Effects of Applying Accumulator Straw in Soil on Nutrient Uptake and Soil Enzyme Activity of *Capsella bursa-pastoris* under Cadmium Stress

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: Accumulator straw; Cadmium stress; *Capsella bursa-pastoris*; Nutrient; Soil enzyme activity

Abstract. The effects of applying four accumulator species (*Conyza canadensis*, *Eclipta prostrate*, *Nasturtium officinale* and *Cardamine hirsute*) straws in cadmium (Cd) contaminated soil on phosphorus (P) and potassium (K) uptake and soil enzyme activity of *Capsella bursa-pastoris* were studied through a pot experiment. Five treatments were used in the experiment: control (no straw applied), and straw applied for each of the four plant species (*C. canadensis*, *E. prostrata*, *N. officinale* and *C. hirsuta*). When applying the four accumulator species straws, the total P and K contents in roots, stems and leaves of *C. bursa-pastoris* increased compared with control. The total P and K contents in roots, stems and leaves of *C. bursa-pastoris* were ranked as: *N. officinale* straw > *C. hirsuta* straw > *C. canadensis* straw > *E. prostrata* straw > control. The soil available P and K contents were also increased by the four accumulator species straws, which were ranked as: *N. officinale* straw > *C. hirsuta* straw > *C. canadensis* straw > *E. prostrata* straw > control. The four accumulator species straws enhanced soil sucrase and soil urease activities, but reduced soil catalase activity. Therefore, applying accumulator straw could used to increase nutrient content and enhance soil enzyme activity of *C. bursa-pastoris* for the phytoremediation of Cd, and the straw of *N. officinale* was the best.

Introduction

The crop straw is an important renewable resource in agricultural production [1]. When apply crop straw in farmland soil, the straw will release organic matter, nitrogen, phosphorus, potassium and other nutrients, which can improve the physical and chemical properties of soil, and promote post crop growth [2]. Soil enzyme plays an important role in soil ecosystem, and also is an important index of soil fertility [3]. *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 applied the straws of Cd-accumulator plants *Conyza canadensis* [5], *Cardamine hirsute* [6], *Eclipta prostrate* [7] and *Nasturtium officinale* [8] into Cd-contaminated soil and planted *C. bursa-pastoris*. The aim of the study was to determine if application of straw from the accumulator species could efficiently promote the nutrient uptake and growth of *C. bursa-pastoris*.

Materials and Methods

Materials. In August 2013, the shoots of *C. canadensis*, *E. prostrata*, *N. officinale* and *C. hirsuta* were collected from the Ya'an campus farm of the Sichuan Agricultural University (29°59′N, 102°59′E), China, from uncontaminated soil areas. The collected shoots of these plants were dried at 80 ℃ to constant weight, finely ground and sieved through a 5-mm-mesh nylon sieve. *Capsella bursa-pastoris* seedlings with two euphyllas were collected from the Ya'an campus farm (from

© 2015. The authors - Published by Atlantis Press

uncontaminated soil) 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 [6].

Experimental Design. The experiment was conducted at the Ya'an campus farm from August to October in 2013. The soil samples were air-dried and passed through a 5-mm sieve. Three kilograms of the air-dried soil was weighed into each polyethylene pot (15 cm high, 18 cm in diameter). Cd was added to soils as $CdCl_2 \cdot 2.5H_2O$ at 50 mg/kg. The pots were soaked in the Cd solutions for 4 weeks, and then the soil in each pot was mixed with the powdered shoots of the studied plants. Six-gram shoots were applied to each pot (2 g shoots per kg soil), and the soil moisture was maintained at 80% of field capacity for 1 week. The five experimental treatments in the experiment were control (no straw applied), and straw applied for each of the four plant species (*C. canadensis*, *E. prostrata*, *N. officinale* and *C. hirsuta*). Each treatment was replicated three times using a completely randomized design with 10-cm spacing between pots. Four uniform seedlings of *C. bursa-pastoris* were transplanted into each pot and the soil moisture content was maintained at 80% of field capacity from the time the plants were transplanted into the pots until the time 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 [9]. The soil samples were collected for determining soil available P and K contents [9] and soil enzyme activity [3].

Results and Discussion

Total P content in *C. bursa-pastoris*. When applying the four accumulator species straws in Cd-contaminated soil, the total P contents in roots, stems and leaves of *C. bursa-pastoris* increased compared with control (Table 1). The total P contents in roots, stems and leaves of *C. bursa-pastoris* were ranked as: *N. officinale* straw > *C. hirsuta* straw > *C. canadensis* straw > *E. prostrata* straw > control. Compared with control, applying straws of *C. canadensis*, *E. prostrata*, *N. officinale* and *C. hirsuta* in soil increased the total P contents in roots of *C. bursa-pastoris* by 5.33% ($p > 0.05$), 5.03% ($p > 0.05$), 7.10% ($p > 0.05$) and 6.21% ($p > 0.05$) respectively, increased by 14.95% ($p < 0.05$), 11.21% ($p < 0.05$), 27.41% ($p < 0.05$) and 16.20% ($p < 0.05$) in stems respectively, and increased by 6.11% ($p < 0.05$), 3.61% ($p < 0.05$), 17.50% ($p < 0.05$) and 15.00% ($p < 0.05$) in leaves respectively.

