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Investigation of growth, and phytoremediation potential of *Ricinus cimmunis* (L.) and *Brassica juncea* (L.) in cadmium contaminated soil

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ABSTRACT: Amongst the various strategies adopted for removal of toxic heavy metal from the contaminated soils, phytoremeditiation has emerged as an economical, eco-friendly acceptable technology in the recent years. Among phytoremediators *Brassica juncea* has been known. In the present study was investigated comparative tolerance and phytoremediation efficiency of Indian mustard and *R. communis* from the metal contaminated soil. The results show that Castor was found more tolerant to Cd and removed more Cd in a given time than Indian mustard. Castor produced 23 and twelve folds higher biomass in terms of fresh weight and dry weight. The amont of Cd accumulated in the roots and shoots of Indian mustard was higher as per unit biomass than that in caster. Total removal of metal from soil was much higher in caster on per plant basis in the same period in presence of stresses. *R. communis* accumulated about seventeen and 1.5 fold higher Cd in their roots and shoots.

Keywords: phytoremediation, castor, Indian mustard, cadmium

INTRODUCTION

Phytorededitiation has emerged as an economical, eco-friendly and aesthetically acceptable technology in the recent years (Huang *et al.,* 2011). *Brassica juncea* is one of the most studied plant found tolerant to most of the toxic heavy metals and suggested to be a potential phytoremediator. The contaminated lands bearing industrial wastes and waste drought and excessive heavy metals simultaneously. *B. juncea* have been found to be sensitive to most of the stresses and its green leaves are used as vegetable and fodder in many part of the Indian subcontinent, therefore other alternatives are required to be investigated for removal of the metals from the contaminated agricultural ecosystems. We have recently reported *Ricinus communis.* (Bauddh and Singh, 2012). As better alternative to *B. juncea.* A considerable portion of the agricultural ecosystem supporting cultivation of *B. juncea* in Indian subcontinent is affected by cadmium; therefore it will be very significant to investigate comparative tolerance and phytoremediation efficiency of *B. juncea* and *R. communis* from the metal contaminated soil. The present study is planned with this perspective to study the tolerance capability and cadmium removal by these two plants in similar agro climatic conditions from the Cd contaminated soil.

MATERIALS AND METHODS

A. Plant materials and experimental design

The seeds of Indian mustard (*B. juncea* L.) and castor (*R. communis* L.) were obtained from the Hamedan Agricultural Research Institute. Seeds were sown in 30-cm-diameter earthen pots filled with 8 kg soil. Soil was mixed with appropriate amount of $CdCl_2$ to T = 0, T = 50, T = 100 and T = 150 mg Cd kg^{-1} soil. The pots with seeds of *B. juncea* were kept directly in naturally illuminated net house of research field station in the Department of Agriculture Buali Sina University Lucknow, Hamedan (during October-December months) having the minimum temperature ranged between 6-20°C, maximum temperature 17- 34°C and with relative humidity 62-71 percent. The seeds were germinated in five day and one plant was maintained in each pot for further studies. *R. communis* needs a comparatively higher temperature for seed germination; hence the pots containing its seeds were kept in Green House with controlled conditions for ten day at 300C with 85 percent relative humidity. After germination, the pots of *R. communis* were shifted in the same net house for comparative study (with *B. juncea*). All the measurements were performed at 30, 60 and 90 day after sowing (DAS).

B. Plant growth analysis

The plants were removed from pots at 30, 60 and 90 DAS and dipped in a water filled bucket. The plant roots were washed carefully to remove the adhering soil particles. Fresh weight of roots and shoots was taken by digital single pan balance. The same plant parts were then placed in an oven at 70°C till the weight became constant. The dried plant parts were weighed to record the dry mass of roots and shoots.

The average fresh and dry biomass accumulation/day/plant was measured as follows

Biomass (mg)/plant/ day of 30 days old plant (B1) = Biomass of 30 days old plant/30

Biomass (mg)/plant/ day of 60 days old plant (B1) = Biomass of 60 days old plant/60

Biomass (mg)/plant/ day of 90 days old plant (B1) = Biomass of 90 days old plant/90

Average Biomass acumulation mg/plant/ day= (B1+B2+B3)/3

C. Estimation of cadmium content

Cadmium content were estimated after digesting the sample in perchloric acid-nitric acid mixture (1:3 v/v) by atomic absorption spectrophotometer. Perplant (by roots and shoots). Cd accumulation was calculated as follow (Ali *et al.*, 2002).

