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NOVEL EVALUATION TECHNIQUES OF PHYTOEXTRACTION OF BARIUM BY CO-CROPPING HYPERACCUMULATOR AND HYPOACCUMULATOR

Botany

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ABSTRACT

Under barium chloride stress, a laboratory investigation was done to assess the phtoextraction capability of hyper accumulator (Brassica juncea Hk. F. & T.). The hypoaccumulator (Vigna radiata (L.) Wilczek.) and the low-accumulating plant (Vigna radiata (L.) Wilczek.) were co-cultivated (hperaccumlator). At varying amounts of barium, the accumulation, translocation, and mobility of barium from the soil to the roots and leaves of co-cultivated hyperaccumulator (Brassica juncea Hk. F. & T.) and hypoaccumulator (Vigna radiata) plants were investigated. Brassica juncea gathered four times as much barium in its roots, shoots, and leaves as Vigna radiata. When grown alone, Vigna radiata seedlings were shown to be susceptible to barium, with low values for the accumulation factor, translocation factor, and metal mobility. This is generally understood that Brassica juncea showed more barium accumulation, more barium translocation from root to shoot, and good barium mobility was raised from level 1 to level 3. It was discovered that Brassica juncea had higher barium accumulation in the root and shoot than Vigna radiata. The current investigation indicates that Vigna radiata is a hypoaccumulator and sensitive to barium. Because Brassica juncea is a hyperaccumulator of barium, it accumulates more metal when co-cultivated with Vigna radiata, resulting in reduced metal toxicity.

KEYWORDS

Hyperacumulator, Barium Stress, Accumulation Factor, Translocation Factor, Mobility Index.

Introduction

Phytoextraction involves the removal of pollutants, the toxic heavy metals and metalloids, by the roots of the plants with subsequent transport to aerial plant organs and metabolized to change into non toxic forms (Sidhu *et al*., 2020). Pollutants accumulated in stems and leaves are harvested with accumulating plants removed from the site, phytoremediation is the use of plants to treat/clean contaminated sites (Bali *et al*. 2020). The effectiveness of a Hyperaccumulation is dependent on the selection of the appropriate plant. Plants native to the target area should be considered since they are adapted to the local climate, insects and diseases (Lia *et al*. 2020). Any plant used as a phytoremediator must be able to tolerate high concentrations of the toxic substances of interest, in addition to any other pollutants found at the particular site, as candidate site for phytoremediation usually have multiple contaminants (Peer *et al*., 2003). The plant used in the phytoremediation technique must have a considerable capacity of metal absorption, its accumulation and strength to decrease the treatment time (Prasad and Freitas 2003).

In the present study, it is aimed to analyse the impact of barium on the accumulation factor, translocation factor and mobility index of *Vigna radiata* (L.) Wilczek. (hypoaccumulator) and hyperaccumulator *Brassica juncea* Hk. F. & T.

Materials and Methods

Seeds of *Vigna radiata* (L.) Wilczek. and *Brassica juncea* Hk. F. & T. were procured from local seed centre, Kovilpatti. *Vigna radiata* (L.) Wilczek. was chosen as experimental plant, whereas the *Brassica juncea* Hk. F. & T. was chosen as hyperaccumulator plants for this study. Optimum number of surface sterilized seeds of both *Vigna radiata* (hypoaccumulator) and *Brassica juncea* (hyperaccumulator) were sown uniformly in all pots.

Appropriate amount of barium were given separately for the experimental plants with different concentration as 2 mM, 4 mM, 6 mM, 8 mM and 10 mM (w/v) in five replicates. Metal concentration in plants such as accumulation factor, translocation factor and mobility index were analysed on the 45th day after planting (DAP).

Accumulation Factor (AF)

The Accumulation Factor (AF) was considered to determine the quantity of heavy metals absorbed by the plant from soil. It is calculated using the formula (Ghosh and Singh, 2005; Yoon *et al*., 2006):

$$\text{Accumulation Factor (AF)} = \frac{\text{Metal Concentration in tissue of whole plant}}{\text{Initial concentration of metal in substrate (soil)}}$$

Translocation Factor (TF)

To evaluate the potential of plant species for phytoextraction, the Translocation Factor (TF) was considered. This ratio is an indication of the ability of the plant to translocate metals from the roots to the aerial parts of the plant (Mellem et al.,2009). It is represented by the ratio:

$$\text{Translocation Factor (TF)} = \frac{\text{Metal concentration in stems + leaves}}{\text{Metel concentration in roots}}$$

Mobility Index (MI)

Mobility Index (MI) was considered to determine the bio mobility and transport of heavy metals in different plant parts. The whole experiment was divided into three categories: Level 1 (Soil – Roots), Level 2 (Roots – Stems) and Level 3 (Stems – leaves). It was calculated by the methods of Kumar et al. (2009)

$$\text{Mobility Index (MI)} = \frac{\text{Concentration of metal in the receiving level}}{\text{Concentration of metal in the source level}}$$

RESULTS AND DISCUSSION

To evaluate the heavy metal accumulation, translocation and mobility in the plant tissue, the Accumulation Factor (AF), Translocation Factor (TF) and Mobility Index (MI) was calculated on the effect of barium on co-cultivately grown Vigna radiata and Brassica juncea were tabulated in tables 1 and 2.

The accumulation factor and translocation factor of both metals show a gradual increase in the Brassica juncea with increasing concentrations of barium. But in the Vigna radiata, the accumulation factor (AF) and translocation factor (TF) were very less even in 4mM concentration of metal treatment. Both factors were recorded below the detectable level which coincides with the findings of Ma et al., (2001). Comparatively low TF values of chromium and high TF values of mercury reveal very low and high translocation of these metals indicating the translocation potential Brassica juncea diffusa (Raskin et al., 1994).

