Effects of Different Rootstocks on Phosphorus and Potassium Uptake in Eggplant Seedlings under Selenium Stress

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Abstract. In the experiment, four new eggplant materials (“190-1-8”, “RS-2”, “RS-5” and “Qinqing”) and wild tomato were used as rootstocks, and eggplant “Fengshengjiaowang” was used as scion to study the effect of different rootstocks on the absorption of phosphorus and potassium by eggplant seedlings under selenium stress. The results showed that after grafting, the absorption of phosphorus in the roots of grafted eggplant seedlings was not significant overall. But grafting can significantly increase potassium uptake by roots of grafted eggplant seedlings. Grafting significantly reduced the content of phosphorus and potassium in scion stems. Phosphorus and potassium content in leaves and rootstock stems vary greatly according to the rootstock. In conclusion, the treatment of using RS-5 and Qinqing as the rootstocks had the best performance overall. For the treatment of using RS-5 as the rootstock, the phosphorus content in roots and leaves was 17.71% and 16.14% higher than that of control, respectively; and the potassium content in the roots and leaves increased by 24.02% and 6.62% compared with the control. For the treatment of using Qinqing as the rootstock, the leaves phosphorus content increased by 16.02% compared with the control, and the root potassium content was 43.20% higher than that of control. The contents of phosphorus and potassium in the rootstock and scion stems performed better than other grafting treatments.

1. Introduction
Phosphorus and potassium are macroelements required to ensure the normal growth of plants. Phosphorus plays a vital role in energy metabolism, sugar metabolism, enzymatic reactions, and photosynthesis [1-2]. It is an important component of nucleic acids and lecithin, and it largely determines the yield and quality of crops [1-2]. The previous study found that under low-phosphorus conditions, the photosynthetic rate, and RuBP carboxylase activity in rice leaves decreased [3]. The root morphology of plants will change when phosphorus is lacking to increase the contact area with soil and absorb more phosphorus [4]. At the same time, many studies have also found that phosphorus deficiency will significantly increase the acid phosphatase activity of plant roots. It is because acid phosphatase can activate phosphorus in the soil and make it more easily absorbed by plant roots [5].

Potassium is an activator of many enzymes, which can effectively regulate the water potential of plant cells and the opening and closing of stomata [6]. It also can promote photosynthesis and the transport of photosynthetic products [7]. At the same time, potassium can enhance the resistance of plants under stress conditions. Under stresses such as drought [8] and low temperature [9], K+ greatly contributes to the osmotic potential, which can reduce the imbalance of water and ions in the cell, accelerate the metabolic process, and cause adaptive changes in membrane proteins. Plant potassium deficiency usually first appeared on the old leaves, the tips or edges of leaves become yellow and even scorched.
Phosphorus and potassium are very important for plant growth and if it is lacking, it will lead to adverse consequences such as crop yield reduction and quality reduction. In agricultural production, chemical fertilizers are usually used to increase yield, but excessive fertilization will not increase yield, but will cause loss of nutrients in the soil. So the point is not how much fertilizer is applied to the soil, but how much the plant can absorb and use the fertilizer.

Grafting is a method of asexual propagation, which widely used in the cultivation and breeding of horticultural plants, because it not only maintains the excellent traits of the female parent (scion), but also promotes ion absorption [11]. The study found that after grafting, the root development of the grafted cucumber was better than that of the control, and it could absorb more nitrogen, phosphorus, potassium, and other mineral elements for the growth of the shoot. At the same time, the chlorophyll content and photosynthetic rate in the leaves of the grafted seedlings were higher than those of the control, which increased the dry matter accumulation in the shoot, provided sufficient organic matter for the further growth of the root. These two aspects promoted the coordinated growth of the root and shoot of the grafted cucumber [12]. Many studies have shown that grafting has a significant effect on improving the nutrient absorption of plants, but research has mostly focused on cucumbers and tomatoes [13], and there have been fewer studies on grafting applied to eggplants to improve their nutrient absorption. So in the study, four new eggplant materials (“190-1-8”, “RS-2”, “RS-5” and “Qinqing”) and wild tomato were used as rootstocks, and eggplant “Fengshengjiaowang” was used as scion to study the effect of different rootstocks on the absorption of phosphorus and potassium by eggplant seedlings under selenium stress.

2. Materials and methods

2.1. Materials
Rootstocks for the experiment were eggplant new materials, including “190-1-8”, “RS-2”, “RS-5”, “Qinqing” and wild tomato. The scion eggplant variety was “Fengshengjiaowang”. All the seeds provided by Chengdu Academy of Agriculture and Forestry Sciences, China. The soil used in the experiment was fluvo-aquic soil, collected from Chengdu Academy of Agriculture and Forestry Sciences in September, 2019.

