Mulching Tolerant Plant Straw on Cd-Contaminated Soil Surface Can Enhance Nutrient Uptake in *Capsella bursa-pastoris*

Jin Wang[1,a], Jun Shi[2,b], Shuting Yang[1,c] and Xiulan Lv[3,d]*

[1]College of Horticulture, Sichuan Agricultural University, Chengdu, Sichuan, China

[2]Mianyang Academy of Agricultural Sciences, Mianyang, Sichuan, China

[3]Institute of Pomology and Olericulture, Sichuan Agricultural University, Chengdu, Sichuan, China

[a]wangjin2510@126.com, [b]tibm@163.com, [c]1250530881@qq.com, [d]xllvjj@163.com

*Corresponding author

Keywords: Tolerant plant straw; Cadmium contamination; *Capsella bursa-pastoris*; Nutrient; Soil enzyme activity

Abstract. The effects of tolerant plants (*Ranunculus sieboldii*, *Mazus japonicus*, *Clinopodium confine* and *Plantago asiatica*) straws on nutrient uptake in Cd-accumulator *Capsella bursa-pastoris* were investigated through pot experiment under Cd-contaminated soil condition. Five treatments were used in the experiment: not mulched with straw (control), mulched with *R. sieboldii* straw, mulched with *M. japonicus* straw, mulched with *C. confine* straw, and mulched with *P. asiatica* straw. Mulching with four tolerant plant species straws on Cd-contaminated soil surface increased phosphorus (P) and potassium (K) contents in roots and shoots of *C. bursa-pastoris* compared with control. The P and K contents in plants were ranked as *P. asiatica* straw > *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > control. The soil available P and K contents were increased by tolerant plant straw, which were ranked as: *P. asiatica* straw > *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > control. Mulching with four tolerant plant species straws also enhanced soil sucrase, urease and catalase activities. Therefore, Mulching with tolerant plant straw could used to increase nutrient content and enhance soil enzyme activity in *C. bursa-pastoris* for the phytoremediation of Cd, and the *P. asiatica* straw was the best.

Introduction

In agricultural production, mulching straw on soil surface is a commonly used technique. Mulching straw can increase the organic matter and other nutrients that from plant straw [1]. So, mulching straw promotes crop plant growth, and improves yield and quality of crop plant [2]. When the straw decays and decomposes, the nutrient in the straw would be released into soil, which can affect soil nutrient availability, soil enzyme activity, microbial population structure, and plant growth [3]. If plant straw was applied to heavy metal-contaminated soil, the straw may regulate hyperaccumulator or accumulator growth and heavy metal accumulation.

Ranunculus sieboldii, *Mazus japonicus*, *Clinopodium confine* and *Plantago asiatica* are Cd-tolerant plants [4]. In this study, we grew seedlings of the Cd-accumulator *Capsella bursa-pastoris* [5] in Cd-contaminated soil. Shoots of the above-mentioned Cd-tolerant species were applied as mulches on the soil surface to screen their efficiency at promoting the nutrient uptake and soil enzyme activity of *C. bursa-pastoris*, and to provide reference for improvement in the phytoremediation ability of *C. bursa-pastoris*.

Materials and Methods

Materials. The shoots of *Ranunculus sieboldii*, *Mazus japonicus*, *Clinopodium confine* and *Plantago asiatica* were collected from the Ya'an campus farm of the Sichuan Agricultural University (29° 59′ N, 102° 59′ E), China, in August 2013, at sites where the soil was not contaminated by heavy metals. The shoots were dried at 80°C to constant weight, then finely ground and sieved through a 5-mm-mesh

© 2015. The authors - Published by Atlantis Press

nylon sieve. *Capsella bursa-pastoris* seedlings with two euphyllas were collected from the Ya'an campus farm at a site not contaminated by heavy metals in September 2013. The inceptisol soil samples were collected from Ya'an campus farm in August 2013. The basic properties of the soil were the same as reference [4].

