Effects of Grafting on Photosynthesis of Eggplant Seedlings under Selenium Stress

Shaokun Pan, Youwan Tang, Chunyi Xi, Ronghai Lu and Yongmei Wu*
Chengdu Academy of Agricultural and Forestry Sciences, Chengdu, Sichuan, 611130, China
*Corresponding author’s e-mail: 691029722@qq.com

Abstract. The effects of eggplant seedlings of Fengshengjiaowang grafting with 190-1-8, RS-2, RS-5, Qinqing, wild tomato on the leaf photosynthesis of Fengshengjiaowang were studied by a pot experiment. The results showed that the seedlings of Fengshengjiaowang grafted with 190-1-8, RS-2, RS-5, Qinqing and wild tomato had different effects on leaf photosynthesis after grafting treatments. Among the six treatments, the leaf Pn, Gs and Tr under treatment ungrafted reached the lowest. The leaf Vpdl under treatment Fengshengjiaowang grafted with 190-1-8 reached the lowest, the leaf Ci under treatment Fengshengjiaowang grafted with RS-5 reached the lowest. The leaf Ci for the treatments of Fengshengjiaowang grafted with 190-1-8, RS-2, RS-5, Qinqing, and wild tomato were significantly lower than ungrafted. The leaf Vpdl for the treatments of Fengshengjiaowang grafted with RS-2, RS-5, Qinqing and wild tomato were significantly higher than ungrafted. In conclusion, grafting will affect the leaf photosynthesis of Se content by Fengshengjiaowang grafted with 190-1-8, RS-2, RS-5, Qinqing and wild tomato. In terms of Pn the treatment of Fengshengjiaowang grafted with wild tomato is the best.

1. Introduction
As an essential trace element, selenium is very important to human health [1]. Organic selenium compounds in plants have anticancer effects [2]. One of the most effective selenium compounds is methylselenocysteine, which can be found in some plants of Cruciferae and Liliaceae [3]. A large number of studies have shown that proper amount of selenium can not only promote the growth and development of plants, increase the selenium content of plants, increase the content of chlorophyll, promote the photosynthesis of plants, but also increase the content of soluble protein of plants and have an impact on the metabolism of nitrogen, sulfur and amino acids [4]. But the content of selenium in the soil is too high, that too much enrichment in plants will not only affect the growth of plants, but also harm human health. When the concentration of Se in soil is 5 mg/kg, the net photosynthetic rate and transpiration rate are the largest in all treatments, which indicates that the low concentration of Se can promote the photosynthetic rate and transpiration rate of eggplant seedlings to a certain extent, but when the high concentration of Se is applied, eggplant seedlings begin to be stressed, and the photosynthetic rate and transpiration rate decrease, thus affecting photosynthesis. The stomatal conductance and intercellular CO₂ concentration of eggplant seedlings decreased significantly with the increase of soil selenium concentration [5]. Grafting is a technique to combine the tissues or organs of the same plant or different plants and promote their growth and development into a complete plant [6]. The main purpose of vegetable grafting is to improve vegetable crops by grafting. Zhang has found that under different concentrations of NaCl stress, the photosynthetic characteristics parameters,
protective enzyme activity, osmoregulation substance content of cucumber grafted seedlings of six rootstocks were higher than that of self rooted seedlings, while the electrolyte leakage rate and MDA content were lower than that of self rooted seedlings, and the salt tolerance ability of grafted seedlings of different rootstocks was also different [7]. Recent studies on grafting have shown that there are complex anvil-spike interaction effects between grafting conjugates, including hormone signaling, protein, and exchange of genetic material and so on. Aloni has suggested that even if the anvil-spike compatibility was satisfied, the anvil-spike interaction effect persisted throughout the life cycle of the grafted conjugates, the upward supply of water and mineral nutrients and the downward flow of photosynthetic products were altered, and the root-top exchange of hormone signals was also affected, which in turn affected plant growth, flowering and fruit quality [8]. Eggplant is a large quantity of vegetables in China and is widely grown in China. The crude protein, crude fat, reduction sugar content and the total amount of essential amino acids of eggplant were significantly increased under soil selenium application (0.15, 0.60, 3.00 mg/kg), which improved the quality of eggplant [5, 9]. Based on this, in this experiment, five different genotype eggplants were grafted with eggplants seedlings of Fengshengjiaowang variety under the selenium stress of the soil through pot experiments, in order to screen out grafting methods that can significantly improve the photosynthetic characteristics of eggplant seedlings.

