Effects of Rape Rootstock on Nutrient Uptake and Soil Enzyme Activity of Post-Grafting Generation of *Capsella bursa-pastoris* under Cd Stress

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Abstract. The effects of rape rootstock on phosphorus (P) and potassium (K) uptake and soil enzyme activity of post-grafting generation of *Capsella bursa-pastoris* under cadmium (Cd) stress was investigated through two pot experiments. Three treatments were used in the experiment: ungrafted (UG), post generation of self-rooted grafting by the two *C. bursa-pastoris* seedling (PSG) and post generation of grafting on the rootstock of rape (PRG). In high and low soil Cd concentration experiments, the grafting increased P and K contents in roots and shoots of post-grafting generation plants of *C. bursa-pastoris* compared with UG under Cd stress. The P and K contents in plants were ranked as PRG > PSG > UG. In two experiments, the soil available P and K contents were increased by post-grafting generation of *C. bursa-pastoris*, which were ranked as: PRG > PSG > UG. The post-grafting generation of *C. bursa-pastoris* enhanced soil sucrase and soil catalase activities in two experiments. The soil urease activity of PSG enhanced compared with UG, but the soil urease activity of PRG decreased. Therefore, grafting could used to increase nutrient content and enhance soil enzyme activity in post generation of *C. bursa-pastoris* for the phytoremediation of Cd.

Introduction

The grafting is a method of plant propagation that is widely used in horticulture, and has played a significant role on improving the yield and quality of fruit and vegetable [1]. The study of Edelstein and Ben-Hur shows that the boron, zinc, strontium, manganese, copper, titanium, chromium, nickel and cadmium (Cd) contents in grafting watermelon fruit are lower than ungrafted watermelon [2]. The grafting increases the nitrogen, phosphorus and potassium content in cucumber seedlings compared with ungrafted seedlings [3]. Therefore, the grafting could regulate nutrient uptake of plant.

Capsella bursa-pastoris is a winter Cd-accumulator plant with small biomass, and the phytoremediation efficiency of Cd is low [4]. In this paper, we used rape as stock to graft *C. bursa-pastoris,* and collected seeds and grew in Cd-contaminated soil. The aim of this paper was to study the effects of rape rootstock on phosphorus (P) and potassium (K) uptake and soil enzyme activity of post-grafting generation plants of *C. bursa-pastoris* under Cd stress.

Materials and Methods

Materials. The *C. bursa-pastoris* seeds were colleted from Ya'an campus farm of the Sichuan Agricultural University (29°59′N, 102°59′E), China, in December 2012, and directly were sown in soil of plastic pots. When the *C. bursa-pastoris* seedlings grew at the bolting stage, the grafting was conducted. There were three grafting treatments in the experiment. (1) ungrafted (UG): *C. bursa-pastoris* seedlings remained untreated. (2) Self-rooted grafting by two different sizes of *C. bursa-pastoris* seedlings (SG): The scion and rootstock were from two different growth stages of *C. bursa-pastoris* seedlings. The lower part of *C. bursa-pastoris* seedlings with heights of 3 cm (5 cm for the whole plant), were the rootstocks. The scions were the upper parts (2 cm) of *C. bursa-pastoris* seedlings with 5 cm of whole plant. (3) Grafting on rootstock of Rape (RG): The lower part of the rape seedlings with heights of 5 cm were the rootstocks, and the upper parts of the *C. bursa-pastoris* seedlings, with heights of 2 cm, were the scions. When the 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, the shade net and the plastic binding films were removed, and all the germinating buds of rootstocks were also removed.

High soil Cd concentration experiment. The high soil Cd concentration experiment was conducted at the Ya'an campus farm from August to October 2013. The non-contaminated purple soil samples were collected from the Ya'an campus farm. The basic properties of the soil were the same as reference [5]. 3.0 kg of soil was weighed into each polyethylene pot (15 cm tall, 18 cm diameter). Cd was added to make a final soil Cd concentration of 50 mg/kg with a saturated heavy metal solution in the form of $CdCl_2 \cdot 2.5H_2O$. The soils were mixed immediately and again after 4 weeks, during which time soil moisture was maintained at 80%. The seeds of different rootstock post-grafting *C. bursa-pastoris* plants were sown separately in the farmland of the Ya'an campus farm (non-contaminated area). When the seedlings grew two expanded euphyllas, four uniformly prepared *C. bursa-pastoris* seedlings from each rootstock treatment were transplanted into each pot. There were three treatments in the experiment: UG, post-grafting generation of SG (PSG), and post-grafting generation of RG (PRG). Each treatment was repeated three times with 10-cm spacing between pots. After *C. bursa-pastoris* matured (35 d), plants were harvested for determining contents of total P and K in roots and shoots [6]. The soil samples were collected for determining soil available P and K contents [6] and soil enzyme activity [7].

