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BIOACCUMULATION FACTORS (BAFs) FOR TRACE METALS AS INFLUENCED BY OF LIME, COMPOST AND MICROBIAL INOCULANTS UNDER MUSTARD-MAIZE CROPPING SYSTEM IN TRACE METAL CONTAMINATED SOIL OF JHARKHAND

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ABSTRACT
A Farmers' field trial was conducted at Patratu (Ramgarh) to study the effect of lime, compost, plant growth promoting rhizobacteria and arbuscular mycorrhizal fungi on bioaccumulation factors (BAFs) for trace metal in mustard-maize cropping system. Results reveal that inoculation of *Glomus mossae* alone resulted in significantly high value of BAFs for all trace metals. However, low BAFs value was recorded with application of lime + vermicompost, in general. Microbial inoculants alone (*Pseudomonas striata* and *Azotobacter chroococcum*) recorded the significant increase in BAFs value as compared to control while amendments decreased the same in most cases. The order of BAFs for Zn was maize grain > maize straw > mustard grain > mustard stover; for Cu, Mn and Fe maize straw > mustard grain > maize grain > mustard stover; for Cd maize straw > maize grain > mustard stover > mustard grain; for Pb mustard stover > maize straw > mustard grain > maize grain and for Ni: mustard stover > maize grain > maize straw > mustard grain. Bioaccumulation factors for micronutrients were in the order of Zn > Cu > Fe > Mn and that of trace metals were Cd > Ni > Pb > Co.

KEY WORDS: Bioaccumulation factors for trace metals, lime, compost, rhizobacteria, arbuscular mycorrhizal fungi

INTRODUCTION

Contamination of trace metals refers to their anthropogenic accumulation, which may or may not inflict any harm to the system or organism. Pollution is the worst example of contamination where irreversible toxicity-damage has already occurred due to buildup of the toxic substances in the system. Heavy metal pollution, particularly after the reports of infamous *itai-itai* and *minamata* diseases from Japan, has created an environmental scare. In India, arsenic poisoning in human beings and selenium toxicity in the live stock are the two similar examples (Rattan *et al.*, 2005). Anthropogenic sources of trace elements are a consequence of industrial development and urbanization. These sources are related to human activities such as mining and smelter activities, fossil fuel combustion, waste incineration and disposal, agricultural practices like use of fertilizers and pesticides (Adriano *et al.*, 1995). Soil remediation is the return of soil to a condition of ecological stability together with the establishment of plant communities it supports or supported to condition prior to disturbance. One of the effective remediation technologies of metal contaminated soils has been the excavation of soil followed by soil washing and subsequent disposal of treated soils (US Environmental Protection Agency, 1991). Since soil removal is prohibitively expensive and impractical in the context of our country, there is a need to evolve cost-effective indigenous *in-situ* technology. Use of chemical amendments like lime, phosphates and organic matter for scavenging, precipitating and inactivating the heavy metals and plant species capable of hyper-accumulating these metals for alleviating the metal-toxicity seem probable options. Plant based bioremediation technologies have been collectively termed as phytoremediation, refers to the use of green plants and their associated micro biota for the *in-situ* treatment of contaminated soil and ground water (Sadowsky, 1999). The inoculation with plant growth promoting rhizobacteria may facilitate plant growth and thus increase phytoextraction efficiency, although it did not greatly influence metal concentrations in plant tissues, but achieved a much larger above ground biomass harvest, thus resulting in a much higher metal removal (Wu *et al.*, 2006). Arbuscular mycorrhizal fungi are soil microorganisms that establish mutual symbiosis with the majority of higher plants, providing a direct physical link between soil and plant roots (Barera and Jeffries, 1995). Jharkhand has several coal mines. The Damodar river basin is a repository of approximately 46 per cent of the Indian coal reserves. Due to extensive coal mining and rapid growth of industries, soil and water resources have been badly contaminated. Besides mining, coal-based industries like coal washeries, coke oven plant, coal fired thermal power plant, steel plants and other related industries in the region are responsible for degradation of environmental quality.