2.2. Grafting
In October 2019, all the seeds were directly sown in moist nutrient soil according category, and raised in a greenhouse at Chengdu Academy of Agriculture and Forestry Sciences. The greenhouse environment was set as follows: The day setting: 14 h, temperature: 25°C, relative humidity: 70%, illumination: 4,000 Lx and the night setting: 10h, temperature: 20°C, relative humidity: 90% illumination: 0 Lx. Grafting was conducted when eggplant seedlings were about 10 cm high. The specific grafting protocol was as follows: The 4 eggplant new material seedlings and wild tomato seedlings were cut from ~6 cm above the ground, leaving the lower parts as rootstocks, and robust shoots (4 cm) of “Fengshengjiaowang” were chosen as scions. The grafting method was cleft grafting, then the grafted plants were bound with 1-cm-wide plastic film to firmly bind the joint between the rootstock and the scion. The soil moisture was maintained at 80%, and the plants were covered with mulch and placed under a sunshade net. After 10 d, the mulch and sunshade net were gradually removed, and the binding plastic film was removed from surviving grafts. All buds germinated from the rootstock were removed [14-17]. The experiment contained 6 treatments, which were: ungrafted (CK), 190-1-8, RS-2, RS-5, Qiqing, and wild tomato.

2.3. Experimental design
The experiment was conducted in the greenhouse of Chengdu Academy of Agriculture and Forestry Sciences from October to December 2019. In October 2019, after the soil was air dried, crushed, mixed and sieved (5 mm), 3.0 kg soil was accurately weighed into each plastic pot (15 cm height × 18 cm diameter). A Na₂SeO₃·5H₂O solution was added to the soil to achieve a final Se concentration of
10 mg kg\(^{-1}\), and the soil moisture was maintained at 80% of field capacity for 4 weeks. After this period, the soil was crushed and mixed thoroughly. Four uniform grafted seedlings were transplanted into each pot in November 2019. Each treatment was repeated three times and watered every day to maintain a soil moisture at 80% of field capacity until the plants were harvested. All the seedlings were cultivated in the greenhouse, and the environment setting was the same as above.

30 d after the plants were transplanted (December 2019), the plants were harvested and washed with tap water, then followed by deionized water for three times. After that, the plants were divided into four parts of roots, rootstock stems, scion stems and leaves. The ungrafted eggplant seedlings were also divided into roots, rootstock stems, scion stems, and leaves at the same height as grafted plants. Finally, deactivation of enzymes in 110 °C for 15 min, and then dry at 80 °C to constant weight. After weighing, the dry sample was ground and passed through a 100 mesh sieve for chemical analysis. Weighed 0.2 g of dry sample and digested it with H\(_2\)SO\(_4\)-H\(_2\)O\(_2\). Then used the solution leafed after digestion to determine the total phosphorus content in various tissues by Mo-Sb anti-spectrophotometer method [18]. The total potassium content in various tissues also can be detected by using the digestion solution with flame photometry [18].

2.4. Statistical analyses
Statistical analyses were performed using SPSS 22.0 statistical software (SPSS Inc., Chicago, IL, USA). Data were analyzed with one-way analysis of variance with least significant difference at the 5% significance level.

3. Results and discussion

3.1. Effects of different rootstocks on phosphorus uptake of eggplant seedlings under selenium stress
Phosphorus content in roots of grafted seedlings of eggplant was different according to different rootstocks (Table 1). The root phosphorus content of grafted seedlings with RS-95 as rootstock was significantly higher than that of control, which was 17.71% (\(p < 0.05\)) higher than that of control. The root phosphorus content of grafted seedlings with wild tomato as rootstock was significantly reduced compared with the control, and was 8.92% (\(p < 0.05\)) lower than the control. The root phosphorus contents of the other three grafted seedlings were not significantly different from that of the control (\(p > 0.05\)). Phosphorus content in the rootstock stems of each grafted seedling also showed different trends. The rootstock stems phosphorus contents of grafted seedlings with Qinqing and wild tomato as rootstocks were significantly higher than that of control, increased by 6.74% (\(p < 0.05\)) and 56.00% (\(p < 0.05\)), respectively. RS-2 and RS-5 as rootstocks reduced the phosphorus content in the rootstock stems of grafted seedlings. And phosphorus content in the rootstock stems of grafted seedlings with 190-1-8 as rootstock was not significantly different from the control. With regard to the phosphorus content of the scion stems, all grafting treatments were significantly lower than the control. The treatments were sorted according to the content of phosphorus in the scion stems: CK > Qinqing > 190-1-8 ≈ wild tomato ≈ RS-5 ≈ RS-2. Using 190-1-8, RS-2 and Qinqing as rootstocks significantly increased the phosphorus content in the leaves of grafted seedlings. The differences between the treatments were not significant, and increased by 18.59% (\(p < 0.05\)), 16.14% (\(p < 0.05\)) and 16.02% (\(p < 0.05\)) respectively compared with the control. The other two grafting treatments reduced the phosphorus content in the leaves of the grafted seedlings.
Table 1 Effects of different rootstocks on phosphorus uptake of eggplant seedlings under selenium stress

