Effects of continuous grafting on nutrient absorption of cutting seedlings of *Nasturtium officinale*

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Abstract. A pot experiment was conducted to study the effects of continuous grafting on nutrient absorption of cutting seedlings of *Nasturtium officinale*. The result showed that the N content of root, stem, leaf and shoot of *N. officinale* of one time grafting could significantly improve compared with the ungrafted. The content P and K of stem, leaf and shoot of *N. officinale* of one time grafting could significantly improve the content of P and K compared with the ungrafted. And N, P and K content in different parts of *N. officinale* of two times grafting and three times grafting was lower than the ungrafted. Therefore, the stem, leaf and shoot of *N. officinale* of one time grafting could significantly improve the nutrient absorption of cutting seedlings of *N. officinale*.

1. Introduction

Grafting is generally acknowledged to have a long history. Citrus grafting has been recorded in the ancient document Shangshu Yugong Bibliography, about 3000 years ago in China [1]. The main utilization of vegetable grafting is the improvement of vegetable crops by grafting. For example, grafting can enhance the disease resistance, drought resistance, salt tolerance of vegetable crops and improve the absorption function of roots to achieve early maturity, increase yield and increase income [2-4]. At the same time, it also changed the absorption characteristics of plant roots. Therefore, it is bound to affect its absorption and distribution of mineral elements [5]. The study found that the ability of nitrogen and potassium uptake by grafted melon seedlings was higher than that of self-rooted seedlings, but the phosphorus uptake by grafted melon seedlings was lower than that of self-rooted seedlings [6]. The study found that the contents of N, P, Ca and Mg in root bleeding fluid of grafted watermelon seedlings were significantly higher than those of self-rooted seedlings [7]. The study also confirmed that cucumber grafting could improve root dry weight and uptake of nitrogen, phosphorus and potassium [8].

Wild vegetable has high nutritional value, and has become popular food at home and abroad [10]. In recent years, the study of wild vegetable resources has developed and been paid more attention by scholars [11]. *Nasturtium officinale* is a perennial cruciferous emergent plant, which is also a wild vegetable and widely distributed in Europe, Asia and North America [12]. Therefore, this study investigated the effects of continuous grafting on nutrient absorption of cutting seedlings of *N. officinale* then to screen the most suitable number of grafting that can increase the nutrient absorption of cutting seedlings of *N. officinale*. 
2. Materials and methods

2.1. Materials
The soil samples used in the experiment were paddy soils that were collected from the Chengdu Campus Farm of the Sichuan Agricultural University (30°71′N, 103°86′E). The basic soil properties were pH 7.42, organic matter 31.73 g/kg, total nitrogen (N) 1.05 g/kg, total phosphorus (P) 0.37 g/kg, total potassium (K) 25.71 g/kg, alkali-hydrolysable N 56.13 mg/kg, available P 17.15 mg/kg, available K 56.65 mg/kg, total Se 0.35 mg/kg. The tested plant is *N. officinale*, potted in the greenhouse of Chengdu Campus of Sichuan Agricultural University. The plant is robust, free from selenium pollution and pests and diseases. *Brassica oleracea* plants were selected as test rootstocks.

From September 2017 to January 2018, *B. oleracea* rootstocks were prepared and *N. officinale* was grafted. Rootstocks were raised every two weeks from September to December 2017 to ensure the same growth of rootstocks for each grafting. Grafting treatment can be divided into three periods: the first period: *B. oleracea* rootstocks were transplanted and grafted the stem tips of 2 cm long of *N. officinale*, which is one time grafting. The second period: 30 days after the first period of grafting survived the *B. oleracea* rootstocks were transplanted and grafted with the stem tips of 2 cm long of *N. officinale* of one time grafting. After the survival, the *N. officinale* was two times grafting. The third period: 30 days after the second period of grafting survived, the *B. oleracea* rootstocks were transplanted and grafted with the stem tips of 2 cm long of two times grafting. After the survival, the *N. officinale* was three times grafting. Thirty days after the third period of grafting, the growth of ungrafted (control), one time grafted, two times grafted and three times grafted were the same, and about 5 cm long branches of *N. officinale* were selected as experimental cutting materials.

2.2. Experimental design
The experiment was conducted from January, 2018 to April, 2018 in the Chengdu Campus of Sichuan Agricultural University. Air-dried soil (3.0 kg) was weighed and placed into each polyethylene pot (11 cm high, 22 cm diameter) in January 2018. Se was added to the soil samples as analytical reagent Na2SeO3 at the concentration of 10 mg/kg. The soils were soaked in the Se solution for 4 weeks, and then the soil in each pot was mixed thoroughly again. In February 2018, the ungrafted and grafted branches of *N. officinale* were cut into pots. There were four treatments in this experiment: ungrafted, one time grafting, two times grafting and three times grafting. Three plants were planted in each pot, and each treatment was repeated six times. The distance between pots was 15 cm, and the pot position exchanged periodically to weaken the impact of the marginal effects. The soil moisture content was maintained at 80% of field capacity until the plants were harvested. After 60 days, the whole plant was harvested and separated from the root, stem and leaf, washed and dried, weighed and crushed, which was used to determine the nitrogen content, phosphorus content and potassium content in various parts of *N. officinale* [12].