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

Treatments	Roots (g/kg)	Stems (g/kg)	Leaves (g/kg)
Control	3.38±0.14a	3.21±0.09c	3.60±0.13b
C. canadensis	3.56±0.19a	3.69±0.05b	3.82±0.07b
E. prostrata	3.55±0.13a	3.57±0.10b	3.73±0.04b
N. officinale	3.62±0.06a	4.09±0.06a	4.23±0.11a
C. hirsuta	3.59±0.15a	3.73±0.12b	4.14±0.03a

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 ($p < 0.05$).

Total K content in *C. bursa-pastoris*. The same as total P content in plants, the accumulator straw also increased total K contents in roots, stems and leaves of *C. bursa-pastoris* (Table 2). The total K contents in roots, stems and leaves of *C. bursa-pastoris* were ranked as: *N. officinale* straw > *C. hirsuta* straw > *C. canadensis* straw > *E. prostrata* straw > control. Applying straws of *C. canadensis*, *E. prostrata*, *N. officinale* and *C. hirsuta* increased the total K content in roots of *C. bursa-pastoris* by 7.57% ($p > 0.05$), 3.16% ($p > 0.05$), 13.48% ($p < 0.05$) and 9.08% ($p > 0.05$) respectively. Compared with control, the total K content in stems of *C. bursa-pastoris* was increased by 15.58% ($p > 0.05$), 5.58% ($p > 0.05$), 31.35% ($p < 0.05$) and 24.23% ($p > 0.05$) of *C. canadensis* straw, *E. prostrata* straw, *N. officinale* straw and *C. hirsuta* straw respectively, and increased by 1.70% ($p > 0.05$), 0.97% ($p >

0.05), 11.77% ($p < 0.05$) and 7.89% ($p > 0.05$) of that respectively. So, applying accumulator straw could enhance the P and K uptakes of *C. bursa-pastoris* from Cd-contaminated soil.

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

Treatments	Roots (g/kg)	Stems (g/kg)	Leaves (g/kg)
Control	7.27±0.14b	5.20±0.11d	8.24±0.30c
C. canadensis	7.82±0.31ab	6.01±0.34bc	8.38±0.17bc
E. prostrata	7.50±0.40ab	5.49±0.28cd	8.32±0.16bc
N. officinale	8.25±0.35a	6.83±0.13a	9.21±0.27a
C. hirsuta	7.93±0.10ab	6.46±0.20ab	8.89±0.21ab

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 ($p < 0.05$).

Soil available P content. When applying the four accumulator species straws in Cd-contaminated soil, the soil available P content increased compared with control (Fig. 1). The soil available P content was ranked as: *N. officinale* straw > *C. hirsuta* straw > *C. canadensis* straw > *E. prostrata* straw > control. Compared with control, the soil available P content of applying *C. canadensis* straw, *E. prostrata* straw, *N. officinale* straw and *C. hirsuta* straw increased by 8.40% ($p > 0.05$), 2.28% ($p > 0.05$), 20.54% ($p < 0.05$) and 13.96% ($p < 0.05$) respectively.

Soil available K content. The soil available K content increased compared with control when applying the four accumulator species straws in Cd-contaminated soil (Fig. 2). The soil available K content was also ranked as: *N. officinale* straw > *C. hirsuta* straw > *C. canadensis* straw > *E. prostrata* straw > control. Compared with control, the soil available K content of applying *C. canadensis* straw, *E. prostrata* straw, *N. officinale* straw and *C. hirsuta* straw increased by 3.64% ($p > 0.05$), 0.84% ($p > 0.05$), 15.78% ($p < 0.05$) and 10.62% ($p < 0.05$) respectively.

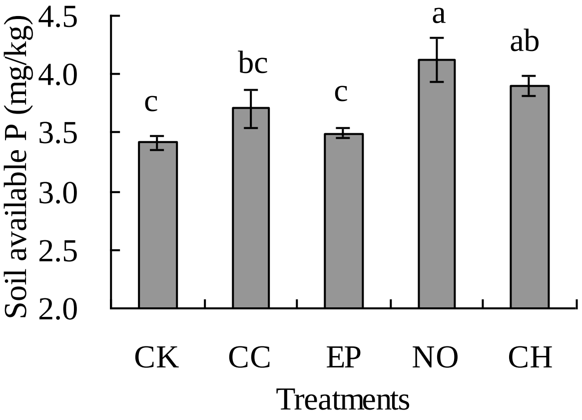

Fig. 1 Soil available K. Values are means of three replicate pots. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$). CK = control, CC = *C. canadensis*, EP = *E. prostrata*, NO = *N. officinale*, CH = *C. hirsuta*.