| Treatment     | Roots (mg g⁻¹) | Rootstock stems (mg g⁻¹) | Scion stems (mg g⁻¹) | Leaves (mg g⁻¹) |
|---------------|----------------|-------------------------|----------------------|-----------------|
| CK            | 2.185±0.056b   | 1.291±0.025c            | 1.642±0.018a         | 2.534±0.045b    |
| 190-1-8       | 2.149±0.072bc  | 1.325±0.042bc           | 1.421±0.032c         | 3.005±0.067a    |
| RS-2          | 2.047±0.081bc  | 0.983±0.024d            | 1.322±0.026e         | 1.970±0.065d    |
| RS-5          | 2.572±0.023a   | 1.048±0.012d            | 1.330±0.024de        | 2.943±0.077a    |
| Qinqing       | 2.099±0.055bc  | 1.378±0.037b            | 1.513±0.002b         | 2.940±0.055a    |
| Wild tomato   | 1.990±0.074c   | 2.014±0.035a            | 1.398±0.048cd        | 2.190±0.054c    |

Values are means ± standard errors of five replicate pots. Different lowercase letters within a column indicate significant differences based on a one-way analysis of variance in SPSS 22.0, followed by the least significant difference test (p < 0.05). The same as follows.

3.2. Effects of different rootstocks on potassium uptake of eggplant seedlings under selenium stress

Grafting increased potassium content in the roots of grafted seedlings (Table 2). Sort each treatment according to the potassium content of the roots as: Qinqing > RS-2 > RS-5 ≈ 190-1-8 ≈ wild tomato > CK. In this order, the potassium content in the roots of each treatment increased by 43.20% (p < 0.05), 32.87% (p < 0.05), 24.02% (p < 0.05), 23.77% (p < 0.05) and 20.82% (p < 0.05) compared with the control, respectively. The rootstock stems potassium contents of grafted seedlings with wild tomato as rootstocks were significantly higher than that of control, which was 3.75% (p < 0.05) higher than that of control. Other grafting treatments significantly reduced the potassium content in rootstock stems of the grafted seedlings. Similar to the variation of phosphorus content in scion stems of grafted seedlings, all grafting treatments also reduced the potassium content of scion stems. The treatments were sorted according to the content of potassium in the scion stems: CK > Qinqing ≈ RS-5 > 190-1-8 > wild tomato ≈ RS-2. Using RS-5 as the rootstock significantly increased the potassium content in the leaves of the grafted seedlings, which was 6.62% (p < 0.05) higher than the control. The potassium content in leaves with Qinqing as the rootstock was no significant difference to which RS-5 as the rootstock, and it also had no significant difference to which of the control (p < 0.05).

Table 2 Effects of different rootstocks on potassium uptake of eggplant seedlings under selenium stress

| Treatment      | Roots (mg g⁻¹) | Rootstock stems (mg g⁻¹) | Scion stems (mg g⁻¹) | Leaves (mg g⁻¹) |
|----------------|----------------|-------------------------|----------------------|-----------------|
| CK             | 12.20±0.06d    | 16.02±0.24b             | 25.96±0.27a          | 25.51±0.59bc    |
| 190-1-8        | 15.10±0.21c    | 11.76±0.11e             | 20.81±0.28c          | 24.14±0.48cd    |
| RS-2           | 16.21±0.27b    | 13.15±0.22d             | 17.37±0.32d          | 21.13±0.55e     |
| RS-5           | 15.13±0.07c    | 11.97±0.11e             | 22.57±0.82b          | 27.20±0.70a     |
| Qinqing        | 17.47±0.46a    | 14.90±0.25c             | 23.33±0.58b          | 26.24±0.47ab    |
| Wild tomato    | 14.74±0.38c    | 16.62±0.26a             | 18.31±0.15d          | 23.17±0.90d     |

4. Conclusions

In conclusion, the treatment of using RS-5 and Qinqing as the rootstocks had the best performance. For the treatment of using RS-5 as the rootstock, the root phosphorus content was 17.71% (p < 0.05) higher than that of control, and the root potassium content was 24.02% (p < 0.05) higher than that of control; the leaves phosphorus content increased by 16.14% (p < 0.05) compared with the control, and the leaves potassium content increased by 6.62% (p < 0.05) compared with the control. For the treatment of using Qinqing as the rootstock, the leaves phosphorus content increased by 16.02% (p < 0.05) compared with the control, and the root potassium content was 43.20% (p < 0.05) higher than that of control. The contents of phosphorus and potassium in the rootstock and scion stems decreased less than in other treatments.

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