootstock has moderate growth, high yield and good fruit quality, so it can be considered as the preferred rootstock-scion combination in the local area.

Key words Apple, Dwarfing rootstock, Growth characteristics, Yield, Quality

1 Introduction

Dense planting of dwarfing rootstock has been widely recommended and applied in apple production today[1-2]. Many excellent dwarfing rootstocks have been introduced and bred successively in China to adapt to modern dense planting mode, among which the intensive and efficient planting mode of apple dwarfing rootstock has been widely referenced and applied[3-6]. Due to the great differences in geographical environment and climate among various planting areas, it is necessary to screen appropriate rootstocks matching with local soil and climate characteristics. At present, there are many studies on dwarfing ability and adaptability of apple dwarfing rootstocks, but less effort has been dedicated to the effects of grafting different dwarfing rootstocks on growth characteristics, yield and fruit quality of spur-type Fuji apple trees.

There are two utilization methods of dwarfing rootstock, self-rooted rootstock and interstock, both of which can inhibit the vigorous growth of scion and promote the transformation of trees from vegetative stage to reproductive stage, with the effects of early flowering, early fruiting, high yield and high quality[7-8]. At present, Fuji series is still the main type of apple in China. Spur-type Fuji 'Tianhong 2' has become the main spur-type Fuji cultivar in central and southern Hebei Province due to short shoots and remarkable ability to control crown and promote flowering and fruiting. Fruit is an important organ of fruit trees, and its quality, yield characteristics and internal nutritional changes can directly reflect the nutrient absorption effect of trees[9-12]. Therefore, it can provide an important scientific basis for selecting suitable rootstock-scion combinations by studying the effects of different dwarfing rootstocks on the growth, yield and fruit quality of main apple cultivars in this region.

Central and southern Hebei is a major apple producing area in China, and hot and rainy summer often leads to excessive vegetative growth of trees, resulting in difficulties in tree potential control and flower bud differentiation. Therefore, it is the key to rootstock-scion combination screening in central and southern Hebei Province by selecting rootstock with strong resistance, good dwarfing and strong adaptability. With 'Tianhong 2' apple grafted on different dwarfing rootstocks as the materials, the growth characteristics, yield and fruit quality of apple trees were analyzed, in order to provide a scientific reference for screening excellent apple rootstock-scion combinations suitable for planting in central and southern Hebei Province.

2 Materials and methods

2.1 Materials The test was conducted in the experimental orchard of Shijiazhuang Pomology Institute from March 2018 to July 2020, with an area of 3.33 hm^2. The soil was sandy loam with good water and fertilizer conditions and medium management level. The apple trees were 5 years old and grew strongly. They were planted in the north-south line with a row spacing of 2 m × 4 m. Trees were slender and spindle-shaped. The tree disks under the tree were ridged and covered with ground cloths, and drip irrigation management model was adopted.

'Tianhong 2'/SH6, 'Tianhong 2'/Qing rootstock 1, 'Tianhong 2'/Qing rootstock 2, 'Tianhong 2'/Mark/*Malus robusta*

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Rehd., 'Tianhong 2'/P22/*M. robusta* Rehd., 'Tianhong 2'/B9/*M. robusta* Rehd., 'Tianhong 2'/M9-T337/*M. robusta* Rehd. and 'Tianhong 2'/Qing rootstock 1/*M. robusta* Rehd. were used as the materials. Each tree was regarded as a plot, with 10 repetitions.

2.2 Measurement indicators

2.2.1 Morphological indicator of apple trees. When new shoots stopped growing in autumn, the crown width, plant height and trunk diameter were measured with a tape measure and a vernier caliper, and the number of main branches was counted[13]. Trunk diameter was the diameter 10 cm above the grafting mouth; crown width was the average value of the north-south and east-west crown diameters.

2.2.2 Investigation of branch structure. Before defoliation, the number of long branches (length ≥ 30 cm), long shoots (15 cm ≤ length < 30 cm), medium withes (5 cm ≤ length < 15 cm) and brachyplasts (length < 5 cm) was investigated, and their proportions were calculated[13-15].

