Effects of Intercropping with Accumulator on Nutrient Uptake of *Galinsoga parviflora* under Cd-Contaminated Soil

Jin Wang[1,a], Shuting Yang[1,b], Jun Shi[2,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]1250530881@qq.com, [c]tibm@163.com, [d]xllvjj@163.com

*Corresponding author

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Abstract. The effects of intercropping with accumulator species (*Capsella bursa-pastoris*, *Cardamine hirsute* and *Galium aparine*) on phosphorus (P) and potassium (K) uptakes of *Galinsoga parviflora* under cadmium (Cd) contaminated soil were studied through the pot experiment. Seven treatments were used in the experiment: monoculture of *G. parviflora*, monoculture of *C. bursa-pastoris*, monoculture of *C. hirsute*, monoculture of *G. aparine*, *G. parviflora* intercropping *C. bursa-pastoris*, *G. parviflora* intercropping *C. hirsute* and *G. parviflora* intercropping *G. aparine*. When intercropping with three accumulator species, the total P and K contents in roots and shoots of *G. parviflora* were ranked as: *G. parviflora* (intercropping with *G. aparine*) > *G. parviflora* (monoculture) > *G. parviflora* (intercropping with *C. hirsute*) > *G. parviflora* (intercropping with *C. bursa-pastoris*). When intercropping with *G. parviflora*, the total P and K contents in roots and shoots of *C. bursa-pastoris* increased, but the total P and K contents in roots and shoots of *C. hirsute* and *G. aparine* decreased compared with monoculture respectively. Therefore, intercropping with *G. aparine* could used to increase nutrient uptake of *G. parviflora* in Cd-contaminated soil.

Introduction

Intercropping is used to improve the yield and quality in agricultural production [1]. Under heavy metal stress, intercropping increase heavy metal uptake in hyperaccumulator, and decrease heavy metal uptake in common plant [2]. But other study shows no effect of heavy metal uptake in two plant spaces [3]. These results indicate that only suitable plant species intercropping could affect heavy metal uptake. *Galinsoga parviflora* is a cadmium (Cd) hyperaccumulator with small biomass [4]. In this experiment, we intercropped *G. parviflora* with three Cd-accumulator species *Capsella bursa-pastoris* [5], *Cardamine hirsute* [6] and *Galium aparine* (screened in early experiment). The aim of the study was to determine if intercropping with accumulator species could efficiently promote the nutrient uptake of *G. parviflora*, and improve the phytoremediation ability of *G. parviflora*.

Materials and Methods

Materials. *G. parviflora*, *C. bursa-pastoris*, *C. hirsute* and *G. aparine* seedlings with two euphyllas were collected from Ya'an campus farm of Sichuan Agricultural University (29°59′N, 102°59′E), China, in September 2013. The purple soil samples came from Cd-contaminated soil in the earlier experiment of Ya'an campus Farm. The basic properties of the soil were the same as reference [4].

Experimental Design. The experiment was conducted at the Ya'an campus farm from September 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). The seven experimental treatments in the experiment were monoculture of *G. parviflora*, monoculture of *C. bursa-pastoris*, monoculture of *C. hirsute*, monoculture of *G. aparine*, *G. parviflora* intercropping *C.*

bursa-pastoris, *G. parviflora* intercropping *C. hirsute* and *G. parviflora* intercropping *G. aparine*. The seedlings of monoculture were 4, and the seedlings of intercropping were 2 of each plant species. Each treatment was replicated three times using a completely randomized design with 10-cm spacing between pots. Four uniform seedlings of *G. parviflora* 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 [7]. The soil samples were collected for determining soil available P and K contents [7] and soil enzyme activity [8].

