

# Effects of Hyperaccumulator Straw on Soil Nutrient Availability and Soil Enzyme Activity of *Cyphomandra betacea* under Cadmium Stress

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**Abstract:** A pot experiment was conducted to study the effects of hyperaccumulator straw on soil nutrient availability and soil enzyme activities of *Cyphomandra beracea* under Cadmium (Cd) stress. Four Cd-hyperaccumulator species (*Solanum photeinocarpum*, *Tagetes erecta*, *Galinsoga parviflora*, *Bidens pilosa*) straws were applied as mulches on the Cd-contaminated soil surface which planted *C. beracea*. The results showed that mulching hyperaccumulator straw on soil surface increased soil organic matter content, and soil available contents of N, P and K. The contents of organic matter content and available N were ranked as: *T. erecta* > *S. photeinocarpum* > *G. parviflora* > *B. pilosa* > control, and the available P and K contents were ranked as: *S. photeinocarpum* > *T. erecta* > *G. parviflora* > *B. pilosa* > control. The straws of *S. photeinocarpum* and *T. erecta* increased the soil catalase, polyphenol oxidase, urease and sucrase activities, but the straws of *G. parviflora* and *B. pilosa* reduced them. Therefore, mulching with the straws of *S. photeinocarpum* and *T. erecta* could promote growth of *C. betacea* under Cd stress.

## Introduction

Heavy metal contaminated soil causes huge losses in the yield of economic crop, and would even get into the food chain [1]. Cadmium (Cd) is one of heavy metal that is not biodegradable and considered to be a very hazardous element to environment [2]. Mulching with plant straw on soil surface is one of the natural methods using in agricultural production, and straw mulch decomposes in the soil and converts into organic matter, allelopathic substances and other nutrients, which can fertilize the soil, improve soil texture and affect physiological and biochemical activities of soil microorganisms [3-4]. If we apply the plant straw in heavy metal contaminated soil, the plant straw could affect the heavy metal bioavailability, and decrease or increase the heavy metal absorption of living plant [5]. *Cyphomandra betacea* is a commercially attractive fruit, which distributes in New Zealand, Sri Lanka, and Southwest of China [6]. In this study, to study effects of hyperaccumulator straw on soil nutrient availability and soil enzyme activity of *C. betacea* under Cd stress, we planted *C. betacea* seedlings in Cd-contaminated soil, and mulching with straws of four Cd-hyperaccumulator species (*Solanum photeinocarpum* [7], *Tagetes erecta* [8], *Galinsoga parviflora* [9] and *Bidens pilosa* [10] on soil surface. The aim of the study was to screen hyperaccumulator straw which could enhance soil nutrient availability and soil enzyme activity of *C. betacea* under Cd stress, and provide a reference for other fruit trees.

## Materials and Method

**Materials.** The inceptisol soil samples were collected from Ya'an campus farm of the Sichuan Agricultural University (29°59'N, 102°59'E), China, in July 2014. The basic properties of the soil were the same as reference [9]. The shoots of *S. photeinocarpum*, *T. erecta*, *G. parviflora* and *B. pilosa* were collected from the Ya'an campus farm (from uncontaminated soil) in July 2014. The shoots were dried at 80°C to constant weight, then finely ground and sieved through a 5-mm-mesh nylon sieve.

**Experimental Design.** The experiment was conducted at the Ya'an campus farm from July to October in 2014. 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  $\text{CdCl}_2 \cdot 2.5\text{H}_2\text{O}$  at 10 mg/kg. The soils were mixed immediately and again after 4 weeks, during which soil moisture was kept at 80%. Three uniform seedlings with five euphyllas of *C. betacea* were transplanted into each pot, and 6 g shoots of four Cd-hyperaccumulator species were applied as mulches on the soil surface in each pot (equivalent to 225 g/m). Five treatments were applied: not mulched with straw (control), mulched with *S. photeinocarpum* straw, mulched with *T. erecta* straw, mulched with *G. parviflora* straw, and mulched with *B. pilosa* 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. betacea* seedlings were transplanted until the plants were harvested.

**Sample Analysis.** 40 days later, the plants were gently removed from the soil. The soil samples were collected, and dried naturally and ground into powder (granule diameter < 0.149 mm and 1 mm) to determine the organic carbon content, available nitrogen (N), available phosphorus (P), available potassium (K) [11] and soil enzyme (catalase, polyphenol oxidase, urease and sucrase) activity [12].

