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Full Length Research Paper

The effects of farm yard manure on cadmium and lead accretion in Amaranth (*Amaranthus oleracea* L.)

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Two pot experiments were carried out to study the effect of farm yard manure (FYM) on Cd and Pb accumulation by Amaranth. Six levels of FYM (0, 2.5, 5, 10, 15 and 20 t ha^{-1}) were applied to Cd and Pb treated soil separately in the pot experiments. The weight of the shoot and root of Amaranth significantly increased following the application of FYM to both Cd and Pb treated soil. The application of FYM in soil significantly decreased Cd and Pb content in Amaranth. Cadmium content in the shoot and root gradually decreased with the increase in level of FYM up to 20 t ha^{-1}. On the other hand, FYM at 10 t ha^{-1} and above drastically reduced the Pb content in both parts of *Amaranth*. The contents of both Cd and Pb in the shoot and root of Amaranth showed a significantly negative correlation (r = -0.84 to -0.87) with the rates of FYM applied to the soil.

Key words: Farm yard manure (FYM), heavy metal, phytoremediation, cadmium (Cd) uptake, lead (Pb) uptake.

INTRODUCTION

Cadmium (Cd) and lead (Pb) are heavy metals that have adverse effect on the soil quality. Wide areas of earth are polluted by heavy metals which may not be degraded by biotic process and may enter the surface and/or underground water resources and may be absorbed by plants and thus enter the food chain and consequently become hazardous to humans and animals. Major sources of heavy metal inputs to ecosystems are mining, smelting and metallurgical industries, sludge disposal and agricultural practices (Horak and Friesl, 2007). Cadmium and Pb accumulation in plants has a positive correlation with their availability and plant growth inhibition (Greger and Bertell, 1992; Kibria et al., 2006; Kibria et al., 2007). Amelioration and rehabilitation of polluted soils can be achieved by *in situ* treatment, such as phytoremediation or immobilization of metals in soil. Immobilization of metals in soil is aimed to significant reduction of their bioavailability by liming and addition of adsorptive materials such as iron oxides, clay minerals, zeolites and organic matter. The efficiency of the metal immobilization in the soil on reduction of absorption of these metals depends strongly on type of the crop (Hornburg and Brümmer, 1990). Plants that hyperaccumulate metals have attracted attention for many years as geobotanical indicators of mineral deposits. More recently, their ability to extract metals from the soil and to concentrate them in the shoot, has given rise to the idea of practical applications such as phytomining and phytoremediation (Lombie et al., 2000). (Yassen et al., 2007) found that application of Farm yard manure (FYM) significantly decreased Cd concentration (41to 31%) in spinach plant grown on soil without heavy metal application and under contaminated soil conditions. Another study conducted by (Kos et al., 2003) showed that Zn and Cd uptake was 3.3 times higher in Amaranthus spp. compared to the control. Amaranth is a popular leafy vegetable crop in Bangladesh and Cd and Pb pollution of the soil of Bangladesh has been reported by Khan (2001) and Kibria (2008). Of late, integrated nutrient management in Bangladesh involving organic manure and chemical fertilizer had received considerable attention. Farm yard manure (FYM) positively influence crop production (Kaihura et al., 1999), improve soil physical properties (Chen et al., 1996) and can be used to reduce heavy metal hazards in plants (Yassen et al., 2007). With this

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view in mind, the aim of this study was to investigate the effect of FYM on Cd and Pb absorption by Amaranth.

MATERIALS AND METHODS

Pot experiments

Two pot experiments were carried out with Amaranth on sandy loam soil in the net house of the Department of Soil Science, University of Chittagong. The soil was collected from the top 15 cm of an uncontaminated agricultural field of Syedpara at Hathazari Upazilla under Chittagong district of Bangladesh. Soil was air dried and ground to pass through a 2 mm sieve to separate dry roots, grasses and gravels, etc. A portion of the soil passed through 2 mm sieve was retained for laboratory analyses.