2. Materials and methods

2.1. Materials
The materials used in the experiment were 190-1-8, RS-2, RS-5, Qinqing, wild tomato and Fengshengjiaowang. All the seeds were collected from Chengdu Academy of Agriculture and Forestry Sciences, China, and air-dried and stored at 4 °C. The cultivar of eggplant was self-retained species of the Horticulture Institute of Chengdu Academy of Agriculture and Forestry Sciences. The soil used in the experiment was fluvo-aquic soil, collected from the Chengdu Academy of Agriculture and Forestry Sciences in September, 2019.

2.2. Grafting
The seeds of 190-1-8, RS-2, RS-5, Qinqing, wild tomato and Fengshengjiaowang were sown at the Chengdu Academy of Agriculture and Forestry Sciences in October, 2019. It was placed in a greenhouse at 25 °C for 14 hours during the day, 70% relative humidity, and a light intensity of 4000 lx, and 10 hours at night, at 20 °C, a relative humidity of 90%, and a light intensity of 0 lx. On 15, November, 2018, the 190-1-8, RS-2, RS-5, Qinqing, wild tomato and Fengshengjiaowang seedlings reached a height of 10 cm, grafting was conducted. The lower part of 190-1-8, RS-2, RS-5, Qinqing, wild tomato seedling, with height of 6 cm, was the rootstock, and the upper part of Fengshengjiaowang seedling (4 cm) was the scion. All leaves of the rootstocks were retained. The grafting method in the experiment was cleft grafting, and the graft union was bound with 1-cm-wide plastic film. After grafting was completed, the soil moisture content was maintained at 80% of field capacity, and all of the seedlings were covered with transparent plastic film and a shade net. After 10 d, the transparent plastic film, shade net, and plastic binding film were removed, progressively [10-12]. There were six grafting treatments in the experiment: ungrafted, and 190-1-8, RS-2, RS-5, Qinqing, wild tomato as the rootstock respectively.

2.3. Experimental design
The experiment was conducted in Chengdu Academy of Agriculture and Forestry Sciences from October to December, 2019. In October, 2019, the soil was air-dried, ground and passed through a 5-mm sieve. Each plastic pot (15 cm high, 18 cm in diameter) was filled with 3 kg of ground soil and soaking uniformly cadmium solution with 10 mg/kg Se (in the form of Na2SeO3·5H2O) for 4 weeks. All pots were watered every day to keep the soil moisture about 80%, and the soils were mixed again after 4 weeks. On 23, November, 2018, after the grafted seedlings survived, three uniformly grafted
3. Results and discussion

3.1. Effect of grafting treatment on leaf Pn

Among the six treatments, the leaf Pn under treatment ungrafted reached the lowest (Figure 1). The leaf Pn for the treatments of Fengshengjiaowang grafted with 190-1-8, Fengshengjiaowang grafted with RS-2, Fengshengjiaowang grafted with RS-5, Fengshengjiaowang grafted with Qinjing, and Fengshengjiaowang grafted with wild tomato were significantly higher than ungrafted, with 102.22% (p < 0.05), 66.07% (p < 0.05), 68.66% (p < 0.05), 72.33% (p < 0.05) and 106.59% (p < 0.05) increase, respectively.

Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 20.0 followed by the least significant difference test (p < 0.05). CK = ungrafted, 19018 = Fengshengjiaowang grafted with 190-1-8, RS2 = Fengshengjiaowang grafted with RS-2, RS5 = Fengshengjiaowang grafted with RS-5, QQ = Fengshengjiaowang grafted with Qinjing, WT = Fengshengjiaowang grafted with wild tomato. The same as following figures.

3.2. Effect of grafting treatment on leaf Gs

Among the six treatments, the leaf Gs under treatment ungrafted reached the lowest (Figure 2). The leaf Pn for the treatments of Fengshengjiaowang grafted with 190-1-8, Fengshengjiaowang grafted with RS-2, Fengshengjiaowang grafted with Qinjing, and Fengshengjiaowang grafted with wild tomato were significantly higher than ungrafted, with 56.90% (p < 0.05), 26.77% (p < 0.05), 28.37% (p < 0.05) and 27.43% (p < 0.05) increase, respectively. However, there was no significant difference between the Fengshengjiaowang grafted with RS-5, and the control treatment.
3.3. Effect of grafting treatment on leaf Ci
Among the six treatments, the leaf Ci under treatment Fengshengjiaowang grafted with RS-5 reached the lowest (Figure 3). The leaf Ci for the treatments of Fengshengjiaowang grafted with 190-1-8, Fengshengjiaowang grafted with RS-2, Fengshengjiaowang grafted with RS-5, Fengshengjiaowang grafted with Qinqing, and Fengshengjiaowang grafted with wild tomato were significantly lower than ungrafted, with 11.81% ($p < 0.05$), 15.12% ($p < 0.05$), 27.50% ($p < 0.05$), 13.66% ($p < 0.05$) and 24.25% ($p < 0.05$) decrease, respectively. Significant differences were shown between treatments.

3.4. Effect of grafting treatment on leaf Tr
Among the six treatments, the leaf Tr under treatment ungrafted reached the lowest (Figure 4). The leaf Tr for the treatments of Fengshengjiaowang grafted with 190-1-8, Fengshengjiaowang grafted with RS-2, Fengshengjiaowang grafted with RS-5, Fengshengjiaowang grafted with Qinqing and Fengshengjiaowang grafted with wild tomato were significantly higher than ungrafted, with 49.43% ($p < 0.05$), 57.61% ($p < 0.05$), 46.76% ($p < 0.05$), 51.91% ($p < 0.05$) and 56.31% ($p < 0.05$) increase, respectively. Significant differences were shown between treatments.

3.5. Effect of grafting treatment on leaf Vpdl
Among the six treatments, the leaf Vpdl under treatment Fengshengjiaowang grafted with 190-1-8 reached the lowest (Figure 5). The leaf Vpdl for the treatments of Fengshengjiaowang grafted with RS-2, Fengshengjiaowang grafted with RS-5, Fengshengjiaowang grafted with Qinqing and Fengshengjiaowang grafted with wild tomato were significantly higher than ungrafted, with 32.66% ($p < 0.05$), 50.07% ($p < 0.05$), 25.20% ($p < 0.05$) and 22.41% ($p < 0.05$) increase, respectively. Significant differences were shown between treatments.
4. Conclusions
The experiment showed that the seedlings of Fengshengjiaowang grafted with 190-1-8, RS-2, RS-5, Qinqing and wild tomato had different effects on leaf photosynthesis after grafting treatments and significant differences were shown between treatments. Among the six treatments, the leaf Pn, leaf Gs and leaf Tr under treatment ungrafted reached the lowest. The leaf Pn and leaf Tr significantly higher than ungrafted, which were increased by 56.90%, 26.77%, 28.37%, 27.43% and 49.43%, 57.61%, 46.76%, 51.91%, 56.31%, respectively. The leaf Vpdl under treatment Fengshengjiaowang grafted with 190-1-8 reached the lowest, and the leaf Ci under treatment Fengshengjiaowang grafted with RS-5 reached the lowest. The leaf Ci for the treatments of Fengshengjiaowang grafted with 190-1-8, RS-2, RS-5, Qinqing, and wild tomato were significantly lower than ungrafted, with 11.81%, 15.12%, 27.50%, 13.66% and 24.25% decrease, respectively. The leaf Vpdl for the treatments of Fengshengjiaowang grafted with RS-2, RS-5, Qinqing and wild tomato were significantly higher than ungrafted, with 32.66%, 50.07%, 25.20% and 22.41% increase, respectively. In conclusion, grafting will affect the leaf photosynthesis of Se content by Fengshengjiaowang grafted with 190-1-8, RS-2, RS-5, Qinqing, wild tomato and in terms of Pn the treatment of Fengshengjiaowang grafted with wild tomato is the best.