MATERIALS AND METHODS

A farmer's field experiment was conducted during *rabi* 2009-10 and *kharif* 2010 at Patratu (Ramgarh) to investigate the effect of lime, compost, plant growth promoting rhizobacteria and arbuscular mycorrhizal fungi on bioaccumulation factors (BAFs) for trace metal in trace metal contaminated soil. The soil was sandy loam in texture with pH 6.08, EC 0.07 dS m^{-1}, organic carbon 2.85 g kg^{-1}, DTPA-extractable Cd 0.20 mg kg^{-1}, DTPA-extractable Pb 3.71 mg kg^{-1}, Total Cd 19.5 mg kg^{-1} and Total Pb 58.2 mg kg^{-1}. Mustard (cv. T 59) and maize (cv. PEHM 2) were grown in sequence at the same site with 10 treatments in randomized block design having three replications. Trace metals concentration including Zn, Cu, Mn, Fe, Cd, Pb, Ni and Co in soil and plant samples were analysed. The available trace metal was determined by extracting soil with DTPA (0.005M DTPA, 0.01M $CaCl_2$, 0.1M TEA), pH adjusted to 7.3 with the help of dilute HCl, maintaining 1:2 soil to extractant ratio and shaking for 2 hrs at 120 rpm (Lindsay and Norvell, 1978). For estimation of total trace metal, soil sample was digested in perchloric-hydrofluoric mixture on platinum crucible near to dryness, residue was dissolved in hydrochloric acid (Hesse, 1994) and metal content was determined on Atomic Absorption Spectrophotometer (EICL AAS4139). Oven dried plant sample was digested in mixture of HNO_3:$HClO_4$ in the ratio of 9:4 at 80^0C until a transparent solution was obtained (Allen *et al.*, 1986). The transparent solution was diluted with double distilled water and filtered. The content of trace metal was determined on Atomic Absorption Spectrophotometer (EICL AAS4139) by employing the appropriate hollow cathode lamp. Bioaccumulation factors (BAFs) of plant components was computed as ratio of concentration of metals in plant components to its DTPA-extractable metal content in soil

RESULTS AND DISCUSSION

Data presented in table 1 and 2 indicates that inoculation of *Glomus mossae* alone resulted in significantly high value of bioaccumulation factor for all trace metals under present study. However, low BAF value was recorded with application of lime + vermicompost, in general. Microbial inoculants alone (*Pseudomonas striata* and *Azotobacter chroococcum*) recorded the significant increase in BAF value as compared to control while amendments decreased the same in most cases. Citterio *et al.* (2005) suggested that AMF association enhances the root to shoot metal translocation to sequester the toxic metals in the shoot cell vacuoles by MTs and PCs. Increased Cd – root : shoot ratio in mycorrhizal plants compared to no-mycorrhizal plants was reported by Joner and Leyval (1997).

The order of BAFs for Zn was maize grain > maize straw > mustard grain > mustard stover; for Cu, Mn and Fe maize straw > mustard grain > maize grain > mustard stover; for Cd maize straw > maize grain > mustard stover > mustard grain; for Pb mustard stover > maize straw > mustard grain > maize grain and for Ni: mustard stover > maize grain > maize straw > mustard grain. Bioaccumulation factors for micronutrients were in the order of Zn > Cu > Fe > Mn and that of trace metals were Cd > Ni > Pb > Co. These results show that as far as entry of trace metals to food chain (plant components) is concerned, Cd has greatest potential, followed by Ni, Pb and Co. Higher BAF for Cd compared to Ni and Pb was reported by Sharma *et al.* (2010), however, Rattan *et al.* (2005) observed the greatest potential of Ni for entry in different plants on sewage effluent irrigated soil.

Distribution pattern of trace metals in plant parts indicate better translocation of Zn, Cu, Fe and Mn from shoot to grain, however, restricted translocation of Cd, Ni, Pb and Co was observed. Restricted translocation of Cd in barley (Fecenko *et al*., 1997) and Pb in maize (Berennan and Shelley, 1999) was reported earlier. The mechanism of phloem and xylem transport of Cd in wheat was explained by Herrne and Feller (1997). They found that a minor quantity of Cd was transported to grain via the phloem, while a high percentage of this element was retained in the peduncle. Precipitation of lead as Pb-phosphate in roots restricts its translocation in maize (Berennan and Shelley, 1999).