In first pot experiment, each earthen pot was filled with 8 kg of soil. Cadmium was applied at 10 mg kg^{-1} soil in 18 pots in solution form as $3Cd(SO_4)_2.8H_2O$. Then FYM was mixed separately with the soil at the rate of 0, 2.5, 5.0, 10.0, 15.0 and 20.0 ton ha^{-1} on air dry weight basis. Each treatment was replicated thrice. The pots were arranged in randomized block design. Second pot experiment was conducted similar to first experiment, however, instead of Cd, Pb was applied at 50 mg kg^{-1} soil in 18 pots in solution form as $Pb(NO_3)_2$. Potted soils mixed with FYM, Cd and Pb were allowed to equilibrate for two weeks in moist condition prior to sowing of seeds. Nitrogen (as Urea), P (as TSP) and K (as MP) were applied in the pots (99 kg N, 18 kg P, 60 kg K ha^{-1} soil). According to Bangladesh Agricultural Research Council (2005) recommendation, half of N and K, and whole of P were applied during soil preparation. The remaining N and K were applied in two equal installments after 2 and 4 weeks of seedling emergence. Healthy and uniform seeds of Amaranth were sown in each pot. After two weeks of seedling emergence, five seedlings were kept in each pot and care was taken to keep uniform seedlings in the pots. Water was applied regularly to the pots to maintain the field capacity of the soils. Plants were harvested after five weeks of sowing seeds. Shoots and roots were separately collected. Roots were washed thoroughly with tap water first to remove adhering soil particles and then with distilled water. Oven dry (at 65°C to constant weight) weights of shoots and roots were recorded.

Soil analysis

The particle size distribution was determined by hydrometer method of Day (1965). Soil pH was measured in a 1:2.5 soil/water suspension with glass electrode pH meter. The organic carbon, cation exchange capacity (CEC), and total elemental analyses were done following the methods described by Jackson (1973). Briefly organic carbon was determined by the wet-oxidation method using potassium dichromate and organic matter content was calculated by multiplying the values with 1.724. The cation exchange capacity (CEC) was determined by saturation with 1 N NH_4OAc at pH 7.0. The soil samples were digested with aqua regia on a sand bath for the determination of total Cd, Pb, Zn, Fe, Mn, P and K. Total nitrogen was determined by micro - Kjeldahl method. Chemicals of analytical reagent grade were used in all the analyses. Phosphorus was determined by vanadomolybdo phosphoric yellow color method in nitric acid system. Potassium was measured by flame photometer and Fe, Mn, Zn, Cd and Pb were determined by flame atomic absorption spectrophotometer (Varian spectra AA-220).

Plant analysis

Oven dried and ground plant samples were digested with a tri-acid mixture (HNO_3, H_2SO_4 and $HClO_4$ mixture at the ratio of 5:1:2) for the determination of Cd and Pb content in the plant tissues (Huq and Alam, 2005). The concentrations of Cd and Pb in the plant digests were measured by atomic absorption spectrophotometer.

Data analysis

Significance of differences among the treatments was evaluated by one way analysis of variance followed by Duncan's multiple range test at the significance level of $p < 0.05$. Pearson's correlation of both Cd and Pb in the shoot and root of Amaranth was determined with the rates of FYM applied to the soil. The statistical software SPSS version 12 (SPSS Inc. 2003) was used in the analysis.

RESULTS AND DISCUSSION

Soil properties

The soil contained 63% sand, 20% silt, 17% clay; and had pH 5.1, organic carbon 0.61%, cation exchange capacity (CEC) 6.43 cmol kg^{-1} soils; total N 0.04%, total P 0.02%, total K 0.26 % and aqua regia extractable Pb 9.6 mg kg^{-1}, Zn 52.02 mg kg^{-1}, Fe 1.472% and Mn 86.90 mg kg^{-1}. While aqua regia extractable Cd was below detection limit (< 0.002 mg kg^{-1}).

Biomass production

The dry matter yields of shoot and root of Amaranth were significantly increased by the addition of FYM to both Cd and Pb treated soils (Table 1). However, there was no significant increase in the dry weight of shoot up to 5 and 2.5 t ha^{-1} FYM application in Cd and Pb treated soil, respectively. An increase of 152 and 231% in the dry weight of shoot and root was observed respectively in Cd treated soil at the highest rate (20 t ha^{-1}) of FYM application in comparison to control. In Pb treated soil, application of FYM at the highest rate (20 t ha^{-1}) increased the shoot and root dry weight by 181 and 209% of the control, respectively.

Cd and Pb accumulation in Amaranth

Cadmium and Pb concentration in Amaranth decreased with increasing rates of FYM added to the soils, with the decrease being more pronounced in shoot for Cd and root for Pb (Table 2). Increasing the rate of FYM addition up to 20 t ha^{-1} gradually reduced the Cd concentration in shoot and root while the addition of FYM at 10 t ha^{-1} and above reduced the Pb concentration to zero in both parts of Amaranth. This decrease may result from the increase of soil sorption capacity in the presence of FYM (He and Singh, 1993a; McBride, 1995; Blum, 1999). The little absorption of Pb by Amaranth may be attributed to its high retention in the soil complex system (Hooda and Alloway, 1994; Berti and Jacobs, 1996).

Table 1. Effects of farm yard manure (FYM) on biomass production (g pot^{-1}) of Amaranth grown in Cd and Pb treated soil.

