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RESEARCH REPORT

Effects of different rootstock grafting on yield and quality of cucumber

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ABSTRACT

In this study, 'Xinli No. 3', 'Shengli rootstock', 'Shenli rootstock' and 'Shengzhen No. 1' were used as rootstock, and 'Jinchun No. 39' cucumber was used as scion to study the effects of different rootstock on the yield and quality of grafted cucumber, and to select high quality rootstock suitable for cucumber grafting. Different rootstock affected the survival rate, phenology, the height of plant, stem diameter, growth potential, yield and quality of cucumber grafting. Among them, the survival rate of 'Shenli rootstock' grafted cucumber is the highest, and the growth of 'Shengzhen No. 1' grafted cucumber is relatively the strongest. There was no significant difference in fruit tuber, melon edge, thorn color and pulp crispness between self-rooted seedling (CK) and each rootstock grafting combination. The average yield of 'Xinli No. 3' grafted cucumber plot was not significantly different from that of self-rooted seedlings (CK). The length of 'Shenli rootstock' and 'Shengli rootstock' grafted cucumber was significantly higher than that of self-rooted seedlings (CK), and the length of 'Shengzhen No. 1' Grafted Cucumber was significantly higher than that of self-rooted seedlings (CK). The contents of vitamin C and soluble protein of 'Shengli rootstock', 'Shenli rootstock' and 'Shengzhen No. 1' grafted cucumber were significantly higher than those of self-rooted seedlings (CK), and the contents of soluble sugar were lower than those of self-rooted seedlings (CK). Therefore, 'Shengzhen No. 1' and 'Jinchun No. 39' have strong compatibility with cucumber. As rootstocks, the grafted cucumber plants not only have strong growth potential and high yield, but also significantly increase the content of soluble protein and vitamin C.

Keywords: Rootstock; Grafting; Cucumber; Quality; Yield

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1. Introduction

Cucumber (*Cucumis sativus* L.) is an important facility vegetable[1]. With the improvement of cultivation level, cultivation area and multiple cropping index, the barrier of protected soil continuous cropping has intensified, which has seriously restricted the intensive and professional sustainable development of China's facility vegetable cultivation industry[2]. Soil borne diseases seriously affect the utilization and absorption of nutrient elements in cucumber, weaken the stress resistance of plants, and reduce the quality and yield. Grafting technology is an important technical means to effectively solve this problem[3]. Grafted cucumber has deep root system and strong absorption capacity, which is mainly manifested in strong stress resistance, low temperature and high humidity resistance, prolonged fruiting period and increased yield. However, different rootstocks have a greater impact on cucumber growth, yield and quality[4]. At present, there are many kinds of cucumber grafted rootstocks in the market, but the quality varies greatly, which seriously affects the yield and quality of cucumber grafted cultivation. Therefore, in this experiment, the self-rooted seedlings of cucumber were used as

the control, and the high-quality rootstocks suitable for cucumber grafting were selected by analyzing the growth, quality and yield of four grafted rootstock.

2. Results and analysis

2.1 Effect of different rootstock varieties on grafting survival rate of cucumber

It can be seen from the survey results (**Table 1**) that the grafting survival rate of 4 rootstocks grafted cucumber is more than 60%. However, the survival rate of different rootstock grafting combinations was significantly different. The survival rate of 'Shenli rootstock' and 'Jinchun 39' cucumber grafted seedlings was higher than that of other rootstocks, and the survival rate was 84%. The survival rates of 'Xinli No. 3' and 'Shengzhen No. 1' were the same, 80% and 78% respectively. The survival rate of 'Shengli rootstock' grafted cucumber is only 60%, and the graft compatibility with 'Jinchun 39' cucumber is poor. Therefore, the survival rate of the same cucumber variety is different due to different rootstocks.