Bini *et al.* (1995) grouped the plants or plant components on the basis of BAFs value as high accumulator (1 to 10), moderate accumulator (0.1 to 1.0), low accumulator (0.1 to 0.01) and non- accumulator (<0.01). On the basis of mean BAFs value (Fig 1), mustard and maize (both plant component) were high accumulator for Zn, Cu, Fe and Cd, mustard and maize grains were moderate accumulator for Pb and Co while mustard grain was moderate accumulator for Ni. Results are in conformity with Bhadarary *et al.* (2004), Rattan *et al.* (2005), Sekara *et al.* (2005), Shanab *et al.* (2007) and Malayeri *et al.* (2008).

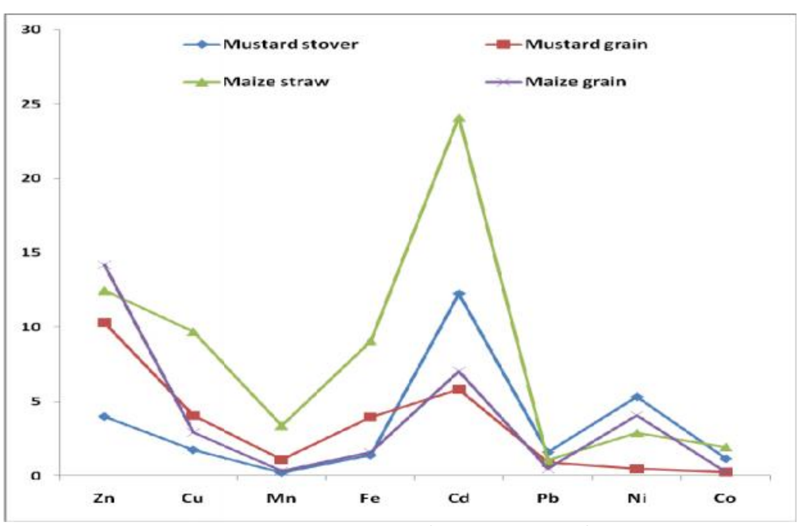

FIGURE 1. Mean bioaccumulation factors (BAFs) for trace metals

TABLE 1: Effect of lime, compost, PGPR and AMF on bioaccumulation factors (BAFs) for Zn, Cu, Mn and Fe

Particulars	Control	Vermi-Compost	Lime		*Pseudomonas striata*		*Azotobacter chroococcum*		*Glomus mossae*		SEm ±	CD (P = 0.05)	CV %
			Alone	VC+	Alone	VC+	Alone	VC+	Alone	VC+			
Zinc													
Mustard Stover	4.00	3.05	3.03	2.71	4.86	4.34	4.62	3.74	5.24	4.26	0.07	0.20	5.92
Mustard Grain	10.18	9.28	9.22	8.85	11.13	10.54	10.95	10.43	11.57	10.82	0.11	0.32	5.90
Maize Straw	9.03	8.88	9.47	9.08	16.22	15.35	13.77	12.35	15.84	14.59	0.42	1.26	10.76
Maize Grain	10.11	10.25	11.34	11.35	17.89	16.87	15.45	14.11	17.91	16.67	0.43	1.28	9.81
Copper													
Mustard Stover	1.75	1.24	1.23	1.18	2.09	1.86	2.05	1.78	2.27	1.93	0.04	0.12	5.30
Mustard Grain	3.94	3.05	3.03	3.03	4.89	4.18	4.75	4.17	5.48	4.17	0.07	0.22	6.37
Maize Straw	6.52	6.98	6.94	7.06	11.64	10.49	11.38	9.73	13.72	12.50	0.38	1.13	11.08
Maize Grain	1.99	2.17	2.10	2.11	3.49	3.16	3.48	2.97	4.20	3.70	0.16	0.46	12.70
Manganese													
Mustard Stover	0.20	0.17	0.16	0.17	0.25	0.22	0.25	0.22	0.28	0.23	0.01	0.02	3.97
Mustard Grain	1.06	0.96	0.96	0.94	1.18	1.10	1.17	1.09	1.24	1.12	0.01	0.03	3.86
Maize Straw	2.62	2.44	2.49	2.48	4.32	3.47	4.34	3.48	4.52	3.60	0.06	0.17	5.25
Maize Grain	0.26	0.24	0.24	0.24	0.43	0.34	0.44	0.34	0.45	0.36	0.01	0.02	4.11
Iron													
Mustard Stover	1.39	1.15	1.18	1.11	1.62	1.43	1.60	1.43	1.66	1.44	0.01	0.03	3.30
Mustard Grain	3.69	3.31	3.33	3.24	4.58	4.02	4.51	3.99	4.63	4.10	0.02	0.06	3.64
Maize Straw	7.46	8.00	8.27	7.93	10.10	9.07	10.34	9.24	10.75	9.50	0.12	0.36	6.98
Maize Grain	1.27	1.19	1.22	1.16	1.89	1.62	2.05	1.66	2.08	1.75	0.03	0.10	5.59