**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

**Soil Nutrient Availability.** When mulching hyperaccumulator straw on Cd-contaminated soil surface, the organic matter content increased compared with control, and was ranked as: *T. erecta* > *S. photeinocarpum* > *G. parviflora* > *B. pilosa* > control (Table 1), which was related to the decomposition matter of straw. The available N content was ranked as: *T. erecta* > *S. photeinocarpum* > *G. parviflora* > *B. pilosa* > control, and the treatments of *S. photeinocarpum*, *T. erecta*, *G. parviflora* and *B. pilosa* increased available N content by 22.01% ( $p < 0.05$ ), 22.44% ( $p < 0.05$ ), 19.24% ( $p < 0.05$ ) and 5.52% ( $p > 0.05$ ) respectively compared with control. The available P and K contents were ranked as: *S. photeinocarpum* > *T. erecta* > *G. parviflora* > *B. pilosa* > control. The treatments of *S. photeinocarpum*, *T. erecta*, *G. parviflora* and *B. pilosa* increased available P content by 92.72% ( $p < 0.05$ ), 70.61% ( $p < 0.05$ ), 39.18% ( $p < 0.05$ ) and 5.56% ( $p > 0.05$ ) respectively compared with control, and the treatments of *S. photeinocarpum*, *T. erecta*, *G. parviflora* and *B. pilosa* increased available K content by 32.83% ( $p < 0.05$ ), 30.15% ( $p < 0.05$ ), 26.16% ( $p < 0.05$ ) and 13.87% ( $p < 0.05$ ) respectively compared with control. So, mulching with the straws of *S. photeinocarpum*, *T. erecta*, *G. parviflora* and *B. pilosa* increased available nutrients of Cd-contaminated soil, which was benefit for *C. betacea* seedlings growth, and was consistent with other studies [13].

Table 1 Soil nutrient availability content

Treatments	Organic matter (mg/g)	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
Control	23.11±0.52b	37.16±0.45b	21.03±0.39d	102.50±1.04d
<i>S. photeinocarpum</i>	25.56±0.58a	45.34±0.63a	40.53±0.04a	136.15±1.71a
<i>T. erecta</i>	25.60±0.63a	45.50±0.73a	35.88±0.11b	133.40±1.92ab
<i>G. parviflora</i>	25.00±0.59ab	44.31±0.48a	29.27±0.91c	129.31±1.78b
<i>B. pilosa</i>	24.21±0.69ab	39.21±1.18b	22.20±0.58d	116.72±0.50c

**Soil Catalase and Polyphenol Oxidase Activities.** When mulching hyperaccumulator straw on Cd-contaminated soil surface, the straws of *S. photeinocarpum* and *T. erecta* increased the soil catalase and polyphenol oxidase activities, but the straws of *G. parviflora* and *B. pilosa* reduced them (Fig. 1 A, B),

which was related to the allelopathic substances from the different species straws [14-15]. The soil catalase and polyphenol oxidase activities were ranked as: *T. erecta* > *S. photeinocarpum* > control > *G. parviflora* > *B. pilosa*, and the *T. erecta* straw increased soil catalase and polyphenol oxidase activities by 100.00% ( $p < 0.05$ ) and 81.25% ( $p < 0.05$ ), respectively.