Table 1. Effects of different rootstock varieties grafting on the survival rate of cucumber grafting

Rootstock variety	Grafting numbers	Grafting No. of survivals	Survival rate of grafting (%)
Shengzhen No. 1	100	78	78
Shenli rootstock	100	84	84
Shengli rootstock	100	60	60
Xinli No. 3	100	80	80

2.2 Effect of different rootstock varieties grafting on cucumber growth and development

2.2.1 Effects of different rootstock varieties grafting on flowering, fruit setting and yield of cucumber

The earliest female flower to open was 'Shengzhen No. 1' grafted cucumber, the last female flower to bloom was the self-rooted seedling, and the first female flower of 'Shengzhen No. 1' had the lowest node position, and the root melon was harvested the earliest, 4 days earlier than the self-rooted seedling. The grafting of 'Shenli rootstock' and 'Shengli rootstock' took the second place, and they were harvested 3 days earlier than the self-rooted seedlings. There was little difference between the grafted and self-rooted seedlings of 'Xinli 3' (**Table 2**). The node position of the first female flower from the root seedling was the highest, and the root melon was harvested the latest.

Table 2. Effects of different rootstock varieties grafting on the fruit-bearing and cucumber yield

Rootstock variety	First female flower node	First female flowering date	Harvest time of root melon	Average yield per section (kg)	Weight of single fruit (g)	Average yield per plant (kg)
Shengzhen No. 1	3.5	10-18	10-28	18.10^{a}	252.20^{a}	1.98
Shenli rootstock	4.6	10-19	10-29	15.27^{b}	251.57^{a}	1.59
Shengli rootstock	4.7	10-21	11-1	13.77^{bc}	218.47^{b}	1.45
Xinli No. 3	4.7	10-22	11-2	12.60^{cd}	247.67^{a}	1.13
Seedling (CK)	4.8	10-23	11-6	10.87^{d}	206.38^{c}	1.22

Note: Different lowercase letters indicate significant difference at 0.05 Level

The average yield per plant of cucumber grafted with different rootstocks was ordered from large to small as: 'Shengzhen No. 1' > 'Shengli rootstock' > 'Shenli rootstock' > 'self-rooted seedlings' > 'Xinli No. 3'. The average yield of 'Xinli No. 3' grafted cucumber plot was not significantly different from that of self-rooted seedlings, 'Shenli rootstock' and 'Shengli rootstock' grafted cucumber yield was significantly higher than that of self-rooted seedlings, and 'Shengzhen No. 1' grafted cucumber yield was significantly higher than that of self-rooted seedlings, an increase of 66.5%. The grafted cucumbers 'Shenli rootstock' and 'Shengli rootstock' were significantly higher than the self-rooted seedlings, which were 26.7% and 40.5% higher than the self-rooted seedlings, respectively. The results showed that 'Shengzhen No. 1' rootstock and 'Shengli rootstock' grafted cucumber had a significant effect on yield increase. The single fruit weight of 'Shengzhen No. 1', 'Shenli rootstock'

and ‘Xinli No. 3’ grafted cucumber was significantly higher than that of self-rooted seedlings, and the single fruit weight of ‘Shengli rootstock’ grafted cucumber was significantly higher than that of self-rooted seedlings.

2.2.2 Effects of different rootstock varieties on cucumber growth

Different rootstock varieties have different effects on cucumber growth. The stem diameter of ‘Shengzhen No. 1’ grafted cucumber, ‘Shenli rootstock’ grafted cucumber, ‘Shengli rootstock’ grafted cucumber, ‘Xinli No. 3’ grafted cucumber and self-rooted seedlings showed an upward trend (**Figure 1**). From 41 days to 53 days after grafting, the stem diameter of the five treatments increased slowly and there was no significant difference among the treatments. From 53 days to 65 days, the stem diameter of the five treatments increased rapidly. Throughout the measurement period, the stem diameter growth rate of ‘Shengli rootstock’ grafted cucumber was the highest, followed by ‘Shengzhen No. 1’ and ‘Shenli rootstock’ grafted cucumber, and the stem diameter growth of ‘Xinli No. 3’ grafted cucumber was relatively small.