TABLE 2: Effect of lime, compost, PGPR and AMF on bioaccumulation factors (BAFs) for Cd, Pb, Ni and Co

Particulars	Control	Vermi-compost	Lime		*Pseudomonas striata*		*Azotobacter chroococcum*		*Glomus mossae*		SEm ±	CD (P = 0.05)	CV %
			Alone	VC+	Alone	VC+	Alone	VC+	Alone	VC+			
Cadmium													
Mustard Stover	13.10	8.30	8.60	8.03	14.53	13.60	14.13	13.50	15.07	13.70	0.30	0.89	10.85
Mustard Grain	6.30	3.90	4.04	3.78	6.93	6.39	6.77	6.35	7.20	6.44	0.14	0.42	10.24
Maize Straw	12.10	14.32	14.92	14.04	32.07	26.65	32.03	25.66	39.19	30.14	2.32	6.90	12.86
Maize Grain	3.59	4.15	4.32	4.07	9.43	7.71	9.45	7.43	11.54	8.72	0.68	2.02	13.32
Lead													
Mustard Stover	1.53	1.36	1.38	1.33	1.82	1.60	1.80	1.58	1.91	1.63	0.02	0.06	2.54
Mustard Grain	0.80	0.65	0.67	0.62	1.10	0.88	1.08	0.86	1.20	0.91	0.02	0.06	3.51
Maize Straw	0.82	0.79	0.82	0.77	1.27	1.06	1.29	1.08	1.43	1.15	0.02	0.07	3.93
Maize Grain	0.38	0.28	0.30	0.26	0.70	0.51	0.73	0.54	0.79	0.56	0.02	0.06	4.82
Nickel													
Mustard Stover	5.17	4.27	4.33	4.22	6.10	5.56	6.05	5.53	6.22	5.61	0.10	0.31	7.83
Mustard Grain	0.47	0.38	0.39	0.38	0.55	0.50	0.54	0.50	0.56	0.50	0.01	0.03	6.35
Maize Straw	2.28	2.09	2.12	2.07	3.58	3.21	3.52	3.18	3.64	3.23	0.12	0.37	12.63
Maize Grain	3.23	2.96	3.00	2.93	5.07	4.55	4.97	4.49	5.14	4.58	0.18	0.52	13.02
Cobalt													
Mustard Stover	1.18	1.15	1.16	1.15	1.18	1.18	1.18	1.08	1.19	1.08	0.04	NS	6.39
Mustard Grain	0.26	0.25	0.25	0.25	0.26	0.26	0.26	0.24	0.26	0.24	0.01	NS	5.00
Maize Straw	1.69	1.85	1.84	1.85	2.17	2.05	2.14	1.87	2.13	1.86	0.08	NS	8.31
Maize Grain	0.24	0.26	0.26	0.26	0.30	0.29	0.30	0.26	0.30	0.26	0.01	NS	7.86

CONCLUSION

On the basis of present study, it can be concluded that inoculation of *Glomus mossae* alone resulted in significantly high value of bioaccumulation factors for all trace metals. However, low BAF value was recorded with application of lime + vermicompost, in general. Microbial inoculants alone (*Pseudomonas striata* and *Azotobacter chroococcum*) recorded the significant increase in BAF value as compared to control while amendments decreased the same in most cases.

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