Experimental Design. The experiment was conducted at the Ya'an campus farm in August–October 2013. The soil samples were air-dried and passed through a 5-mm sieve in August 2013, and then 4.0 kg of the air-dried soil was weighed into each polyethylene pot (15 cm high, 18 cm diameter). Cadmium was added to the soil samples as $CdCl_2 \cdot 2.5\ H_2O$ at 10 mg/kg. The pots were soaked in the Cd solution for 4 weeks, and then the soil in each pot was mixed thoroughly. Five uniform seedlings of *C. bursa-pastoris* were transplanted into each pot, and 6 g shoots of four Cd-tolerant species were applied as mulches on the soil surface in each pot (equivalent to 225 g/m^2). Five treatments were applied: not mulched with straw (control), mulched with *R. sieboldii* straw, mulched with *M. japonicus* straw, mulched with *C. confine* straw, and mulched with *P. asiatica* straw. Each treatment was repeated three times with a completely randomized design with 10-cm spacing between pots. The soil moisture was maintained at 80% of field capacity from when the *C. bursa-pastoris* plants were transplanted until the plants were harvested. At maturity (after 35 d), the entire 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].

Results and Discussion

Total P content in roots of *C. bursa-pastoris*. Mulching with four tolerant plant species straws on Cd-contaminated soil surface increased the total P content in roots of *C. bursa-pastoris* (Fig. 1), which was consistent with other studies, because the P content was quite different in different plant species [3]. The total P content in roots of *C. bursa-pastoris* was ranked as: *P. asiatica* straw > *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > control. Compared with control, mulching with straws of *R. sieboldii*, *M. japonicus*, *C. confine* and *P. asiatica* increased the total P contents in roots of *C. bursa-pastoris* by 27.62% ($p < 0.05$), 31.07% ($p < 0.05$), 42.96% ($p < 0.05$) and 54.43% ($p < 0.05$) respectively.

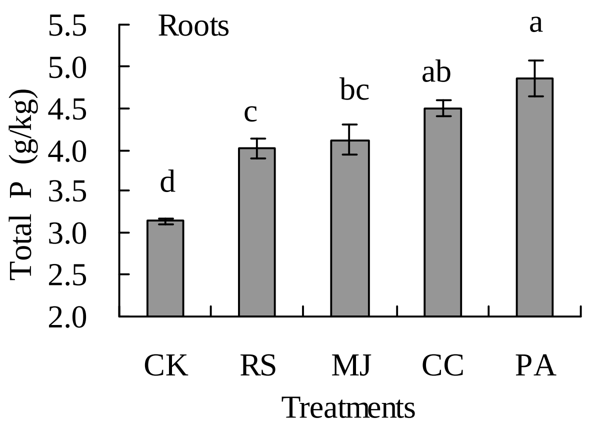

Fig. 1 Total P in roots of *C. bursa-pastoris*. Values are means of three replicate pots. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$). CK = control, RS = *R. sieboldii*, MJ = *M. japonicus*, CC = *C. confine*, PA = *P. asiatica*.

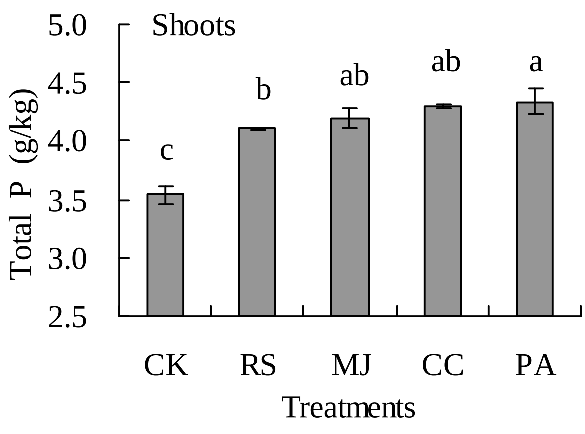

Fig. 2 Total P in shoots of *C. bursa-pastoris*. Values are means of three replicate pots. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$). CK = control, RS = *R. sieboldii*, MJ = *M. japonicus*, CC = *C. confine*, PA = *P. asiatica*.