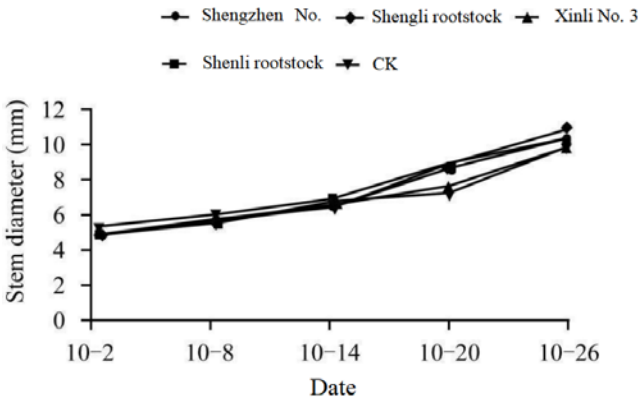

Figure 1. Effects of different rootstocks grafting on the stem diameter of cucumber.

The growth rate of plant height by grafting with different rootstocks showed an increasing trend (**Figure 2**), and the growth rate of plant height was roughly the same. After 30~40 days of planting, the growth rate of plant height reached the fastest. The increasing amount of plant height of each variety is ‘Xinli No. 3’ > ‘Shengli rootstock’ > ‘Shenli rootstock’ > ‘Shengzhen No. 1’ > self-rooted seedlings.

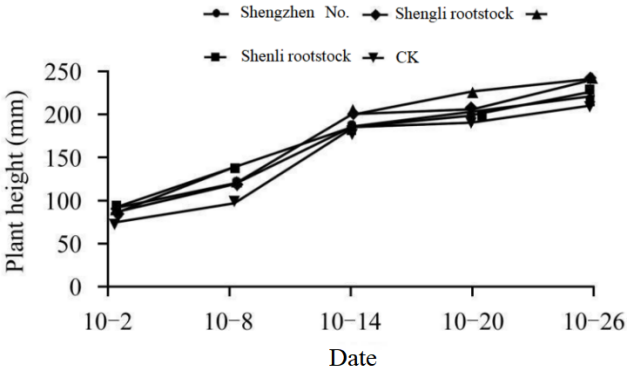

Figure 2. Effects of different rootstocks grafting on the plant height of cucumber.

2.3 Determination of appearance properties and appearance quality of cucumber fruits grafted with different rootstock varieties

2.3.1 Effect of different rootstock varieties grafting on cucumber fruit appearance

After ‘Shengzhen No. 1’, ‘Shenli rootstock’, ‘Shengli rootstock’ and ‘Xinli No. 3’ grafted cucumber and self-rooted seedlings, the color of cucumber skin is dark green. Except that ‘Shenli rootstock’ grafted cucumber and self-rooted seedlings have long rods, other grafted cucumber combinations have medium rods; there was no significant difference in fruit tuber, melon edge, thorn color and pulp crispness between self-rooted seedlings (CK) and rootstock grafting combinations (**Table 3**).

Table 3. Effects of different rootstock varieties grafting on the fruit appearance character of cucumber

Rootstock variety	Peel color	Density of fruit scars	Color of fruit thorn	Fruit edges and comers
Shengzhen No.1	Dark green	Low	White	No
Shenlirootstock	Dark green	Low	White	No
Shenglirootstock	Dark green	Low	White	No
Xinli No.3	Dark green	Low	White	No
Seedling (CK)	Dark green	Low	White	No

2.3.2 Effect of different rootstock varieties grafting on appearance quality of cucumber fruit

The effects of grafting of four Rootstock Varieties on cucumber fruit growth were different (**Table 4**).