Treatment (FYM, t ha^{-1})	Biomass production (g pot^{-1})			
	Cd treated soil		Pb treated soil	
	Shoot	Root	Shoot	Root
0	4.25^{d}	0.48^{d}	3.75^{e}	0.51^{d}
2.5	4.59^{d}	0.86^{c}	4.41^{e}	0.87^{c}
5	5.53^{d}	0.91^{c}	5.16^{d}	0.87^{c}
10	7.21^{c}	1.16^{bc}	6.98^{c}	1.14^{bc}
15	8.87^{b}	1.47^{ab}	8.82^{b}	1.39^{ab}
20	10.73^{a}	1.59^{a}	10.54^{a}	1.58^{a}
Significance of F value (P)	0.001	0.05	0.01	0.05

Mean values in the column followed by the same letter(s) are not significantly different according to Duncan's multiple range test (DMRT) ($P \leq 0.05$). Each value is the mean of 3 replicates.

Table 2. Effects of farm yard manure (FYM) on Cd and Pb accumulation in Amaranth grown in Cd and Pb treated soil respectively.

Treatment (FYM, t ha^{-1})	Cd concentration (mg kg^{-1} plant tissue)		Pb concentration (mg kg^{-1} plant tissue)	
	Shoot	Root	Shoot	Root
0	30.36^{a}	49.98^{a}	2.59^{a}	15.42^{a}
2.5	20.57^{b}	40.91^{b}	1.47^{b}	5.58^{b}
5	18.00^{bc}	39.48^{bc}	0.89^{c}	3.75^{c}
10	15.83^{bc}	35.39^{bc}	0.00	0.00
15	13.57^{cd}	30.41^{cd}	0.00	0.00
20	9.26^{d}	24.52^{d}	0.00	0.00
Significance of F value (P)	0.001	0.05	0.01	0.05

Mean values in the column followed by the same letter(s) are not significantly different according to DMRT ($P \leq 0.05$). Each value is the mean of 3 replicates.

The typical behaviour of Pb in contaminated soils includes high retention (McBride, 1995), low mobility (Sheppard and Thibault, 1992) and low bioavailability (Kádár, 1994; Alloway, 1995). This behaviour is associated with its high affinity to soil organic matter (McBride, 1995). Increased adsorption of Cd by soil components with increasing amounts of organic matter has also been reported by others (Christensen, 1989; Eriksson, 1998). Addition of 320 g kg^{-1} organic matter decreased the soil pH by around one pH-unit, but it increased the soil CEC by six fold in the sand and 1.5 fold in the sandy loam and clay loam soil (He and Singh, 1993b). He and Singh (1993a) attributed the decreased Cd concentration in plant with higher levels of organic matter addition was predominantly due to the effect of increasing CEC in soil. In the present study, addition of FYM might cause an increase of soil CEC that have increased the ability of soils to adsorb Cd and Pb ions. He and Singh (1993a) reported that addition of 20 g kg^{-1} organic matter (sphagnum peat) to the sand and sandy loam soil significantly reduced the Cd concentration in ryegrass. Eriksson (1988) also reported that Cd uptake by ryegrass and winter rape was considerably reduced in both sand and clay soils when peat was added, and the reduction in uptake of Cd by plant was more pronounced in the sand than in the clay soil even though the exchangeable Cd did not differ between the two soils. In another study by Kibria et al. (2011), the grain Cd content of rice was significantly reduced by 27% by FYM and 62% by FYM mixed with lime.

A significant negative Pearson's correlation was found between Cd concentration in *Amaranth* and rate of application FYM (r = -0.841 and -0.869 for shoot and root, respectively); and between Pb concentration in Amaranth and FYM (r = -0.859 and -0.868 for shoot and root, respectively) applied to the soil. It indicates a low mobility as well as low availability of Cd and Pb in soil caused by FYM. In both pot and field investigations, Eriksson (1988) also found a negative relationship between the Cd concentration in plants and the organic matter content in soils. Organic matters with suitable reactive groups, such as hydroxyl, phenoxyl, and carboxyl effectively control the adsorption and complex of heavy metals with soil, and the activity of metals in soils (Alloway, 1995). The rise in pH caused by FYM applied in acid soil (Kaihura et al., 1999) would also decrease soil Cd and Pb availability through increasing Cd and Pb adsorption. High pH increases adsorption sites by increasing negative charges on the soil surface and reducing competing cations.

CONCLUSION

Farm yard manure can be a very effective amendment to reduce the accumulation of Cd and Pb in Amaranth and other crops growing on Cd and Pb contaminated soils.

Further research in field condition is needed to fully understand the effects of FYM on crop Cd and Pb accumulation.

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