Results and Discussion

Effects of intercropping on total P content in four plant species. When intercropping with *C. bursa-pastoris*, *C. hirsute* and *G. aparine* under Cd-contaminated soil, the total P contents in roots and shoots of *G. parviflora* were ranked as: *G. parviflora* (intercropping with *G. aparine*) > *G. parviflora* (monoculture) > *G. parviflora* (intercropping with *C. hirsute*) > *G. parviflora* (intercropping with *C. bursa-pastoris*) (Fig. 1). Compared with monoculture, intercropping with *C. bursa-pastoris* and *C. hirsute* decreased the total P content in roots of *G. parviflora* by 4.19% ($p > 0.05$) and 1.82% ($p > 0.05$) respectively, decreased by 13.44% ($p < 0.05$) and 6.98% ($p > 0.05$) in shoots of *G. parviflora* respectively. Intercropping with *G. aparine* increased the total P contents in roots and shoots of *G. parviflora* by 1.19% ($p > 0.05$) and 21.58% ($p < 0.05$) compared with monoculture respectively. When intercropping with *G. parviflora*, the total P contents in roots and shoots of *C. bursa-pastoris* increased, but the total P contents in roots and shoots of *C. hirsute* and *G. aparine* decreased compared with monoculture respectively. Compared with respective monoculture, intercropping with *G. parviflora* increased total P contents in roots and shoots of *C. bursa-pastoris* by 29.56% ($p < 0.05$) and 10.69% ($p < 0.05$) respectively, decreased total P contents in roots and shoots of *C. hirsute* by 38.39% ($p < 0.05$) and 29.63% ($p < 0.05$) respectively, and decreased total P contents in roots and shoots of *C. hirsute* by 26.83% ($p < 0.05$) and 14.76% ($p < 0.05$) respectively.

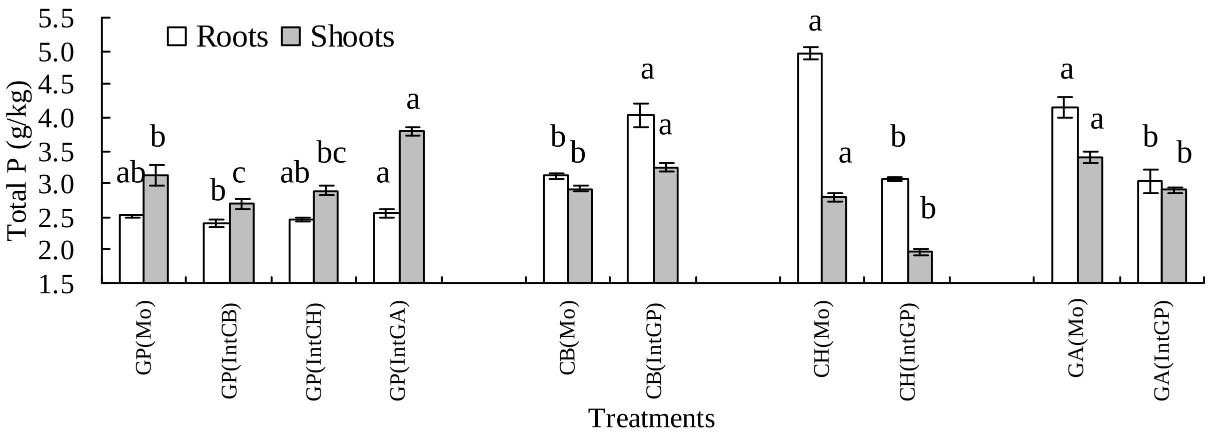

Fig. 1 Effects of intercropping on total P content in four plant species. Values are means of three replicate pots. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$). GP(Mo) = monoculture of *G. parviflora*, CB(Mo) = monoculture of *C. bursa-pastoris*, CH(Mo) = monoculture of *C. hirsute*, GA(Mo) = monoculture of *G. aparine*, GPIntCB = *G. parviflora* intercropping with *C. bursa-pastoris*, GPIntCH = *G. parviflora* intercropping with *C. hirsute*, GPIntGA= *G. parviflora* intercropping with *G. aparine*.

Effects of intercropping on total K content in four plant species. The same as total P content in *G. parviflora*, when intercropping with *C. bursa-pastoris*, *C. hirsute* and *G. aparine* in Cd-contaminated soil, the total K contents in roots and shoots of *G. parviflora* were ranked as: *G. parviflora* (intercropping with *G. aparine*) > *G. parviflora* (monoculture) > *G. parviflora* (intercropping with *C. hirsute*) > *G. parviflora* (intercropping with *C. bursa-pastoris*) (Fig. 2). Compared with monoculture, intercropping with *C. bursa-pastoris* and *C. hirsute* decreased the total