Table 4. Effects of different rootstock varieties grafting on fruit growth of cucumber

Rootstock variety	Fruit length (cm)	Fruit width (cm)	Fruit shape index	Fruit stalk length (mm)
Shengzhen No.1	24.131^{ab}	2.999^{b}	8.10^{a}	47.07^{a}
Shenli rootstock	24.771^{ab}	3.794^{a}	6.56^{b}	39.79^{c}
Shengli rootstock	27.701^{a}	3.702^{a}	7.57^{ab}	43.84^{b}
Xinli No.3	26.311^{a}	3.428^{ab}	7.73^{ab}	43.35^{b}
Seedling (CK)	26.392^{a}	3.449^{ab}	7.71^{ab}	46.24^{a}

Note: Different lowercase letters indicate significant difference at 0.05 Level

Except that 'Xinli No. 3' grafted cucumber had no significant difference in fruit diameter with self-rooted seedlings (CK), the fruit diameter of 'Shenli rootstock' and 'Shengli rootstock' grafted cucumber was significantly higher than that of self-rooted seedlings, 10% and 7.3% higher than that of self-rooted seedlings, respectively; the fruit diameter of 'Shengzhen No. 1' grafted cucumber was significantly lower than that of self-rooted seedlings, which was 13% lower than that of self-rooted seedlings. The fruit shape index of 'Shengzhen No. 1' grafted cucumber was significantly higher than that of self-rooted seedlings, while that of 'Shenli rootstock' grafted cucumber was significantly lower than that of self-rooted seedlings. There was no significant difference between the other two grafted cucumber combinations and self-rooted seedlings. The stem length of cucumber grafted with 'Shengli rootstock' and 'Shenli rootstock' were significantly lower than that of self-rooted seedlings, which were 5.2% and 13.9% shorter than that of self-rooted seedlings, respectively. There was no significant difference in fruit length between grafted cucumber combinations and self-rooted seedlings.

2.3.3 Correlation analysis between fruit appearance quality of different rootstock varieties

It can be seen from the results (**Table 5**) that the longitudinal diameter, transverse diameter and single fruit weight of different rootstock varieties are positively correlated, and negatively correlated with fruit shape index, stem length and stem to melon ratio. The cross diameter of different rootstock varieties was positively correlated with single fruit weight, and negatively correlated with fruit shape index, handle length and handle to melon ratio; among different rootstock varieties, the fruit shape index was positively correlated with the stem length and the stem to melon ratio, and negatively correlated with the single fruit weight; among different rootstock varieties, the stem length was positively correlated with the stem to melon ratio, and negatively correlated with the single fruit weight; there was a negative correlation between the ratio of stem to melon and the weight of single fruit among different rootstock varieties.

Table 5. Effects of different rootstock varieties grafting on the correlation coefficient of cucumber fruit growth

Correlation coefficient	Longitudinal diameter	Horizontal diameter	Fruit shape index	Fruit stalk length	The ratio of fruit neck to fruit	Weight of single fruit
Longitudinal diameter	1	-	-	--	--	--
Horizontal diameter	0.99**	1	-	--	--	--
Fruit shap eindex	-0.89*	-0.95**	1	--	--	--
Fruit stalk length	-0.69	-0.64	0.50	1	--	--
The ratio of fruit neck to fruit	-0.93**	-0.91*	0.78	0.87*	1	--
Weight of single fruit	0.80	0.72	-0.53	-0.93**	-0.87*	1

Note: *: Significant correlation at the 5% level; **: Significant correlation at the 1% level