2.3. Statistical analyses
Statistical analysis was carried out by using SPSS 18.0 statistical software. The data were analyzed by one-way ANOVA, with the least significant difference at the 5% confidence level.

3. Results and discussion

3.1. Effects of prior grafting with different numbers on N content of *N. officinale* cuttings
The N content of root, leaf and shoot of *N. officinale* of one time grafting were significant differences compared with the ungrafted, and the content N of root, leaf and shoot of *N. officinale* of one-time grafting were increased by 18.4 %, 17% and 15.64% compared with the ungrafted, respectively. However, the content of stem of *N. officinale* of one time grafting was no significant difference compared with the ungrafted. The N content of root, stem, leaf and shoot of *N. officinale* of two times grafting were...
grafting was lower than that of the ungrafted. The N content in different parts of *N. officinale* of two times grafting was the lowest among the four treatments.

| Number of grafts | Root (mg/g) | Stem (mg/g) | Leaf (mg/g) | Shoot (mg/g) |
|------------------|-------------|-------------|-------------|--------------|
| Ungrafted        | 18.04±1.59b | 14.23±0.94a | 22.76±1.76c | 18.93±1.29b  |
| One time Grafting | 21.36±1.53a | 15.23±1.17a | 26.63±1.40b | 21.89±1.18a  |
| Two times grafting| 14.87±0.92c | 8.53±0.49c  | 20.26±0.91d | 14.36±0.65c  |
| Three times grafting | 17.50±0.79b | 12.25±0.92b | 30.98±1.77a | 21.35±1.23a  |

Values are means ± standard errors. Means with the same letter within each column are not significantly different at *p* < 0.05.

### 3.2. Effects of prior grafting with different numbers on P content of *N. officinale* cuttings

Prior grafting with different numbers on P content of *N. officinale* cuttings from large to small is: ungrafted > one time grafting > two times grafting > three times grafting. The P content of stem and leaf of *N. officinale* of one time grafting were higher than the ungrafted. On the contrary, the P content of stem and leaf of *N. officinale* of two times grafted and three times grafting were lower than the ungrafted. The P content of shoot of *N. officinale* of ungrafted and one time grafting was higher than two times grafting and three times grafting.

| Number of grafts | Root (mg/g) | Stem (mg/g) | Leaf (mg/g) | Shoot (mg/g) |
|------------------|-------------|-------------|-------------|--------------|
| Ungrafted        | 6.25±0.31a  | 16.18±1.63b | 5.31±0.41b  | 10.19±1.02a  |
| One time grafting | 5.76±0.19b  | 17.65±0.93a | 6.08±0.37a  | 10.89±0.50a  |
| Two times grafting| 4.33±0.24c  | 8.97±0.46c  | 4.13±0.31c  | 6.56±0.34b  |
| Three times grafting | 3.38±0.19d  | 9.72±0.72c  | 3.86±0.40c  | 6.87±0.54b  |

Values are means ± standard errors. Means with the same letter within each column are not significantly different at *p* < 0.05.

### 3.3. Effects of prior grafting with different numbers on K content of *N. officinale* cuttings

The K content of stem, leaf and shoot of *N. officinale* of one time grafting were significant differences compared with the ungrafted, and the K content of stem, leaf and shoot of *N. officinale* of one time grafting were increased by 8%, 15.67% and 9.3% compared with the ungrafted, respectively. However, the K content of root of *N. officinale* of one time grafting was no significant difference compared with the ungrafted. The K content of root, stem, leaf and shoot of *N. officinale* of two times grafting and three times grafting was lower than that of the ungrafted. And K content in different parts of *N. officinale* of three times grafting was the lowest among the four treatments.

| Number of grafts | Root (mg/g) | Stem (mg/g) | Leaf (mg/g) | Shoot (mg/g) |
|------------------|-------------|-------------|-------------|--------------|
| Ungrafted        | 32.45±1.33a | 43.90±2.85b | 24.89±1.82b | 33.43±1.01b  |
| One time grafting | 31.38±1.61a | 47.41±3.24a | 28.79±1.68a | 36.53±2.13a  |
| Two times grafting| 16.36±0.80b | 31.50±1.79c | 20.55±0.95c | 26.06±1.14c  |
| Three times grafting | 14.81±0.93c | 31.45±1.56c | 19.21±1.18c | 25.50±1.28c  |

Values are means ± standard errors. Means with the same letter within each column are not significantly different at *p* < 0.05.
4. Conclusions
According to the experiment, the N content of root, stem, leaf and shoot of *N. officinale* of one-time grafting could significantly increase compared with the ungrafted. The P and K content of stem, leaf and shoot of *N. officinale* of one time grafting could significantly improve compared with the ungrafted. And N, P and K content in different parts of *N. officinale* of two times grafting and three times grafting was lower than the ungrafted. Therefore, the stem, leaf and shoot of *N. officinale* of one time grafting could significantly improve the nutrient absorption of cutting seedlings of *N. officinale*.

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