Acknowledgments
This work was financially supported by the Project of National Large Vegetable Industry Technology System (CARS-23-G-34); Sichuan Innovation Team of National Modern Agricultural Industry Technology System (2019-2023); “13th Five-Year” Breeding Project of Sichuan Province (2016NZ0033); Special Project of Chengdu Science and Technology Bureau in 2019.

References
[1] Deffuant, C., Celerier, P., Boiteau, H.L. (1994) Serum selenium in melanoma and epidermotropic cutaneous T-cell lymphoma. Acta Derm. Venereol., 74: 90-92.
[2] Clark, L.C., Jr, C.G., Turnbull, B.W. (1996) Effects of selenium supplementation for cancer prevention in patients with carcinoma of the skin. A randomized controlled trial. Nutritional Prevention of Cancer Study Group. Jama, 276: 1957-1963.
[3] Mo, H.Z., Zhu, Y., Zhang, M. (2006) Selenium enrichment pattern in flowering Chinese cabbage, cabbage and asparagus. Agro Food Ind. Hi Tech, 17: 39-42.
[4] Xue, T., Hartikainen, H., Piironen, V. (2001) Antioxidative and growth-promoting effect of selenium on senescing lettuce. Plant and Soil, 237: 55-61.
[5] Pan, S.K., Lu, R.H., Xiang, J. (2018) Effects of different concentrations of selenium on physiological characteristics and selenium enrichment of eggplant seedlings. Northern Hort., 2018: 13-18.
[6] Lu S.F. Grafting at organ, tissue, and cell levels. (1994) J. of Bot., 6: 23-23.
[7] Zhang, Z.K., Liu, S.Q., Zhang, Q. (2009) Effects of NaCl stress on physiological and biochemical indexes of grafted cucumber seedlings on different rootstocks. China Veget., 1: 33-38.
[8] Aloni, B., Cohen, R., Karni, L. Hormonal signaling in rootstock-scion interactions. (2010) Sci. Hort., 127: 119-126.
[9] Zhang, K., Sun, Z.M., Liu, J.T. (2013) Comparison of nutrient absorption characteristics of different radish varieties in Bashang region in northwest Hebei. Plant Nutr. Fert. Sci., 19: 191-199.
[10] Zhang, X., Zhang, F., Wang, J., Lin, L., Liao, M., Tang, Y., Sun, G., Wang, X., Lv, X., Deng, Q., Chen, C., Ren, W. (2019) Cutting after grafting affects the growth and cadmium accumulation of Nasturtium officinale. Environ. Sci. Pollut. Res., 26: 15436-15442.
[11] Yao, H., Zhang, F., Qing, M., Chen, M., Lu, Z., Zhang, Q., Lin, L., Liao, M., Chen, S., Huang, Z., Chen, C., Ren, W. (2019) Effects of mutual grafting on the cadmium accumulation characteristics of two ecotypes of Solanum photeinocarpum. Int. J. Phytoremediation, 21: 503-508.
[12] Liu, Q., Huo, R., Lin, L., Liao, M., Wang, J., Tang, Y., Liang, D., Xia, H., Wang, X., Lv, X., Jiang, W., Ren, W. (2019) Effects of different rootstocks on cadmium accumulation of grafted Cyphomandra betacea seedlings. Int. J. Environ. An. Ch., 99: 1247-1254.