2.4 Effect of Different Rootstock Varieties grafting on internal quality of Cucumber Fruit

According to the results (**Table 6**), except that the soluble sugar content of 'Shenli rootstock' grafted cucumber is not significantly different from that of self-rooted seedlings, other grafted cucumber combinations are significantly different from that of self-rooted seedlings and are all lower than that of self-rooted seedlings; the content of soluble protein in cucumber fruits of different grafting combinations was significantly higher than that of self-rooted seedlings. The content of soluble protein in Cucumber Fruits grafted with 'Shengli rootstock', 'Shengzhen No. 1' and 'Xinli No. 3' rootstock was significantly higher than that of self-rooted seed-

lings, increased by 25%, 28.8% and 30.8% respectively 'Shenli rootstock' grafted cucumber was significantly higher than that of self-rooted seedlings, which increased by 11.5%. Except that the vitamin C content of 'Xinli No. 3' grafted cucumber was not significantly different from that of self-rooted seedlings, the vitamin C content of other grafted cucumber combinations was significantly higher than that of self-rooted seedlings. The vitamin C content of 'Shengzhen No. 1' and 'Shengli rootstock' grafted cucumber was the highest, increased by 34.1% and 28.6% respectively. The vitamin C content of 'Shenli rootstock' grafted cucumber was 12% higher than that of self-rooted seedlings.

Table 6. Effects of different rootstock varieties grafting on the nutritional quality of cucumber fruits

Root stockvariety	Solubility sugar content (%)	Soluble protein content (%)	Vc content (mg/kg)
Seedling (CK)	1.3367^{a}	1.04^{c}	92.00^{c}
Shengzhen No.1	1.0833^{b}	1.30^{a}	123.33^{a}
Shengli rootstock	1.0867^{b}	1.34^{a}	118.33^{a}
Shenli rootstock	1.3733^{a}	1.16^{b}	103.00^{b}
Xinli No.3	1.0633^{b}	1.36^{a}	93.67^{c}

Note: Different lowercase letters indicate significant difference at 0.05 Level

3. Discussion

This experiment found that the reasons affecting the survival rate of cucumber grafting: (1) the grafting time between scion and rootstock, (2) the grafting affinity between scion and rootstock, (3) the grafting method and post grafting management. In this experiment, 'Shenli rootstock' as grafting rootstock has the highest survival rate, and 'Shengli rootstock' as grafting rootstock has the lowest survival rate.

The growth potential energy of cucumber was enhanced by grafting[5]. The results showed that there was no significant difference between rootstock grafted varieties and self-rooted seedlings within 30 days after planting. The growth rate of plant height and stem diameter was the fastest 30~40 days after planting; thus, the growth rate of grafted cucumber was significantly higher than that of self-rooted seedlings.

It was found that there was no significant difference in the fruit tuber, melon edge, thorn color and pulp crispness between self-rooted seedlings (CK) and rootstocks. Grafting had a significant effect on the fruit diameter and fruit shape index of cucumber, but there was no significant difference in fruit length and handle length between grafted combinations and self-rooted seedlings. The average yield of 'Xinli No. 3' grafted cucumber plot was not significantly different from that of self-rooted seedlings. The average yield of 'Shengli rootstock' and 'Shenli rootstock' grafted cucumber plot was significantly higher than that of self-rooted seedlings, and 'Shengzhen No. 1' grafted cucumber was extremely significantly higher than that of self-rooted seedlings, indicating that 'Shengzhen No. 1' rootstock and 'Shengli rootstock' grafted cucumber had a significant effect on yield increase. The effect of grafting on fruit quality is generally negative[6,7]. This effect is generally greatly related to the characteristics of rootstock varieties selected for grafting. However, this effect can be reduced or avoided by screening suitable grafting rootstocks through experiments.

In this study, except that 'Xinli No. 3' grafted cucumber has no significant difference in vitamin C content with self-rooted seedlings, the vitamin C content of other grafted combinations is significantly higher than that of self-rooted seedlings, which is inconsistent with the research results of Wang[8] that grafting significantly reduces vitamin C content, indicating that different rootstock grafting has different effects on the vitamin C content of cucumber fruit[9]. The content of soluble protein in cucumber fruit of different rootstock grafting combinations was significantly higher than that of self-rooted seedlings; except that the soluble sugar content of grafted cucumber from 'Shenli rootstock' was not significantly different from that of self-rooted seedlings, other grafted combinations were lower than that of self-rooted seedlings. This is inconsistent with the research results of Pei *et al*.[10] that grafting significantly improves the soluble sugar content of cucumber fruit. It was also confirmed that different rootstocks had different effects on cucumber fruit quality. Due to different