Low soil Cd concentration experiment. The low soil Cd concentration experiment was conducted at the Ya'an campus farm from August to October 2013. The purple soil samples came from the cadmium contaminated soils in the earlier experiment of the Ya'an campus Farm. The basic properties of the soil were the same as reference [8]. The cultivation and management of *C. bursa-pastoris* seedlings were as described in the high soil Cd concentration experiment. After *C. bursa-pastoris* matured (35 d) plants were harvested. The plants and soils were processed as described in the high soil Cd concentration experiment.

Statistical Analyses. Statistical analyses were performed using SPSS 13.0 statistical software (IBM, Chicago, IL, USA). Data were analyzed by one-way analysis of variance with least significant difference at a 5% confidence level.

Results and Discussion

Total P content in plant. In high soil Cd concentration experiment, grafting increased the total P content in post-grafting generation plants of *C. bursa-pastoris* (Table 1). Compared with UG, the total P contents in roots of PSG and PRG increased by 6.91% ($p > 0.05$) and 15.47% ($p < 0.05$) respectively, and increased by 11.83% ($p > 0.05$) and 16.86% ($p < 0.05$) respectively in shoots of PSG and PRG. In low soil Cd concentration experiment, grafting also increased the total P content in post-grafting generation plants of *C. bursa-pastoris* (Table 1). The total P contents in roots of PSG and PRG increased by 3.08% ($p > 0.05$) and 24.66% ($p < 0.05$) respectively, and increased by 2.07% ($p > 0.05$) and 6.90% ($p > 0.05$) respectively in shoots of PSG and PRG compared with UG. So, grafting could increase P uptake in *C. bursa-pastoris*, and the rape stock was the best.

Total K content in plant. The same as total P content in plants, the total K content in post-grafting generation of *C. bursa-pastoris* was increased by grafting (Table 2). In high soil Cd concentration experiment, the total K contents in roots of PSG and PRG increased by 64.29% ($p < 0.05$) and 72.73% ($p < 0.05$) respectively compared with UG, and the total K contents in shoots increased by 28.92% ($p < 0.05$) and 33.98% ($p < 0.05$) respectively compared with UG. In low soil Cd concentration experiment, the total K contents in roots of PSG and PRG increased by 17.99% ($p < 0.05$) and 27.51% ($p < 0.05$) respectively compared with UG, and the total K contents in shoots increased by 27.68% (*p*

< 0.05) and 32.92% (p < 0.05) respectively compared with UG. So, grafting could also increase P uptake in *C. bursa-pastoris*, and the rape stock was the best, which was beneficial to the growth of *C. bursa-pastoris*.

Table 1 Total P content in *C. bursa-pastoris* in two experiments

Treatments	High soil Cd concentration experiment		Low soil Cd concentration experiment	
	Roots (g/kg)	Shoots (g/kg)	Roots (g/kg)	Shoots (g/kg)
UG	3.62±0.13b	3.38±0.11b	2.92±0.10b	2.90±0.11a
PSG	3.87±0.17ab	3.78±0.16ab	3.01±0.08b	2.96±0.13a
PRG	4.18±0.11a	3.95±0.15a	3.64±0.06a	3.10±0.14a

Table 2 Total K content in *C. bursa-pastoris* in two experiments

Treatments	High soil Cd concentration experiment		Low soil Cd concentration experiment	
	Roots (g/kg)	Shoots (g/kg)	Roots (g/kg)	Shoots (g/kg)
UG	3.08±0.08b	4.15±0.14b	3.89±0.10c	4.01±0.13b
PSG	5.06±0.20a	5.35±0.11a	4.59±0.08b	5.12±0.17a
PRG	5.32±0.10a	5.56±0.20a	4.96±0.06a	5.33±0.18a

Soil available P and K contents in high soil Cd concentration experiment. In high soil Cd concentration experiment, the soil available P content was increased by post-grafting generation of *C. bursa-pastoris* (Table 3). The soil available P content was ranked as: PRG > PSG > UG. Compared with UG, the soil available P contents of PSG and PRG increased by 7.25% (p > 0.05) and 22.54% (p < 0.05) respectively. The soil available K content was also increased by post-grafting generation of *C. bursa-pastoris* in high soil Cd concentration experiment (Table 3). The soil available K content was ranked as: PRG > PSG > UG. The soil available K contents of PSG and PRG increased by 2.73% (p > 0.05) and 4.89% (p < 0.05) respectively compared with UG. Therefore, the post-grafting generation of *C. bursa-pastoris* enhanced the use efficiency of soil available P and K, and could promote the growth of *C. bursa-pastoris* which could enhance the phytoremediation ability of *C. bursa-pastoris*.