2.2.3 Tree yield. When the fruits were mature, 10 healthy, insect-free and non-traumatic fruits were randomly collected from the east, west, south and north directions in the middle and upper crown of each tree, with a total of 100 fruits in each rootstock-scion combination. The average single fruit weight was measured with a centesimal balance and the number of fruits per plant was counted. Yield of apple trees was calculated according to the following formula: Yield per 667 m^2 = (Number of plants per 667 m^2 × Number of fruits per plant × Single fruit weight)/1 000 × 0.8 (Coefficient)[16-17].

2.2.4 Fruit quality. A total of 100 fruits were randomly collected from each rootstock-scion combination. The colored area was investigated; the vertical and transverse diameters of fruits were measured with a vernier caliper; the soluble solid content was determined with PAL-1 handheld digital refractometer; and the total acid content was determined with GMK-835F apple acidity meter. The high-quality fruit rate was calculated. Each treatment had 3 repetitions[18].

2.3 Data processing All data were processed by Microsoft Office Excel 2010 and conducted variance analysis by SPSS19.0. The significance of difference was compared by Duncan's multiple range test of single-factor ANOVA[16-18].

3 Results and analysis

3.1 Effect on growth characteristics of apple trees As shown in Table 1, there were differences in tree height, crown width, number of main branches and trunk diameter of 'Tianhong 2' apple trees grafted on 8 different dwarfing rootstocks. 'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock led to the largest crown width (130.00 cm); followed by 'Tianhong 2'/SH6 as self-rooted rootstock, 'Tianhong 2'/Qing rootstock 1/ *M. robusta* Rehd., 'Tianhong 2'/Qing rootstock 1 as self-rooted rootstock, 'Tianhong 2'/P22/*M. robusta* Rehd.; 'Tianhong 2'/M9-T337/*M. robusta* Rehd. led to the smallest crown width (115.00 cm). 'Tianhong 2'/Qing rootstock 1 as self-rooted rootstock resulted in the largest tree height (356.67 cm), while 'Tianhong 2'/B9/*M. robusta* Rehd. resulted in the lowest tree height (290.70 cm). Each combination had different influences on trunk diameter; 'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock led to the thickest trunk diameter (7.54 cm), while 'Tianhong 2'/B9/*M. robusta* Rehd. led to the thinnest trunk diameter (5.94 cm). 'Tianhong 2'/SH6 as self-rooted rootstock had the largest number of main branches (23.67), while 'Tianhong 2'/M9-T337/*M. robusta* Rehd. had the smallest number of main branches (13.33).

Table 1 Effects of different dwarfing rootstocks on the growth characteristics of 'Tianhong 2' apple trees

Scion-rootstock combination	Crown width//cm	Tree height//cm	Trunk diameter//cm	Number of main branches
'Tianhong 2'/SH6 as self-rooted rootstock	125.37 ± 20.82 ab	343.33 ± 11.55 a	7.44 ± 0.08 ab	23.67 ± 3.06 a
'Tianhong 2'/Qing rootstock 1 as self-rooted rootstock	121.67 ± 7.64 ab	356.67 ± 35.12 a	7.28 ± 0.17 ab	19.42 ± 4.04 b
'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock	130.00 ± 10.00 a	350.40 ± 36.06 a	7.54 ± 0.43 a	18.33 ± 1.15 bc
'Tianhong 2'/Mark/*Malus robusta* Rehd.	116.67 ± 28.87 bc	298.20 ± 20.00 ab	6.68 ± 0.09 bc	17.67 ± 2.52 b
'Tianhong 2'/P22/*M. robusta* Rehd.	120.00 ± 17.32 ab	296.45 ± 45.09 b	6.55 ± 0.53 bc	15.39 ± 2.31 b
'Tianhong 2'/B9/*M. robusta* Rehd.	118.33 ± 5.77 b	290.70 ± 20.00 c	5.94 ± 0.38 cd	15.45 ± 5.00 b
'Tianhong 2'/M9-T337/*M. robusta* Rehd.	115.00 ± 3.23 bc	295.50 ± 34.64 bc	5.98 ± 0.90 cd	13.33 ± 2.52 c
'Tianhong 2'/Qing rootstock 1/*M. robusta* Rehd.	123.50 ± 6.16 ab	353.33 ± 55.68 a	6.96 ± 0.35 bc	19.53 ± 2.08 bc

Note: Different lowercase letters in the same column indicate significant difference at 0.05 level ($P < 0.05$); the same below.