management techniques and cultivation seasons, the effects of different rootstocks on cucumber yield were also different. In this experiment, 'Shengzhen No. 1' has the highest yield, followed by 'Shengli rootstock' and 'Shenli rootstock', and 'Xinli No.3' has a lower yield of grafted cucumber than self-rooted seedlings, which has a lot to do with the planting management process of this experiment. First, due to the unskilled management technology, the incidence rate of cucumber is high and the growth speed is slow during the growth process. The second is that the experiment was carried out in the school, which inevitably led to the difference between the actual output and the results.

4. Materials and methods

4.1 Test materials

The scion cucumber variety is *Cucumis sativus* 'jinchun No.39', and the seeds are provided by Tianjin Cucumber Research Institute. The varieties of rootstock pumpkin are 'Shengzhen No.1' (Shenyang Shengdiya Agricultural High Tech Co., Ltd.), 'Shenli rootstock' (Shandong Shouguang Jinfeng Co., Ltd.), 'shengli rootstock (Beijing lifengxin seedling Co., Ltd), 'Xinli No.3' (Beijing Dongfang Huihai Agricultural Technology Co., Ltd.). The cucumber self-rooted seedling 'Jichun 39' was used as a comparison.

4.2 Test design

4.2.1 Scion and rootstock sowing and grafting

The experiment was conducted in the intelligent greenhouse of the horticultural experiment station of Tarim University. After the test materials were soaked and germinated in warm soup, on July 28, 2017, 100 plants of 'Shengzhen No. 1', 'Shenli rootstock', 'Shengli rootstock' and 'Xinli No. 3' used as rootstocks were sown in a nutrient bowl (8 cm × 8 cm), and sowed cucumbers in each nutrient bowl at the same time, and 100 plants of 'Jinchun 39' were sown with cave plates. On August 12, when the pumpkin grew to one leaf and one heart, the cotyledon of the scion was spread out, the close grafting method was adopted[11]. First, deal with the rootstock: put the stem on the side perpendicular to the long line of the two cotyledons of the pumpkin, and use a special grafting blade next to the cotyledons of the pumpkin. The blade is 30°~45° with the stem of the pumpkin. Quickly and accurately cut down the section about 0.5 cm in length at one time. Secondly, scion treatment: the stem parallel to the long line of the two cotyledons of the cucumber is next to the 2 cm position of the cotyledons of the cucumber with a special grafting blade, and the blade is 30°~45° with the stem of the cucumber. The profile with a length of about 0.5 cm is quickly and accurately cut upward at one time. Finally, after the rootstock and scion are treated, the two sections shall be fully contacted immediately, and no gap shall be left on the section. The section shall be clamped with a grafting clamp or wrapped with a film for fixation.

After grafting, cucumber cotyledons are located above and pumpkin cotyledons are located below to ensure that the long line between cucumber and pumpkin cotyledons is vertical to avoid shading and affect normal growth. The grafted seedlings shall be immediately moved into the small plastic arch shed built in advance, and the shading net shall be laid for complete shading. The humidity in the arch shed shall be controlled at 80%~90%. After 3 days, the shading net shall be gradually removed, and the plastic film shall be opened for wind protection. After 10 days, the shading net and plastic film shall be completely removed and transferred to normal cultivation management. When the scion cucumber starts to have new true leaves and starts to grow, the grafted seedlings will survive. After that, remove the grafting clip and cut off all the stems of the scion cucumber immediately below the healing position with a blade. Let cucumber make full use of Rootstock to grow pumpkin roots. Scion cucumber is prone to water shortage and plant wilting after root cutting. It is necessary to shade and increase humidity. Before cutting the root system of scion cucumber, the grafted seedlings should be watered. After removing the growth point of rootstock pumpkin, its leaf axil has a strong ability to produce lateral branches. It is necessary to remove the sprouts with a blade in time to avoid competing with scion cucumber for nutrition. The cut stems of

scion cucumber are easy to produce adventitious roots under the condition of moist and weak light, so they should be removed in time.