More or less similar results have been reported in the accumulation pattern of heavy metals in Bidens tripartita (Zheljazkov et al., 2008). Those authors suggested that accumulation potential of plants towards heavy metal depends on the availability of the metals in the soil/ growth media as well as on the plant genotype. But in the present study, the accumulation factor and translocation factor were less in the hypoaccumulator (Vigna radiata). This may be due to the hyperaccumulator accumulating more metals and leave hypoaccumulator free from metal toxicity (Cid et al., 2016).

If the accumulation factor (AF) and translocation factor (TF) values are above one, the plant is suitable for phytoremediation (Yoon et al., 2006; Zhelyjazkov et al., 2008). In the present investigation, accumulation factor (AF) and translocation factor (TF) values are above one, in Brassica juncea, suggesting that they are best suited for phytoextraction of barium toxicity.

The mobility index (MI) of Brassica juncea is higher than one for Level 3, the mobility index was more than 0.6 for Levels 1 and 2, indicating the moderate rate of mobility of metals form soil to roots, higher mobility rate in stem to leaves, and low from roots to stem. In contrary, in the hypoaccumulator Vigna radiata these levels are not noticed, because the hyperaccumulator plants absorbed the metals freed the hypoaccumulator Vigna radiata. Similar findings were provided by Yusuf et al., (2002); An et al., (2004)(Lachapelle et al., 2021).

Based on the result obtained on accumulation factor (AF), translocation factor (TF) and mobility index (MI), it is suggested that Brassica juncea spinosus , Hk.F.&T. is best suited for remediating barium.

Table – 1 Impact of barium chloride concentration in hyperaccumulator (Brassica juncea Hk. F. & T.) and hypoaccumulator (Vigna radiata (L.) Wilczek.)

Metal Concentration	Accumulation Factor (AF)			Translocation Factor (TF)		
	Barium Stress on *Vigna radiata* (L.) Wilczek.	After Co–Cultivation		Barium Stress on *Vigna radiata* (L.) Wilczek.	After Co–Cultivation	
		Vigna radiata (L.) Wilczek.	*Brassica juncea* Hk. F. & T.		*Vigna radiata* (L.) Wilczek.	*Brassica juncea* Hk. F. & T.
Control	BDL	BDL	BDL	BDL	BDL	BDL
2mM	0.490 ± 0.014	BDL	1.483 ± 0.064	0.125 ± 0.008	BDL	1.103 ± 0.018
4mM	0.301 ± 0.029a*	BDL	1.520 ± 0.072a*	0.121 ± 0.038a*	BDL	1.158 ± 0.093a*
6mM	0.251 ± 0.071a*	0.005 ± 0.026a#	1.586 ± 0.048a*	0.119 ± 0.073a*	BDL	1.196 ± 0.008a*
8mM	0.235 ± 0.026a*	0.004± 0.013a#	1.654 ± 0.013a*	0.112 ± 0.010a*	0.765 ± 0.0021 a#	1.272 ± 0.037a*
10mM	0.213 ± 0.037a*	0.001± 0.061a#	1.824 ± 0.004a*	0.103 ± 0.042a*	0.711 ± 0.034a#	1.327 ± 0.016a*

Table –2 Impact of barium chloride concentration in hyperaccumulator (Brassica juncea Hk. F. & T.) and hypoaccumulator (Vigna radiata (L.) Wilczek.)

Metal Concentration	Mobility Index (MI)								
	Level 1 (Soil to Root)			Level 2 (Root to Stem)			Level 3 (Stem to Root)		
	Barium Stress on *Vigna radiata* (L.) Wilczek.	After Co–Cultivation		Barium Stress on *Vigna radiata* (L.) Wilczek.	After Co–Cultivation		Barium Stress on *Vigna radiata* (L.) Wilczek.	After Co–Cultivation	
		Vigna radiata (L.) Wilczek.	*Brassica juncea* Hk. F. & T.		*Vigna radiata* (L.) Wilczek.	*Brassica juncea* Hk. F. & T.		*Vigna radiata* (L.) Wilczek.	*Brassica juncea* Hk. F. & T.
Control	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
2mM	0.437 ± 0.068	BDL	0.681 ± 0.074	0.055 ± 0.039	BDL	0.380 ± 0.018	1.630 ± 0.072	BDL	1.378 ± 0.090
4mM	0.268 ± 0.002a*	BDL	0.705 ± 0.002a*	0.053 ± 0.017 a*	BDL	0.432 ± 0.039a*	1.496 ± 0.015a*	BDL	1.512 ± 0.043a*
6mM	0.224 ± 0.034a*	0.001 ± 0.055a#	0.704 ± 0.018a*	0.050 ± 0.011a*	BDL	0.436 ± 0.082a*	1.235 ± 0.073a*	BDL	1.656 ± 0.042a*
8mM	0.212 ± 0.075a*	0.003 ± 0.012a#	0.753 ± 0.069a*	0.050 ± 0.047 a*	0.505 ± 0.012a#	0.528 ± 0.010a*	1.065 ± 0.020 a*	0.585 ± 0.0064a*	1.766 ± 0.043a* b*
10mM	0.193 ± 0.031a*	0.003 ± 0.078a#	0.803 ± 0.083a*	0.046 ± 0.053a*	0.449 ± 0.034a#	0.535 ± 0.083a*	1.030 ± 0.014a*	0.516 ± 0.0026a*	1.904 ± 0.016a*

Values are an average of three observations. Mean ± SE, a – refers to value compared with control in various concentrations of metals, a* – refers to significant ($P \leq 0.05$ – Tukey test). a# – refers to non-significant.

BDL – Below Detectable Level, S – R: Soil to Root, R – S: Root to Stem, S – L: Stem to Leaf

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