3.2 Effect on branch structure Different dwarfing rootstocks had varying effects on the branch structure of 'Tianhong 2' apple trees (Table 2). The total number of long shoots (proportion of long branches + long shoots) of 'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock was the highest of 19.27%; followed by 'Tianhong 2'/M9-T337/*M. robusta* Rehd. (16.10%), 'Tianhong 2'/Qing rootstock 1 as self-rooted rootstock (11.93%), 'Tianhong 2'/SH6 as self-rooted rootstock (10.70%); and the total number of long shoots of 'Tianhong 2'/P22/*M. robusta* Rehd. was the lowest (7.62%). The sum of the proportions of medium withes and brachyplasts of 'Tianhong 2'/Mark/*M. robusta* Rehd., 'Tianhong 2'/P22/*M. robusta* Rehd. and 'Tianhong 2'/B9/*M. robusta* Rehd. was more than 90%, significantly higher than that of other combinations.

Table 2 Effects of different dwarfing rootstocks on the branch structure of 'Tianhong 2' apple trees

Scion-rootstock combination	Total number of branches	Proportion // %			
		Long branch	Long shoot	Medium withe	Brachyplast
'Tianhong 2'/SH6 as self-rooted rootstock	547.67 ± 55.41 a	9.17 ± 5.19 abc	1.53 ± 0.92 a	4.34 ± 4.13 ab	84.95 ± 3.93 ab
'Tianhong 2'/Qing rootstock 1 as self-rooted rootstock	406.33 ± 70.44 b	8.49 ± 2.13 abc	3.03 ± 1.79 a	4.71 ± 1.82ab	88.76 ± 11.4 a
'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock	550.67 ± 61.00 a	17.46 ± 2.52 a	1.81 ± 0.79 a	3.61 ± 2.81ab	77.11 ± 16.09 d
'Tianhong 2'/Mark/*Malus robusta* Rehd.	329.67 ± 70.19 d	7.18 ± 3.77 c	2.23 ± 2.14 a	6.54 ± 2.94 ab	84.05 ± 2.77 abc
'Tianhong 2'/P22/*M. robusta* Rehd.	376.00 ± 131.02 c	6.14 ± 4.84 bc	1.48 ± 1.60 a	6.48 ± 1.40 a	85.89 ± 11.92 ab
'Tianhong 2'/B9/*M. robusta* Rehd.	342.33 ± 88.86 cd	8.71 ± 3.49 bc	1.26 ± 3.23 a	5.59 ± 2.09 ab	84.43 ± 6.45 cd
'Tianhong 2'/M9-T337/*M. robusta* Rehd.	354.00 ± 101.73 c	12.66 ± 7.77 ab	3.44 ± 2.21 a	1.16 ± 1.02 b	82.74 ± 11.81 cd
'Tianhong 2'/Qing rootstock 1/*M. robusta* Rehd.	397.67 ± 71.06 b	9.85 ± 7.88 abc	2.08 ± 0.94 a	3.09 ± 1.88 b	84.98 ± 10.73 ab

3.3 Effect on apple yield The effects of different dwarfing rootstocks on the yield of 'Tianhong 2' apple trees are shown in Table 3. The average single fruit weight of 'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock was the highest (257.50 g); the average single fruit weights of 'Tianhong 2'/SH6 as self-rooted rootstock, 'Tianhong 2'/Qing rootstock 1 as self-rooted rootstock, and 'Tianhong 2'/Qing rootstock 1/*M. robusta* Rehd. were greater than 250 g, and fruits were uniform; the average single fruit weights of 'Tianhong 2'/B9/*M. robusta* Rehd., 'Tianhong 2'/P22/*M. robusta* Rehd. and 'Tianhong 2'/M9-T337/*M. robusta* Rehd. were 250.67, 244.50 and 242.33 g, respectively. The number of fruits per plant of 'Tianhong 2'/Mark/*M. robusta* Rehd., 'Tianhong 2'/P22/*M. robusta* Rehd. and 'Tianhong 2'/B9/*M. robusta* Rehd. was 150-160, significantly lower than that of other rootstocks (>180). Different rootstocks had significant effects on the yield of 'Tianhong 2' apple trees. 'Tianhong 2'/SH6 as self-rooted rootstock had the highest yield of 3 250.08 kg/667 m^2, while 'Tianhong 2'/B9/*M. robusta* Rehd. had the lowest yield of 2 512.51 kg/667 m^2.