Total P content in shoots of *C. bursa-pastoris*. Mulching with four tolerant plant species straws on Cd-contaminated soil surface increased the total P content in shoots of *C. bursa-pastoris* (Fig. 2), which was the same as the total P content in roots of *C. bursa-pastoris*. The total P content in shoots of *C. bursa-pastoris* was also ranked as: *P. asiatica* straw > *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > control. Compared with control, mulching with straws of *R. sieboldii*, *M. japonicus*, *C. confine* and *P. asiatica* increased the total P contents in shoots of *C. bursa-pastoris* by 16.09% ($p < 0.05$), 18.69% ($p < 0.05$), 21.51% ($p < 0.05$) and 22.72% ($p < 0.05$) respectively.

Total K content in roots of *C. bursa-pastoris*. Mulching with four tolerant plant species straws on Cd-contaminated soil surface also increased the total K content in roots of *C. bursa-pastoris* (Fig. 3), which was consistent with other studies [3]. The total K content in roots of *C. bursa-pastoris* was ranked as: *P. asiatica* straw > *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > control. Compared with control, mulching with straws of *R. sieboldii*, *M. japonicus*, *C. confine* and *P. asiatica* increased the total K contents in roots of *C. bursa-pastoris* by 27.40% ($p < 0.05$), 48.93% ($p < 0.05$), 58.91% ($p < 0.05$) and 74.82% ($p < 0.05$) respectively.

Total K content in shoots of *C. bursa-pastoris*. Mulching with four tolerant plant species straws on Cd-contaminated soil surface increased the total K content in shoots of *C. bursa-pastoris* (Fig. 4), which was the same as the total K content in roots of *C. bursa-pastoris*. The total K content in shoots of *C. bursa-pastoris* was also ranked as: *P. asiatica* straw > *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > control. Compared with control, mulching with straws of *R. sieboldii*, *M. japonicus*, *C. confine* and *P. asiatica* increased the total K contents in shoots of *C. bursa-pastoris* by 11.69% ($p < 0.05$), 18.88% ($p < 0.05$), 39.78% ($p < 0.05$) and 42.92% ($p < 0.05$) respectively. So, mulching with tolerant plant straw on Cd-contaminated soil surface could efficiency increase K uptake in shoots of *C. bursa-pastoris*, and the *P. asiatica* straw was the best. Because the plant straw contains many nutrients (includes P and K), which are released during the process of straw decay and decomposition and can be absorbed by living plants [8].

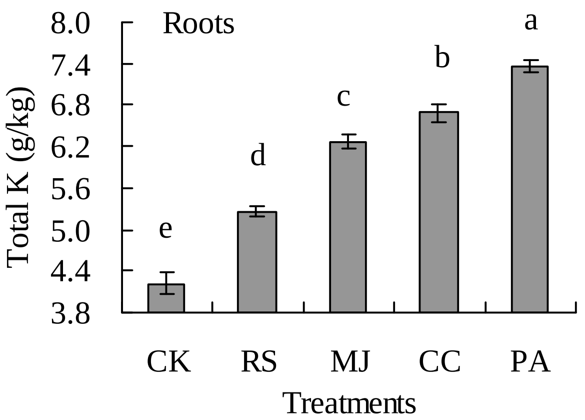

Fig. 3 Total K in roots of *C. bursa-pastoris*. Values are means of three replicate pots. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$). CK = control, RS = *R. sieboldii*, MJ = *M. japonicus*, CC = *C. confine*, PA = *P. asiatica*.

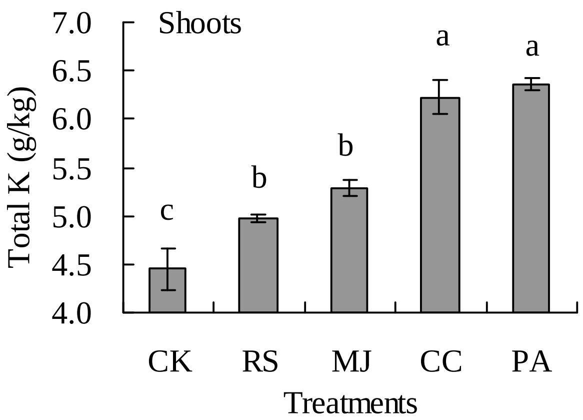

Fig. 4 Total K in shoots of *C. bursa-pastoris*. Values are means of three replicate pots. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$). CK = control, RS = *R. sieboldii*, MJ = *M. japonicus*, CC = *C. confine*, PA = *P. asiatica*.