Total Cd extraction by roots/shoot (mg/plant) = Dry biomass of roots/shoot (g) * metal accumulated (µg/g dry wt) by roots/shoot)

RESULTS

A. Root and shoot biomass production in response to Cd

Application of the stresses to the plants resulted in general reduction in the growth of *B. juncea* and *R. communis* in terms of fresh and dry biomass production (Tables 1 and 2). All three levels of Cd caused very significant decrease in biomass production in *B. juncea*. Roots are generally more affected than the shoots. Cadmium (150 mg Cd kg^{-1} soil) caused more inhibition in biomass production in comparison to another doses.

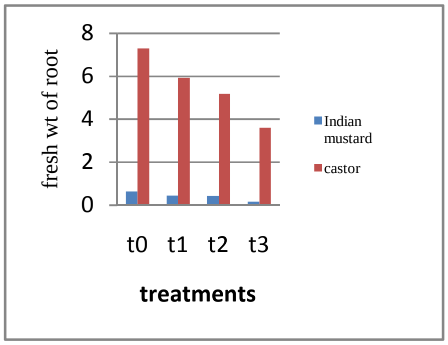
Table 1: Effect of cadmium chloride on the fresh and dry biomass of *B. juncea* at 30, 60 and 90 day of sowing. T_0 = control, T_1 = Cd 50 (mg),T_2 = Cd 100(mg) and T_3 = Cd 150(mg).

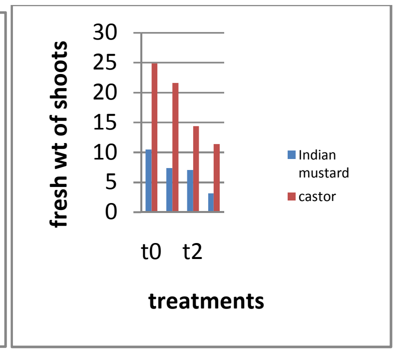
Treatments	**Roots**			**Shoots**		
Fresh biomass(mg)	**30(DAS)**	**60(DAS)**	**90(DAS)**	**30(DAS)**	**60(DAS)**	**90(DAS)**
T_0	0.09^{a}	0.52^{a}	1.3^{a}	4.96^{a}	10.27^{a}	16.25^{a}
T_1	0.06^{b}	0.37^{b}	0.9^{b}	3.24^{b}	7.46^{b}	11.55^{b}
T_2	0.04^{c}	0.28^{c}	1^{b}	3.06^{b}	6.88^{c}	11.16^{b}
T_3	0.03^{c}	0.19^{d}	0.26^{c}	2.04^{c}	4.21^{d}	3.16^{c}
Dry biomass (mg)						
T_0	0.02^{a}	0.17^{a}	0.19^{a}	0.58^{a}	1.75^{a}	1.94^{a}
T_1	0.01^{b}	0.14^{b}	0.16^{b}	0.41^{b}	1.37^{b}	1.65^{b}
T_2	0.01^{b}	0.12^{c}	0.14^{c}	0.29^{c}	1^{c}	1.41^{c}
T_3	o.oo9^{c}	0.07^{d}	0.09^{d}	0.20^{d}	0.52^{d}	0.84^{d}

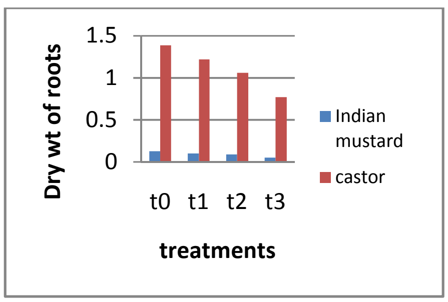
Table 2: Effect of cadmium chloride on the fresh and dry biomass of R.communis at 30,60 and 90 day of sowing. T_0 = control, T_1 = Cd 50 (mg),T_2 = Cd 100(mg) and T_3 = Cd 150(mg).

Treatments	**Roots**			**Shoots**		
Fresh biomass(mg)	**30(DAS)**	**60(DAS)**	**90(DAS)**	**30(DAS)**	**60(DAS)**	**90(DAS)**
T_0	0.68^{a}	8.51^{a}	12.8^{a}	7.48^{a}	27.21^{a}	39.89^{a}
T_1	0.59^{b}	6.38^{b}	10.8^{b}	6.81^{b}	24.82^{b}	33.28^{b}
T_2	0.51^{c}	5.95^{c}	9.1^{c}	4.44^{c}	18.62^{c}	20.18^{c}
T_3	0.38^{d}	4.17^{d}	6.27^{d}	3.71^{d}	14.72^{d}	15.71^{d}
Dry biomass (mg)						
T_0	0.14^{a}	1.25^{a}	2.78^{a}	1.31^{a}	5.41^{a}	9.09^{a}
T_1	0.12^{b}	1.08^{b}	2.46^{b}	1.12^{b}	5.21^{b}	7.81^{b}
T_2	0.07^{c}	0.97^{c}	2.16^{c}	0.62^{c}	3.51^{c}	5.82^{c}
T_3	o.o6^{c}	0.65^{d}	1.59^{d}	0.42^{d}	4.08^{d}	4.08^{d}