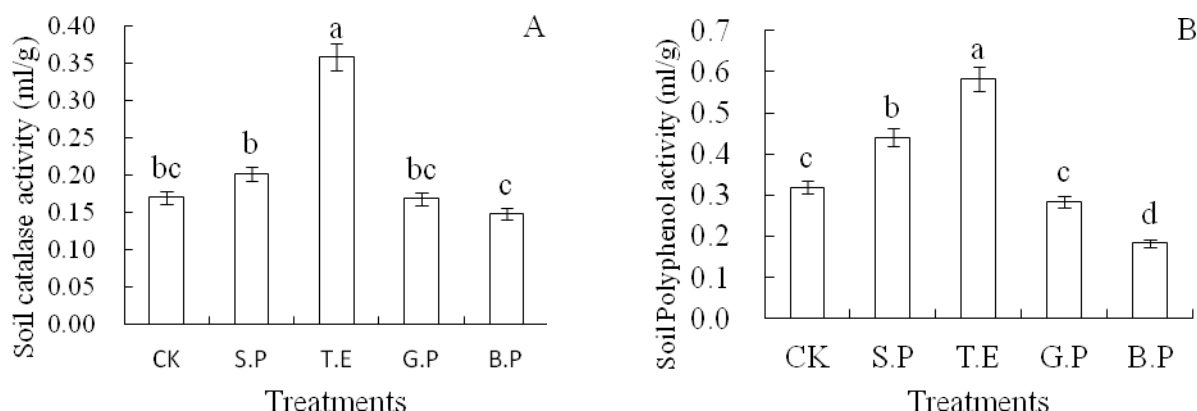


Fig. 1 Effects of hyperaccumulator straws mulching on soil catalase activity and soil polyphenol oxidase activity. A = Soil catalase activity, B = Soil polyphenol oxidase activity. CK = not mulched with straw (control), S.P = mulched with *S. Photeinocarpum* straw, T.E = mulched with *T. erecta* straw, G.P = mulched with *G. parviflora* straw, B.P = mulched with *B. pilosa* straw.

**Soil Urease and Sucrase Activities.** The same as soil catalase and polyphenol oxidase activities, when mulching hyperaccumulator straw on Cd-contaminated soil surface, the straws of *S. photeinocarpum* and *T. erecta* increased the soil urease and sucrase activities, but the straws of *G. parviflora* and *B. pilosa* reduced them (Fig. 2 A, B), which was also related to the allelopathic substances from the different species straws [14-15]. The soil urease and sucrase activities were ranked as: *T. erecta* > *S. photeinocarpum* > control > *G. parviflora* > *B. pilosa*, and the *T. erecta* straw increased soil urease and sucrase activities by 24.19% ( $p < 0.05$ ) and 15.70% ( $p < 0.05$ ), respectively. Therefore, the straws of *S. photeinocarpum* and *T. erecta* could use to enhance soil enzyme activity under Cd stress of *C. betacea*, and the *T. erecta* straw was the best.

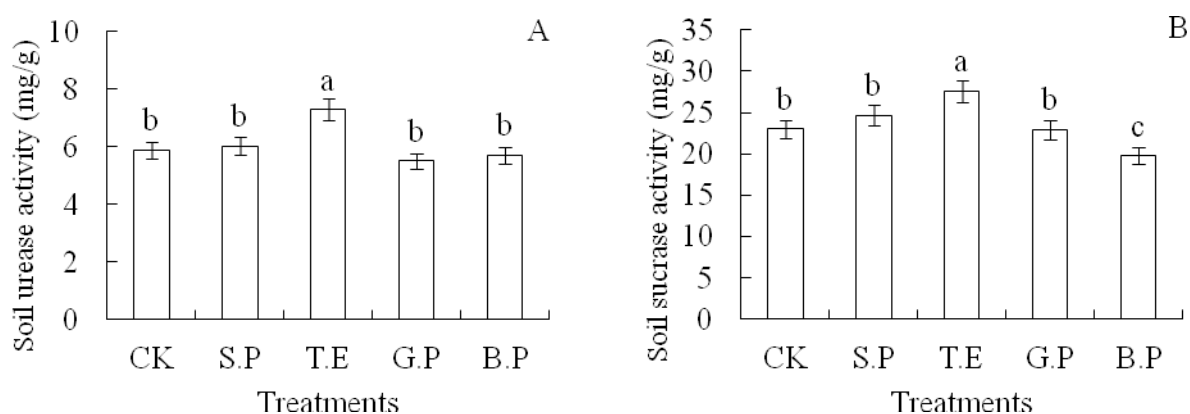


Fig. 2 Effects of hyperaccumulator straws mulching on soil urease and sucrase activities. A = Soil urease activity, B = Soil sucrase activity. CK = not mulched with straw (control), S.P = mulched with *S. Photeinocarpum* straw, T.E = mulched with *T. erecta* straw, G.P = mulched with *G. parviflora* straw, B.P = mulched with *B. pilosa* straw.

## Conclusions

Mulching hyperaccumulator straw on Cd-contaminated soil surface of *C. betacea* increased organic matter content, available N content, available P content and available K content of soil. The organic matter content and available N content were ranked as: *T. erecta* > *S. photeinocarpum* > *G. parviflora* > *B. pilosa* > control, and the available P and K contents were ranked as: *S. photeinocarpum* > *T. erecta* > *G. parviflora* > *B. pilosa* > control. Mulching hyperaccumulator straw on Cd-contaminated soil surface, the straws of *S. photeinocarpum* and *T. erecta* increased the soil catalase, polyphenol oxidase, urease and sucrase activities, but the straws of *G. parviflora* and *B. pilosa* reduced them. Therefore, mulching with the straws of *S. photeinocarpum* and *T. erecta* could promote growth of *C. betacea* under Cd stress.

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