K content in roots of *G. parviflora* by 8.36% ($p < 0.05$) and 6.47% ($p > 0.05$) respectively, decreased by 14.08% ($p < 0.05$) and 5.60% ($p < 0.05$) in shoots of *G. parviflora* respectively. Intercropping with *G. aparine* increased the total K contents in roots and shoots of *G. parviflora* by 21.29% ($p < 0.05$) and 4.16% ($p > 0.05$) compared with monoculture respectively. When intercropping with *G. parviflora*, the total K contents in roots and shoots of *C. bursa-pastoris* increased, but the total K contents in roots and shoots of *C. hirsute* and *G. aparine* decreased compared with respective monoculture. Compared with respective monoculture, intercropping with *G. parviflora* increased total K contents in roots and shoots of *C. bursa-pastoris* by 2.97% ($p > 0.05$) and 1.77% ($p > 0.05$) respectively, decreased total K contents in roots and shoots of *C. hirsute* by 14.60% ($p > 0.05$) and 12.35% ($p > 0.05$) respectively, and decreased total K contents in roots and shoots of *C. hirsute* by 4.22% ($p > 0.05$) and 1.83% ($p > 0.05$) respectively.

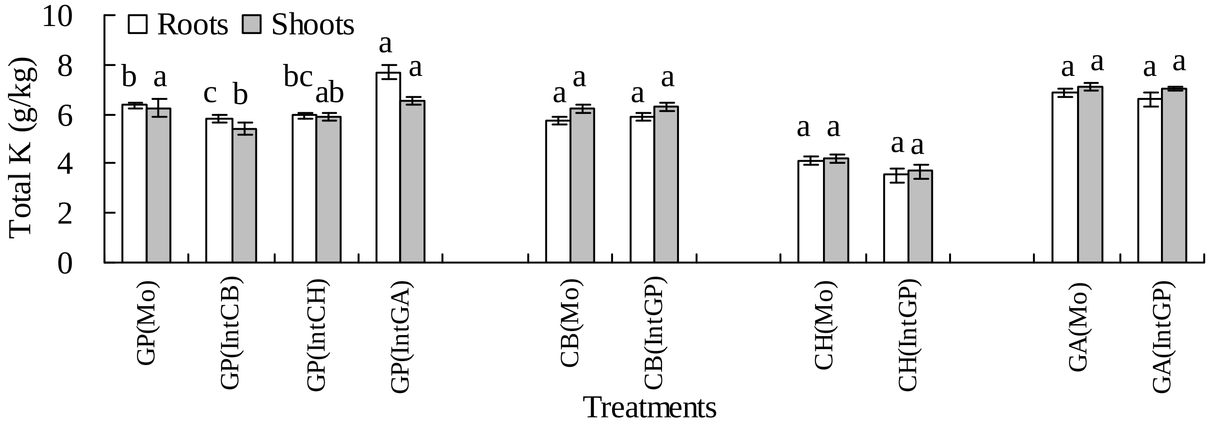

Fig. 1 Effects of intercropping on total K content in four plant species. Values are means of three replicate pots. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$). GP(Mo) = monoculture of *G. parviflora*, CB(Mo) = monoculture of *C. bursa-pastoris*, CH(Mo) = monoculture of *C. hirsute*, GA(Mo) = monoculture of *G. aparine*, GPIntCB = *G. parviflora* intercropping with *C. bursa-pastoris*, GPIntCH = *G. parviflora* intercropping with *C. hirsute*, GPIntGA= *G. parviflora* intercropping with *G. aparine*.

Soil available P content. When *G. parviflora* intercropped with *C. bursa-pastoris*, the soil available P content was higher than that of both *G. parviflora* (monoculture) and *C. bursa-pastoris* (monoculture) (Table 1). The soil available P content of *G. parviflora* intercropping with *C. hirsute* was lower than that of *G. parviflora* (monoculture), and higher than that of *C. hirsute* (monoculture) respectively. The soil available P content of *G. parviflora* intercropping with *G. aparine* was higher than that of both *G. parviflora* (monoculture) and *G. aparine* (monoculture).