A decrease of 80.0 and 50.93 percent in the root fresh wt. and 80.57 and 60.59 percent in the shoots fresh wt. in 90 DAS was found in *B. juncea* and *R. communis*, respectively when all these stresses viz Cd were present at a time over the no stress controls. Similarly the root dry wt. decreased by 50.77 and 42.92 percent and shoot dry wt. decreased by 80.58 and 55.11 percent in *B. juncea* and *R. communis* respectively under the stresses. However, the effects of stress was more deteriorating in *B. juncca* when compared with *R. communis*. Further, the rate of fresh and dry biomass production per plant basis was much higher in roots and shoots of *R. communis* than that in *B. juncea*. The increase in rate of root fresh weight was twelve fold higher and that of shoot fresh weight was two fold higher in *R. communis* than *B. juncea.*







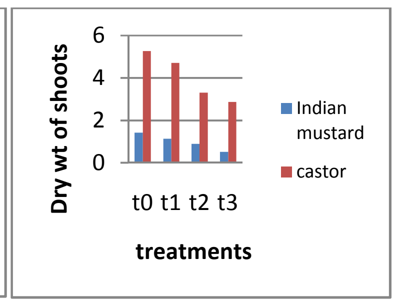


Table 3: Cadmium accumulation in the roots and shoots of *B. juncea* and *R. communis* 30, 60 and 90 day of sowing. T0=control, t_1 =Cd 50 (mg),t_2 =Cd 100(mg) and t_3 = Cd 150.

Treatments	(Cd level in roots) g g^{-1} dry (μwt)			(Cd level) in shoots) g g^{-1} dry (μwt)		
B. juncea	30(DAS)	60(DAS)	90(DAS)	30(DAS)	60(DAS)	90(DAS)
T_0	1.41^a	4.86^a	5.90^a	0.3^a	2.15^a	3.96^a
T_1	722.82^b	810.86^b	944.29^b	205.46^b	537.63^b	685.96^b
T_2	922.18^c	1185.64^b	1314.12^c	283.82^c	605.91^c	827.45^c
T_3	1025.65^d	1384.25^b	1544.87^d	324.35^d	793.18^d	1058.65^d
R. communis						
T_0	1.81^a	2.32^a	3.18^a	0.67^a	1.62^a	1.91^a
T_1	351.34^b	604.18^b	837.61^b	80.82^b	156.54^b	195.95^b
T_2	395.86^c	707.83^c	1086.35^c	80.91^b	160.83^b	200.13^b
T_3	448.02^c	788.58^d	1255.52^d	90.61^c	195.51^c	235.82^c

B. Cadmium accumulation

The bioaccumulation of Cd was 1.437 fold and 5 fold higher in the roots than that in the shoots in *B. juncea* and in *R.communis*, respectively. Cadmium bioaccumulation metal per unit biomass was higher in *B. juncea*; whereas, rate of Cd bioaccumulation was more in *R. communis* as Indian mustard produced less biomass in the same duration under the stresses. A total count of Cd phytoextraction per plant was significantly more in *R. communis* (3.588 fold higher than *B. juncea*) which was able to remove higher Cd in the same duration from the contaminated soil.

DISCUSSION

The study revealed that Cd in the soil simultaneously influenced not only growth, protein, proline and Malondialdehyde (MDA) content but also Cd bioaccumulation in roots and its translocation to the shoots in *R. communis* and *B. juncea*. *R. communis* appeared relatively less sensitive towards the deteriorating effects of Cd, as compared to *B. juncea*. The results are in accordance to our earlier report on superiority of *R. communis* in relation to growth, enhanced levels of stress metabolites and phyto accumulation of the metal over *B. juncea*, when Cd stress was applied alone (Bauddh and Singh, 2012). A reduction in the root and shoot biomass was observed as a function of quantity of the metal. A few reports are available which indicate that *R. communis* has good tolerance and phytoremidiation potential for Cd and other heavy metals (Huang *et al.*, 2011), however, no study is available to investigate its effectiveness when exist the metal contamination which is a common situation in the urban and peri urban regions. Similarly the suitability of *R. communis* over the widely studied oil seed crop *B. juncea* has also seen studied rarely (Bauddh and Singh, 2012).

CONCLUSIONS

The data presented in this paper indicated that *R.communis* is more tolerant to Cd contamination *B. juncea* in terms of plant growth, bioaccumulation of proline and MDA, protein levels and Cd accumulation in plant parts. The amount of Cd removed from soil in three months under 25 µM of Cd is significantly higher in *R. communis* than Indian mustard.

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