4.2.2 Planting

After 24 days of grafting, the cucumber seedlings were three leaves and one heart. The grafted cucumber seedlings with the same growth status were selected, and the high-temperature sterilized substrate was evenly loaded into the cultivation bag using the substrate bagging soilless cultivation method (cultivation bag specification: length: 50 cm, width: 40 cm). Cut a "mouth-shaped" planting opening with a length of 10 cm and a width of 8 cm from both ends of the cultivation bag. Before planting, fill the cultivation bag with clean water, soak it for 1~2 h, soak the substrate inside thoroughly, and take out a small amount of substrate from the planting mouth. Put the seedlings with soil lumps into the cultivation bag with "mouth-shaped" planting mouth, cover it with substrate positive pressure, and immediately use the dropper system to pour water to prevent the newly planted seedlings from losing water and wilting, and then plant the grafted cucumber seedlings in the cultivation bag. The test site in the greenhouse is 8 m long and 5 m wide, and 90 matrix bags were placed in the north-south direction of 80 cm × 30 cm line spacing.

4.2.3 Post planting management

The pruning method adopts single stem pruning and vine hanging cultivation. The pruning management is the same as the general growth management. The greenhouse is an intelligent sunlight greenhouse. Cucumber stems and vines grow fast and have strong ability to produce lateral branches. Lateral branches should be removed in time. Hanging vines are used for cultivation in greenhouse. When the height of cucumber plant is 30 cm, carry out vine hanging, timely remove tendrils, old leaves and diseased leaves, and pay attention to the management of fertilizer and water pests[4]. The experiment was single factor, with 4 treatments and one control treatment. Each treatment of 10 plants was repeated for 3 times and arranged randomly in the greenhouse. The row spacing is 80 cm, the plant spacing is 35 cm, and the test plot area is 40 m^2.

4.3 Determination and analysis

4.3.1 Determination of survival rate of grafted seedlings with different rootstocks

From the 19th to 20th days after grafting, 100 grafted seedlings were selected for each grafting treatment to investigate the grafting survival rate. The survival rate = (number of mature seedlings/ number of grafted seedlings) × 100%.

4.3.2 Observation and determination of plant growth

Five plants with the same growth were selected for tagging in each treatment in the determination area and used for the determination of growth indicators, yield indicators and quality. After 20 days of planting, 5 plants were randomly investigated in each plot to measure the stem diameter and plant height of cucumber plants. Then measure every 6 days for 5 consecutive times. Plant height (height from cultivation bag surface to plant growth point), stem diameter (next to the lower part of ear cotyledon)[12].

4.3.3 Output measurement

In the full fruit period, the fruit was harvested by individual plant in time, and the weight of each plant in each treatment was weighed by electronic scale. Record and count the fruit weight and yield per plant.

4.3.4 Quality measurement

At the full fruit stage, 3 fruits were randomly selected from each treatment and repeated for 3 times. The skin color, the density of melon lump, the prick color, the melon edge and the flesh crispness were measured. The appearance quality of fruit was measured by Vernier caliper; calculate the fruit shape index. Fruit shape index = fruit length/fruit coarseness. According to the methods of Li *et al.*[13], the content of vitamin C in fruit was determined by iodine titration, the content of soluble protein in fruit was determined by Coomassie brilliant blue method, and the content of soluble sugar in fruit was determined by anthrone colorimetry.

4.4 Data statistics

The test data were sorted and analyzed by Excel 2010 and DPS software.

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Conflict of interest

The authors declared no conflict of interest.

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