# Effects of Applying Accumulator Straw in Cd-Contaminated Soil on Nutrient Uptake of *Galinsoga parviflora*

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**Abstract.** The effects of applying four accumulator species (*Conyza canadensis*, *Cardamine hirsute*, *Eclipta prostrate* and *Nasturtium officinale*) straws in cadmium (Cd) contaminated soil on phosphorus (P), potassium (K) and nitrogen (N) uptakes of *Galinsoga parviflora* were studied through the 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*, *C. hirsute*, *E. prostrata* and *N. officinale*). When applying the four accumulator species straws in Cd-contaminated soil, only *E. prostrata* straw and *N. officinale* straw increased the total P and K contents in roots, stems and leaves of *G. parviflora* compared with control, and *E. prostrata* straw was the best. Only applying straws of *C. canadensis*, *C. hirsute* and *N. officinale* increased the total N content in stems and leaves of *G. parviflora* compared with control, and the rank was *C. canadensis* straw > *N. officinale* straw > *C. hirsuta* straw > control. Therefore, only suitable applying accumulator straw could used to increase nutrient uptake of *G. parviflora* in Cd-contaminated soil.

## Introduction

Applying the crop straw into soil can increase nutrient such as phosphorus (P), potassium (K) and nitrogen (N) in soil [1]. However, some studies show that the straws of wheat, corn, soybean and bean inhibit the growth of these crop species seedlings [2]. Therefore, if we apply cadmium (Cd) accumulator straw into soil, and plant hyperaccumulator, the nutrient uptake of hyperaccumulator could be enhanced. *Conyza canadensis* [3], *Cardamine hirsute* [4], *Eclipta prostrate* [5] and *Nasturtium officinale* [6] are Cd-accumulator plants. In this paper, we applied the straw made from the shoots of *C. canadensis*, *C. hirsute*, *E. prostrate* and *N. officinale* into Cd-contaminated soil and planted the Cd-hyperaccumulator plant *Galinsoga parviflora* [7]. 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 *G. parviflora*.

## Materials and Methods

**Materials.** In August 2013, the shoots of *C. canadensis*, *C. hirsute*, *E. prostrate* and *N. officinale* were collected from the Ya’an campus farm of Sichuan Agricultural University (29°59′N, 102°59′E), China, from uncontaminated soil areas. The collected shoots of these plants were dried at 80 °C to constant weight, finely ground and sieved through a 5-mm-mesh nylon sieve. *Galinsoga parviflora* seedlings with two pairs of euphyllas were collected from the Ya’an campus farm (from 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 [7].

**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 40 mg/kg [8-9]. 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 [8-9]), 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*, *C. hirsute*, *E. prostrate* and *N. officinale*). 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 50 d), the entire plants were harvested for determining contents of total P, K and N in roots, stems and leaves [10]. The soil samples were collected for determining soil available P and K contents [10].

## Results and Discussion

**Total P content in *G. parviflora*.** When applying the four accumulator species straws in Cd-contaminated soil, the total P contents in roots and stems of *G. parviflora* were ranked as: *E. prostrata* straw > *N. officinale* straw > control > *C. hirsuta* straw > *C. canadensis* straw (Table 1). Compared with control, applying straws of *C. canadensis* and *C. hirsute* in soil decreased the total P contents in roots of *G. parviflora* by 14.92% ($p < 0.05$) and 5.65% ($p > 0.05$) respectively, decreased by 14.33% ($p < 0.05$) and 14.66% ($p < 0.05$) in stems respectively. Applying straws of *E. prostrate* and *N. officinale* increased the total P contents in roots of *G. parviflora* by 13.71% ($p < 0.05$) and 2.42% ($p > 0.05$) respectively, increased by 5.86% ($p > 0.05$) and 1.63% ($p > 0.05$) in stems respectively compared with control. The total P content in leaves of *G. parviflora* was ranked as: *E. prostrata* straw > *N. officinale* straw > control > *C. hirsuta* straw > *C. canadensis* straw (Table 1). Applying straws of *C. canadensis* and *C. hirsute* in soil decreased the total P contents in leaves of *G. parviflora* by 15.12% ($p < 0.05$) and 5.56% ($p < 0.05$) respectively, and applying straws of *E. prostrate* and *N. officinale* increased the total P contents in leaves of *G. parviflora* by 6.79% ($p < 0.05$) and 1.85% ($p > 0.05$) respectively compared with control.

Table 1 Total P content in *G. parviflora*

| Treatments | Roots (g/kg) | Stems (g/kg) | Leaves (g/kg) |
|---|---|---|---|
| Control | 2.48±0.116bc | 3.07±0.087a | 3.24±0.022b |
| *C. canadensis* | 2.11±0.038d | 2.63±0.108b | 2.75±0.104d |
| *C. hirsuta* | 2.34±0.014c | 2.62±0.027b | 3.06±0.003c |
| *E. prostrata* | 2.82±0.031a | 3.25±0.082a | 3.46±0.033a |
| *N. officinale* | 2.54±0.008b | 3.12±0.024a | 3.30±0.020b |

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 *G. parviflora*.** The same as total P content in plants, the total K contents in roots, stems and leaves of *G. parviflora* were also ranked as: *E. prostrata* straw > *N. officinale* straw > control > *C. canadensis* straw > *C. hirsuta* straw (Table 2). Applying straws of *E. prostrate* and *N. officinale* increased the total K content in roots of *G. parviflora* by 7.55% ($p > 0.05$) and 5.22% ($p > 0.05$) respectively compared with control. Compared with control, the total K content in stems of *G. parviflora* was increased by 5.88% ($p > 0.05$) and 5.03% ($p > 0.05$) of *E. prostrata* straw and *N. officinale* straw respectively, and increased total K content in leaves by 9.39% ($p > 0.05$) and 5.03% ($p > 0.05$) of that respectively. So, only applying accumulator straw of *E. prostrata* and *N. officinale* could enhance the P and K uptakes of *G. parviflora* from Cd-contaminated soil.