Soil enzyme activity in high soil Cd concentration experiment. The post-grafting generation of *C. bursa-pastoris* enhanced soil sucrase and soil catalase activities in high soil Cd concentration experiment (Table 3). The soil sucrase and soil catalase activities were ranked as: PRG > PSG > UG. Compared with UG, the soil sucrase activities of PSG and PRG enhanced by 65.72% (p < 0.05) and 112.29% (p < 0.05) respectively, and soil catalase activities of that enhanced by 1.44% (p > 0.05) and 8.61% (p > 0.05) respectively. The soil urease activity of PSG enhanced compared with UG, but the soil urease activity of PRG decreased, which might be related to the characteristics of soil enzyme.

Table 3 Soil nutrient content and soil enzyme activity in high soil Cd concentration experiment

Treatments	Soil available P (mg/kg)	Soil available K (mg/kg)	Soil sucrase activity (mg/g)	Soil urease activity (mg/g)	Soil catalase activity (ml/g)
UG	3.86±0.11b	119.22±1.10b	0.423±0.020c	0.408±0.016b	0.209±0.019a
PSG	4.14±0.07b	122.48±2.15ab	0.701±0.081b	0.490±0.012a	0.212±0.007a
PRG	4.73±0.15a	125.05±1.34a	0.898±0.044a	0.256±0.009c	0.227±0.016a

Soil available P and K contents in low soil Cd concentration experiment. The same as in high soil Cd concentration experiment, the soil available P content was also increased by post-grafting generation of *C. bursa-pastoris* in low soil Cd concentration experiment, and the soil available P content was ranked as: PRG > PSG > UG (Table 4). The soil available K content was also increased by post-grafting generation of *C. bursa-pastoris* in low soil Cd concentration experiment, and the soil available P content was ranked as: PRG > PSG > UG (Table 4).

Soil enzyme activity in low soil Cd concentration experiment. The post-grafting generation of *C. bursa-pastoris* enhanced soil sucrase and soil catalase activities in low soil Cd concentration experiment (Table 4), which was the same as in high soil Cd concentration experiment. However, the PSG enhanced soil urease activity compared with UG, but PRG decreased that (Table 4). Overall, the grafting could enhance the soil enzyme activity, which was benefit for the growth of plant roots.

Table 4 Soil nutrient content and soil enzyme activity in low soil Cd concentration experiment

Treatments	Soil available P (mg/kg)	Soil available K (mg/kg)	Soil sucrase activity (mg/g)	Soil urease activity (mg/g)	Soil catalase activity (ml/g)
UG	3.22±0.10c	118.17±2.59a	1.173±0.146b	0.289±0.014a	0.217±0.004a
PSG	3.83±0.14b	121.32±2.38a	1.420±0.128b	0.357±0.065a	0.223±0.017a
PRG	4.46±0.06a	124.10±1.27a	1.874±0.126a	0.276±0.006a	0.232±0.012a

Conclusions

In high and low soil Cd concentration experiments, the grafting increased P and K contents in roots and shoots of post-grafting generation plants of *C. bursa-pastoris* compared with UG under Cd stress. The P and K contents in plants were ranked as PRG > PSG > UG. In two experiments, the soil available P and K contents were increased by post-grafting generation of *C. bursa-pastoris*, which were ranked as: PRG > PSG > UG. The post-grafting generation of *C. bursa-pastoris* enhanced soil sucrase and soil catalase activities in two experiments. The soil urease activity of PSG enhanced compared with UG, but the soil urease activity of PRG decreased. Therefore, grafting could used to increase nutrient content and enhance soil enzyme activity in post generation of *C. bursa-pastoris* under Cd stress.

References

[1] G.L. Chen and C.L. Nie: *Vegetable Grafting Cultivation Techniques* (Jindun Press, Beijing 2005).

[2] M. Edelstein and M. Ben-Hur, in: Proceedings of the International Symposium on Water Resources Management, edited by J. Wilson, Honolulu, Hawaii, USA (2007).

[3] Y. Sun, W. Huang, X.H. Tian, Y. Wu, Q. Ding and C.T. Zhou: Plant Nutrition and Fertilizer Science Vol. 8 (2002), P. 181.

[4] Y. Liu, L. Lin, Q. Jin and X. Zhu: Environmental Progress & Sustainable Energy Vol. 34 (2015), p. 663.

[5] L.J. Lin, Q. Jin, Y.J. Liu, B. Ning, M.A. Liao and L. Luo: Environ. Toxicol. Chem. Vol. 33 (2014), P. 2422.

[6] S.D. Bao: *Agrochemical Soil Analysis* (3rd edition, China Agriculture Press, Beijing 2000).

[7] L.K. Zhou: *Soil Enzymology* (Science Press, Beijing 1987).

[8] L. Lin, Q. Liu, J. Shi, J. Sun, M. Liao and L. Mei: Environ. Toxicol. Chem. Vol. 33 (2014), p. 1950.