Soil available P and K contents. The soil available P content was increased by mulching with four tolerant plant species straws (Table 1). The soil available P content was ranked as: *P. asiatica* straw > *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > control. Compared with control, mulching with straws of *R. sieboldii*, *M. japonicus*, *C. confine* and *P. asiatica* increased the soil available P content by 12.10% ($p < 0.05$), 30.34% ($p < 0.05$), 21.85% ($p < 0.05$) and 30.61% ($p < 0.05$) respectively. The soil available K content was also increased by mulching with four tolerant plant species straws (Table 1). The soil available K content was ranked as: *P. asiatica* straw > *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > control. Compared with control, mulching with straws of *R. sieboldii*, *M. japonicus*, *C. confine* and *P. asiatica* increased the soil available K content by 2.61% ($p > 0.05$), 5.23% ($p < 0.05$), 6.74% ($p < 0.05$) and 8.01% ($p < 0.05$) respectively. The increase rate of soil available K content was higher than soil available P content.

Soil enzyme activity. Mulching with four tolerant plant species straws on Cd-contaminated soil surface increased soil enzyme activity (Table 1), which was consistent with other studies [3]. The soil sucrase activity was ranked as: *C. confine* straw > *P. asiatica* straw > *M. japonicus* straw > *R. sieboldii* straw > control, soil urease activity was *C. confine* straw > *M. japonicus* straw > *P. asiatica* straw > *R. sieboldii* straw > control, and soil catalase activity was *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > *P. asiatica* straw > control. These results could be related to the different characteristics of soil enzyme.

Table 1 Soil available P and K contents and soil enzyme activity

Treatments	Soil available phosphorus (mg/kg)	Soil available potassium (mg/kg)	Soil sucrase activity (mg/g)	Soil urease activity (mg/g)	Soil catalase activity (ml/g)
Control	2.901±0.042d	113.04±1.47c	0.164±0.005b	0.308±0.008b	0.174±0.011c
R. sieboldii	3.252±0.073c	115.99±1.40bc	0.178±0.010b	0.317±0.013b	0.259±0.006b
M. japonicus	3.491±0.011b	118.95±1.34ab	0.221±0.009a	0.415±0.011a	0.263±0.010b
C. confine	3.535±0.012b	120.66±0.48a	0.240±0.013a	0.433±0.014a	0.306±0.014a
P. asiatica	3.789±0.048a	122.09±1.29a	0.232±0.011a	0.323±0.007b	0.245±0.006b

Values are means of three replicate pots. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$).

Conclusions

Mulching with four tolerant plants (*Ranunculus sieboldii*, *Mazus japonicus*, *Clinopodium confine* and *Plantago asiatica*) straws on Cd-contaminated soil surface increased P and K contents in roots and shoots of *Capsella bursa-pastoris* compared with control. The P and K contents in plants were ranked as *P. asiatica* straw > *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > control. The soil available P and K contents were increased by tolerant plant straw, which were ranked as: *P. asiatica* straw > *C. confine* straw > *M. japonicus* straw > *R. sieboldii* straw > control. Mulching with four tolerant plant species straws enhanced soil sucrase, urease and catalase activities.

References

[1] H. Zhu, J. Wu, D. Huang, Q. Zhu, S. Liu, Y. Su, W. Wei, J.K. Syers and Y. Li: Plant and Soil Vol. 331 (2010), p. 427.

[2] P.J.A. van Asten, P.M. van Bodegom, L.M. Mulder and M.J. Kropff: Nutr. Cycl. Agroecosys. Vol. 72 (2005), p. 255.

[3] F.A. Einhellig: Agronomy Journal 88 (1996), p. 886.

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

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

[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] A. Whitbread, G. Blair, Y. Konboon, R. Lefroy and K. Naklang: Agr. Ecosyst. Environ. Vol. 100 (2003), p. 251.