Table 2 Total K content in *G. parviflora*

| Treatments | Roots (g/kg) | Stems (g/kg) | Leaves (g/kg) |
|---|---|---|---|
| Control | 7.28±0.028b | 4.76±0.057b | 7.56±0.071c |
| *C. canadensis* | 6.95±0.071c | 4.43±0.042c | 6.68±0.113e |
| *C. hirsuta* | 7.13±0.099bc | 4.57±0.099c | 7.04±0.085d |
| *E. prostrata* | 7.83±0.042a | 5.04±0.049a | 8.27±0.099a |
| *N. officinale* | 7.66±0.085a | 4.89±0.085ab | 7.94±0.106b |

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 N content in *G. parviflora*.** When applying the four accumulator species straws in Cd-contaminated soil, the total N content in roots of *G. parviflora* decreased, and ranked control > *C. hirsuta* straw > *C. canadensis* straw > *E. prostrata* straw > *N. officinale* straw (Table 3). Compared with control, applying straws of *C. canadensis*, *C. hirsute*, *E. prostrata* and *N. officinale* in soil decreased the total N contents in roots of *G. parviflora* by 23.91% ($p < 0.05$), 9.35% ($p < 0.05$), 26.30% ($p < 0.05$)and 28.48% ($p < 0.05$) respectively. The total N contents in stems and leaves of *G. parviflora* were ranked as: *C. canadensis* straw > *N. officinale* straw > *C. hirsuta* straw > control > *E. prostrata* straw. Applying straws of *C. canadensis*, *C. hirsute* and *N. officinale* increased the total N contents in stems of *G. parviflora* by 15.51% ($p < 0.05$), 7.24% ($p > 0.05$) and 10.81% ($p > 0.05$) respectively, increased by 21.88% ($p < 0.05$), 0.43% ($p > 0.05$) and 6.92% ($p > 0.05$) in stems respectively compared with control.

Table 3 Total N content in *G. parviflora*

| Treatments | Roots (g/kg) | Stems (g/kg) | Leaves (g/kg) |
|---|---|---|---|
| Control | 9.20±0.16a | 10.64±0.91b | 16.32±0.45b |
| *C. canadensis* | 7.00±0.28c | 12.29±0.41a | 19.89±0.83a |
| *C. hirsuta* | 8.34±0.06b | 11.41±0.58ab | 16.39±0.86b |
| *E. prostrata* | 6.78±0.11cd | 7.74±0.34c | 14.36±0.51c |
| *N. officinale* | 6.58±0.07d | 11.79±0.30ab | 17.45±0.64b |

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, only the straws of *E. prostrata* and *N. officinale* increased the soil available P content compared with control (Table 4). The soil available P content was ranked as: *E. prostrata* straw > *N. officinale* straw > control > *C. hirsuta* straw > *C. canadensis* straw. Compared with control, applying *C. canadensis* straw and *C. hirsuta* straw decreased the soil available P content by 4.47% ($p > 0.05$) and 1.40% ($p > 0.05$) respectively, and *E. prostrata* straw and *N. officinale* straw increased 16.48% ($p < 0.05$) and 11.17% ($p < 0.05$) respectively.

**Soil available K content.** The same as the soil available P content, the soil available K content decreased compared with control when applying *C. canadensis* straw and *C. hirsuta* straw in Cd-contaminated soil, and *E. prostrata* straw and *N. officinale* straw increased the soil available K content (Table 4). The soil available K content was also ranked as: *E. prostrata* straw > *N. officinale* straw > control > *C. hirsuta* straw > *C. canadensis* straw.

**Alkali soluble N content.** Except applying *E. prostrata* straw decreased alkali soluble N content, *C. canadensis* straw, *C. hirsuta* straw and *N. officinale* straw increased alkali soluble N content compared with control (Table 4). The alkali soluble N content was ranked as: *C. canadensis* straw> *N. officinale* straw> *C. hirsuta* straw> control > *E. prostrata* straw.

Table 4 Soil available nutrient concentration

| Treatments | Soil available phosphorus (mg/kg) | Soil available potassium (mg/kg) | Alkali soluble nitrogen (mg/kg) |
|---|---|---|---|
| Control | 3.58±0.134b | 120.32±1.87ab | 124.63±3.98c |
| *C. canadensis* | 3.42±0.164b | 115.41±1.99b | 165.21±0.45a |
| *C. hirsuta* | 3.53±0.039b | 118.92±2.72b | 136.81±1.42b |
| *E. prostrata* | 4.17±0.025a | 125.85±2.62a | 122.74±2.39c |
| *N. officinale* | 3.98±0.187a | 121.37±1.94ab | 143.24±4.29b |

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*, *C. hirsuta*, *E. prostrata* and *N. officinale*) straws in Cd-contaminated soil, only *E. prostrata* straw and *N. officinale* straw increased the total P and K contents in roots, stems and leaves of *G. parviflora* compared with control, and *E. prostrata* straw was the best. Only applying straws of *C. canadensis*, *C. hirsute* and *N. officinale* increased the total N content in stems and leaves of *G. parviflora* compared with control, and the rank was *C. canadensis* straw > *N. officinale* straw > *C. hirsuta* straw > control. Therefore, only suitable applying accumulator straw could used to increase nutrient uptake of *G. parviflora* in Cd-contaminated soil.

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