Table 3 Effects of different dwarfing rootstocks on the apple yield of 'Tianhong 2'

Scion-rootstock combination	Average single fruit weight // g	Number of fruits per plant	Yield // kg/667 m^2
'Tianhong 2'/SH6 as self-rooted rootstock	256.33 ± 2.52 b	188.68 ± 9.67 a	3 250.08 ± 23.42 a
'Tianhong 2'/Qing rootstock 1 as self-rooted rootstock	255.83 ± 2.52 c	183.41 ± 6.42 b	3 153.16 ± 20.69 bc
'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock	257.50 ± 2.00 a	185.42 ± 8.13 b	3 208.43 ± 21.55 ab
'Tianhong 2'/Mark/*Malus robusta* Rehd.	253.67 ± 3.51 e	161.40 ± 5.56 c	2 751.37 ± 17.46 d
'Tianhong 2'/P22/*M. robusta* Rehd.	244.50 ± 5.57 g	157.92 ± 4.94 d	2 594.64 ± 16.38 e
'Tianhong 2'/B9/*M. robusta* Rehd.	250.67 ± 4.04 f	149.15 ± 4.38 e	2 512.51 ± 16.29 e
'Tianhong 2'/M9-T337/*M. robusta* Rehd.	242.33 ± 2.52 g	179.18 ± 11.21 a	2 917.87 ± 19.93 c
'Tianhong 2'/Qing rootstock 1/*M. robusta* Rehd.	254.67 ± 4.04 d	183.88 ± 6.95 b	3 146.82 ± 20.34 bc

3.4 Effect on apple quality As shown in Table 4, 'Tianhong 2'/SH6 as self-rooted rootstock, 'Tianhong 2'/Qing rootstock 1 as self-rooted rootstock, 'Tianhong 2'/Qing rootstock 1/*M. robusta* Rehd. and 'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock had large colored area (over 93%); 'Tianhong 2'/P22/*M. robusta* Rehd. and 'Tianhong 2'/B9/*M. robusta* Rehd. had smaller colored areas (90.8 % and 90.5%). Vertical and transverse diameter analysis results showed that the vertical diameters of 'Tianhong 2'/SH6 as self-rooted rootstock, 'Tianhong 2'/Qing rootstock 1 as self-rooted rootstock, 'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock and 'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock were all greater than 68.00 mm, and their transverse diameters were greater than 84.00 mm; the fruits grafted on other dwarfing rootstocks had significantly lower vertical and transverse diameters. Different dwarfing rootstocks had different effects on the soluble solid content of 'Tianhong 2' fruits; the soluble solid content of 'Tianhong 2'/P22/*M. robusta* Rehd. was the highest of 16.90%, and that of 'Tianhong 2'/B9/*M. robusta* Rehd. was the lowest of 15.42 %, with a difference of 1.48 percentage points. The ratios of soluble solid to acid differed greatly among scion-rootstock combinations; the ratio of soluble solid to acid of 'Tianhong' 2/Mark/*M. robusta* Rehd. was the highest of 45.29, and that of 'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock was the lowest of 32.20. 'Tianhong 2'/SH6 as self-rooted rootstock had the largest high-quality fruit rate of 85.87%, and 'Tianhong 2'/B9/*M. robusta* Rehd. had the smallest high-quality fruit rate of 75.84%, with a difference of 10.03 percentage points.

Based on the results of fruit appearance and internal quality measurement, SH6 as self-rooted rootstock and Qing rootstock series were the preferred scion-rootstock combinations.