Soil available K content. When *G. parviflora* intercropped with *C. bursa-pastoris*, the soil available K content was lower than that of both *G. parviflora* (monoculture) and *C. bursa-pastoris* (monoculture) (Table 1). The soil available K content of *G. parviflora* intercropping with *C. hirsute* was lower than that of *G. parviflora* (monoculture), and higher than that of *C. hirsute* (monoculture) respectively. The soil available K content of *G. parviflora* intercropping with *G. aparine* was higher than that of both *G. parviflora* (monoculture) and *G. aparine* (monoculture).

Soil enzyme activity. The soil sucrase activities of *G. parviflora* intercropping with *C. bursa-pastoris* and *G. parviflora* intercropping with *C. hirsute* were between two species monocultures respectively (Table 1). The soil sucrase activity of *G. parviflora* intercropping with *G. aparine* was higher than that of both *G. parviflora* (monoculture) and *G. aparine* (monoculture). When intercropped, the soil urease activities of *G. parviflora* intercropping with *C. bursa-pastoris* and *G. parviflora* intercropping with *G. aparine* were lower two species monocultures respectively, and *G. parviflora* intercropping with *C. hirsute* was between two species monocultures. The soil catalase activities of *G. parviflora* intercropping with *C. bursa-pastoris* and *G. parviflora* intercropping with

C. hirsute was higher than that of two species monocultures respectively, and *G. parviflora* intercropping with *G. aparine* was between that of two species monocultures.

Table 1 Soil available nutrient concentration 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)
GP(Mo)	4.25±0.20ab	124.70±0.42ab	0.297±0.014e	0.471±0.021ab	0.245±0.005bc
CB(Mo)	3.02±0.04e	121.81±2.56abc	0.865±0.010a	0.476±0.013a	0.259±0.013b
CH(Mo)	3.35±0.11d	118.27±1.03cd	0.545±0.029d	0.345±0.006d	0.223±0.004c
GA(Mo)	4.09±0.09bc	120.24±1.08bc	0.555±0.024d	0.475±0.016a	0.314±0.017a
GPIntCB	4.26±0.06ab	115.44±0.79d	0.661±0.009b	0.443±0.010b	0.260±0.016b
GPIntCH	3.94±0.07c	121.99±2.81abc	0.533±0.004d	0.408±0.001c	0.253±0.013bc
GPIntGA	4.41±0.04a	125.56±2.21a	0.605±0.014c	0.411±0.006c	0.311±0.021a

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 ($p < 0.05$). GP(Mo) = monoculture of *G. parviflora*, CB(Mo) = monoculture of *C. bursa-pastoris*, CH(Mo) = monoculture of *C. hirsute*, GA(Mo) = monoculture of *G. aparine*, GPIntCB = *G. parviflora* intercropping with *C. bursa-pastoris*, GPIntCH = *G. parviflora* intercropping with *C. hirsute*, GPIntGA= *G. parviflora* intercropping with *G. aparine*.

Conclusions

When intercropping with three accumulator species (*C. bursa-pastoris*, *C. hirsute* and *G. aparine*), the total P and K contents in roots and shoots of *G. parviflora* were ranked as: *G. parviflora* (intercropping with *G. aparine*) > *G. parviflora* (monoculture) > *G. parviflora* (intercropping with *C. hirsute*) > *G. parviflora* (intercropping with *C. bursa-pastoris*). When intercropping with *G. parviflora*, the total P and K contents in roots and shoots of *C. bursa-pastoris* increased, but the total P and K contents in roots and shoots of *C. hirsute* and *G. aparine* decreased compared with monoculture respectively. Therefore, intercropping with *G. aparine* could used to increase nutrient uptake of *G. parviflora* in Cd-contaminated soil.

References

[1] C. Li, X. He, S. Zhu, H. Zhou, Y. Wang, Y. Li, J. Yang, J. Fan, J. Yang, G. Wang, Y. Long, J. Xu, Y. Tang, G. Zhao, J. Yang, L. Liu, Y. Sun, Y. Xie, H. Wang and Y. Zhu: PLoS ONE Vol. 4 (2009), p. e8049.

[2] S.N. Whiting, J.R. Leake, S.P. McGrath and A.J. Baker: Environmental Science & Technology Vol. 35 (2001), p. 3237.

[3] B. Yang, W.S. Shu and Z.H. Ye: Chemosphere Vol. 52 (2003), p. 1593.

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

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

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