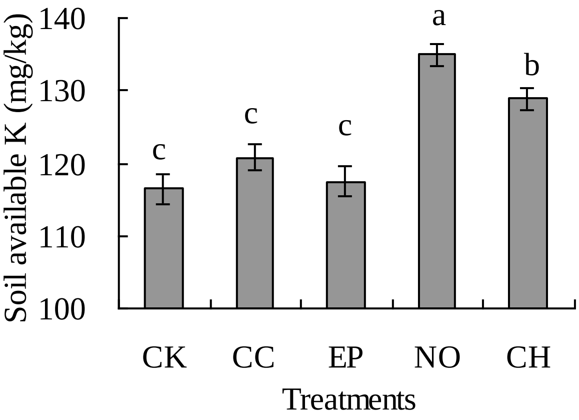

Fig. 2 Soil available K. Values are means of three replicate pots. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$). CK = control, CC = *C. canadensis*, EP = *E. prostrata*, NO = *N. officinale*, CH = *C. hirsuta*.

Soil enzyme activity. The four accumulator species straws enhanced soil sucrase and soil urease activities of Cd-contaminated soil, but reduced soil catalase activity (Table 3). The soil sucrase activity was ranked as: *C. canadensis* straw > *C. hirsuta* straw > *N. officinale* straw > *E. prostrata* straw > control, soil urease activity was ranked as: *N. officinale* straw > *C. hirsuta* straw > *C. canadensis* straw > *E. prostrata* straw > control, and soil catalase activity was ranked as: control > *E. prostrata* straw> *C. canadensis* straw > *C. hirsuta* straw > *N. officinale* straw. Compared with control, applying *C. canadensis* straw, *E. prostrata* straw, *N. officinale* straw and *C. hirsuta* straw enhanced soil sucrase activity by 96.20% ($p < 0.05$), 8.86% ($p < 0.05$), 18.57% ($p < 0.05$) and 43.25% ($p < 0.05$) respectively, and soil urease activity enhanced by 157.02% ($p < 0.05$), 69.36% ($p < 0.05$), 191.91% ($p < 0.05$) and 186.81% ($p < 0.05$) respectively, and soil catalase activity reduced by 2.19% ($p > 0.05$), 1.46% ($p > 0.05$), 15.69% ($p < 0.05$) and 9.85% ($p < 0.05$) respectively.

Table 3 Soil enzyme activity

Treatments	Soil sucrase activity (mg/g)	Soil urease activity (mg/g)	Soil catalase activity (ml/g)
CK	0.474±0.006d	0.235±0.010d	0.274±0.011a
C. canadensis	0.930±0.008a	0.604±0.016b	0.268±0.007ab
E. prostrata	0.516±0.036d	0.398±0.013c	0.270±0.008ab
N. officinale	0.562±0.005c	0.686±0.008a	0.231±0.013c
C. hirsuta	0.679±0.009b	0.674±0.018a	0.247±0.006bc

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

When applying the four accumulator species (*C. canadensis*, *E. prostrata*, *N. officinale* and *C. hirsuta*) straws in Cd-contaminated soil, the total P and K contents in roots, stems and leaves of *C. bursa-pastoris* increased compared with control. The total P and K contents in roots, stems and leaves of *C. bursa-pastoris* were ranked as: *N. officinale* straw > *C. hirsuta* straw > *C. canadensis* straw > *E. prostrata* straw > control. The soil available P and K contents were also increased by the four accumulator species straws, which were ranked as: *N. officinale* straw > *C. hirsuta* straw > *C. canadensis* straw > *E. prostrata* straw > control. The four accumulator species straws enhanced soil sucrase and soil urease activities, but reduced soil catalase activity. Therefore, applying accumulator straw could used to increase nutrient content and enhance soil enzyme activity of *C. bursa-pastoris* in Cd-contaminated soil.

References

[1] Y.Y. Shen and H. Chen: Chinese Agricultural Science Bulletin Vol. 25 (2009), p. 291.

[2] Y.H. Jiang, Z.R. Yu and Y.L. Ma: Vol. 32 (2001), p. 209.

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

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

[5] S. Wei, Q. Zhou, U.K. Saha, H. Xiao, Y. Hu, L.P. Ren and P. Gu: Journal of Hazardous Materials Vol. 163 (2009), p. 32.

[6] L. Lin, J. Shi, Q. Liu, M. Liao and L. Mei: Environmental Monitoring and Assessment Vol. 186 (2014), p. 4051.

[7] L. Luo, L.J. Lin, M.A. Liao, X. Zhang and D.Y. Yang: Acta Agriculturae Boreali-Sinica Vol. 29 (2014), p. 216.

[8] L.J. Lin, L. Luo, M.A. Liao, X. Zhang and D.Y. Yang: Resources and Environment in the Yangtze Basin Vol. 24 (2015), p. 684.

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