4 Discussion

4.1 Effects of different dwarfing rootstocks on the growth characteristics of 'Tianhong 2' apple trees Dwarfing rootstock mainly limits the growth potential of the tree and achieves the dwarfing effect by weakening the transport of nutrients and water through affinity loss of rootstock and scion, and further influences the growth characteristics of the tree[15,19-20]. Zhao Tongsheng *et al.*[16] showed that there were significant differences in tree height and crown width of 'Miyazakifuji' apple between SH as self-rooted rootstock and as interstock. Zhao Deying *et al.*[21]

found that the better the effect of dwarfing rootstock on controlling tree growth, the stronger the shoot-controlling ability, the higher the proportion of brachyplasts, the more beneficial the accumulation of nutrients and the formation of flower buds, and the earlier the realization of flowering and fruiting. Li Hongjian *et al.* [22] put forward that weaker trees were conducive to early fruiting and high yield, but easily led to premature senescence. In this study, by analyzing the growth of 'Tianhong 2' apple trees grafted on 8 dwarfing rootstocks, it was found that the plant height, crown width, number of main branches and trunk diameter of apple trees with M9-T337, B9, P22 and Mark as interstocks were obviously small and the trees were dwarfing, while 'Tianhong 2'/SH6 as self-rooted rootstock showed balanced growth potential and moderate tree vigour; the trees treated with Qing rootstock as self-rooted rootstock were slightly tall, especially the proportion of long branches + long shoots of 'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock was as high as 19.27%, and the trees were overgrown. The general view of pomology suggests that the long shoot ratio of 10% – 15% is beneficial to the formation of reasonable tree potential of dwarfing rootstock trees[15–16, 18,22]. Our research results demonstrated that the proportion of brachyplasts of apple trees with Mark, P22 and B9 as interstocks was too high, while that of long shoots was seriously insufficient. The proportion of long shoots of apple trees with SH6 as self-rooted rootstock was 10.70%, and that of medium withes and brachyplasts was in line with the normal growth demand of spur-type apple, which could satisfy the shaping of branch structure, and was conducive to the later development of tree potential and the formation of yield. The total number of branches after 5 years of planting was about 50 000 – 60 000 branch/667 m^2, which conformed to the population reference index of apple branches with high yield and stable yield and the appropriate range of branch structure. 'Tianhong 2' apple tree has the characteristics of strong brachyplast performance and high flowering ability. When 'Tianhong 2' is planted with a row spacing of 4 m × 2 m in central and southern Hebei Province, it is not suitable to select the rootstock type with strong dwarfing ability (such as B9, P22, M9-T337, *etc.*), because the proportion of brachyplast in these trees is too high and that of medium withes and long shoots is insufficient, which will easily lead to premature senescence of tree potential, and is not conducive to the formation of early population structure in the orchard. Rootstocks with medium dwarfing and crown-controlling abilities should be selected. Compared with interstock, self-rooted rootstock has the advantages of easy reproduction, strong crown-controlling ability, early fruiting and high yield, and neat orchard appearance. 'Tianhong 2'/SH6 as self-rooted rootstock had a plant height of 3.43 m and a crown width of 1.25 m, showing more balanced growth than other trees grafted on self-rooted rootstock.

Table 4 Effects of different dwarfing rootstocks on the apple quality of 'Tianhong 2'

Scion-rootstock combination	Colored area // %	Vertical diameter // mm	Transverse diameter // mm	Soluble solid content // %	Ratio of soluble solid to acid	High-quality fruit rate // %
'Tianhong 2'/SH6 as self-rooted rootstock	93.5 ± 2.6 a	69.97 ± 1.55 a	85.43 ± 6.82 a	15.78 ± 2.62 bc	43.23 ± 0.79 a	85.87 ± 4.23 a
'Tianhong 2'/Qing rootstock 1 as self-rooted rootstock	93.4 ± 2.3 a	68.90 ± 1.46 a	84.45 ± 5.43 b	15.86 ± 1.54 b	32.37 ± 0.45c	83.85 ± 3.65 b
'Tianhong 2'/Qing rootstock 2 as self-rooted rootstock	93.2 ± 1.9 a	68.06 ± 1.29 b	84.36 ± 5.12 b	15.78 ± 1.22 bc	32.20 ± 0.38c	82.63 ± 3.37 b
'Tianhong 2'/Mark/*Malus robusta* Rehd.	91.6 ± 1.1 b	66.14 ± 0.84 c	83.06 ± 4.35 c	15.85 ± 1.35 b	45.29 ± 0.86 a	78.52 ± 4.98 c
'Tianhong 2'/P22/*M. robusta* Rehd.	90.8 ± 0.8 c	66.38 ± 0.96 c	81.97 ± 3.69 d	16.90 ± 2.40 a	41.73 ± 0.64 b	76.93 ± 3.17 d
'Tianhong 2'/B9/*M. robusta* Rehd.	90.5 ± 0.6 c	67.27 ± 1.18 b	83.18 ± 4.65 c	15.42 ± 0.88 d	32.81 ± 0.51 c	75.84 ± 4.26 e
'Tianhong 2'/M9-T337/*M. robusta* Rehd.	91.8 ± 1.3 b	67.77 ± 1.31 b	83.96 ± 4.87 c	16.27 ± 1.23 a	41.72 ± 0.66 b	78.76 ± 4.34 c
'Tianhong 2'/Qing rootstock 1/*M. robusta* Rehd.	93.3 ± 2.2 a	68.45 ± 1.43 a	84.65 ± 5.64 b	15.83 ± 1.47 b	32.45 ± 0.48 c	82.15 ± 3.85 b

4.2 Effects of different dwarfing rootstocks on the yield and fruit quality of 'Tianhong 2' Suitable dwarfing rootstock can balance the dynamic relationship between vegetative growth and reproductive growth, form suitable tree structure, and then have a direct effect on apple yield and quality formation[16–17,22–23]. This paper studied the effects of 8 different dwarfing rootstocks on 'Tianhong 2' apple in southern Hebei Province, and found that the yield of 'Tianhong 2' was lower when B9, P22, M9-T337 and Mark were used as interstocks. Combined with the analysis of tree growth indicators, such rootstocks have strong dwarfing ability, weak tree body growth, and poor performance in average single fruit weight and number of fruits per plant, and ultimately lead to low yield. Therefore, for rootstocks with strong dwarfing properties, it is recommended to graft with common varieties in production, which can give full play to their characteristics of strong dwarfing and crown-controlling ability. In addition, B9 and Mark rootstocks have poor toughness and poor lodging resistance, so supports should be set up to prevent strong winds from breaking the tree body. M9-T337 show poor cold resistance in Hebei region when grafting trees, and is easy to sprout when grafting red Fuji cultivars, so it is not suitable for planting in Hebei region. 'Tianhong 2'/SH6 as self-rooted rootstock had large average single fruit weight (256.33 g), large number of fruits per plant (188.68), the highest yield [(3 250.08 ± 23.42) kg/667 m^2], high fruit colored area (> 93%) and high ratio of soluble solid to acid (43.23), and the soluble solid content reached the requirement of high-quality fruit (15.78%). Therefore, this combination had the best comprehensive evaluation of yield and fruit quality.

5 Conclusions

Through comprehensive analysis and evaluation of tree growth and fruiting data of different rootstock-scion combinations, it was found that after grafting on different dwarfing rootstocks, 'Tianhong 2'/SH6 as self-rooted rootstock had the best comprehensive production effect in terms of tree growth, yield and fruit quality. Therefore, considering the growth characteristics and yield and quality of apple trees, this rootstock-scion combination is a preferred choice in the development of dwarfing rootstock apple cultivation in southern Hebei Province.

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mally at a culture temperature of 25 – 30 ℃. At 25 ℃ and below, pollen germination was slow, and the germination rate was low. When the temperature increased to 30 ℃, the pollen germination time was earlier, and the germination rate of Yangmei pollen was significantly increased. From this, it can be concluded that the *in vitro* culture temperature of Yangmei pollen at 30 ℃ was more suitable for germination than at 25 ℃.

(iii) *In vitro* pollen culture is currently recognized as a good method for measuring pollen viability, but this method requires specific temperature and a longer time (112 h of cultivation in this experiment) to achieve. Therefore, this method is used when conditions permit. At the same time, a certain number of repetitions are required to ensure the accuracy of the measured results.

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