

EFFECTS OF LEAD ON GROWTH, YIELD AND MINERAL NUTRITION OF RICE (*Oryza sativa* L.)

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Abstract

A pot experiment was conducted to evaluate the effect of lead (50, 100, 150 and 200 mg kg⁻¹) on rice (*Oryza sativa*) and remediation of metal contamination by applying cow dung, poultry litter and lime to alleviate lead toxicity. The lengths, fresh and dry weights of shoot, root and macronutrients decreased with increasing level of lead compared to the control. The maximum reduction was observed in the pots treated with 200 mg kg⁻¹ lead (19.50 and 20.03% for grain, 17.15 and 19.75% for shoot and 17.96 and 30.02% for root on the fresh and dry weight, respectively). The highest reduction in macronutrient content was observed in 200 mg kg⁻¹ lead treated pot where N, P, K, Ca and Mg concentrations were reduced by 31.14, 47.44, 22.49, 21.84 and 31.58% for shoot and 28.95, 55.64, 37.5, 49.33 and 23% for root, respectively. On the other hand lead concentration in roots and shoots were increased with increasing lead treatment compared to the control. Treatments of the amendments (cow dung, poultry litter and lime) had positive effects though cow dung outshining the rest of them. This particular organic matter had considerable decreasing impacts in lead uptake by rice. Cow dung treated pots increased fresh and dry weight by 31.48 and 32.07% for grain, 14.08 and 35.30% for shoot and 57.09 and 34.48% for root compared to pot treated with 100 mg kg⁻¹ lead. Cow dung remediated lead concentration by 48.85, 65.00 and 62.00% for grain, shoot and root, respectively.

Key words: Lead; Amendments; Cow dung; Poultry litter; Lime; Bridhan-49.

INTRODUCTION

Lead toxicity has increased in Bangladesh due to increased disposal of municipal and industrial solid and liquid wastes, vehicle exhausts to the soil (Kibria, 2013). With sharp rise in the use of motor vehicles, use of lead acid battery (LAB) has also increased in Bangladesh and as a result, manufacturing of LAB has also increased proportionally (Ahmad *et al.*, 2014). Workers in these industries are at constant risk of exposure of lead and thus increasing lead content in soil (Ahmad *et al.*, 2014). When lead present at an elevated level in soil, are absorbed by the root system, accumulate in different parts of plants, reduce their growth and impairs metabolism. Lead pollution coats the surface of the leaves and reduces the amount of light reaching it and as a result the growth of crops has become stunted or killing the plants by reducing photosynthesis, inhibiting respiration, encouraging an elongation of plant cells influencing root development by causing pre-mature aging (Chamon *et al.*, 2005a).

Rice seed germination rate and the amount/quality of chlorophyll decrease remarkably with increasing lead concentration. The decrease in grain yield of rice due to lead toxicity was reported by Chatterjee *et al.* (2004).

Lead works as a dangerous neurotoxin to human and animals. WHO (2009) documented that lead exposure accounts for about 0.6% of the global burden of diseases, particularly in developing nations. According to Bangladesh Bureau of Statistics (BBS 2004) throughout the country, 22,480 persons were engaged in the battery recharging/recycling establishments and about one-fourth (24.6%) of them are child workers (5-17 years). There is adequate chance of exposure to lead among the workers as the health of them in these establishments is much neglected leading to the risk of lead contamination and development of severe health hazard.

Trace metal contaminated sites are of a great concern in this rapidly growing trend of urbanization and industrialization and requires remediation of polluted sites. Organic matter amendments are highly

effective because of their inexpensive and ready availability and additional benefits for plant growth and soil properties and the addition of organic matter substantially reduce metal uptake was reported by Bassuk (1986).

Considering the above findings, two separate pot experiments were performed to investigate the effect of lead on growth, yield and nutrition of rice as well as to observe the effect of amendments like cow dung, poultry litter and lime for remediation of lead contamination.

MATERIAL AND METHODS

Pot experiments were conducted at the experimental field of Soil Science Department, Government Bangla College, Mirpur, Dhaka during June, 2011 to June, 2012. The soils used for pot experiments belongs to Belabo series under the Agro-ecological zone, Madhupur Tract (AEZ-28) comprising of moderately well drained, yellow-brown, mottled clays occupying level upland sites. Physical, chemical and physico-chemical properties of the experimental soil were determined (according to Jackson, 1962 and Black, 1965) (texture: silt loam, pH: 6.05, Ec: 105.4 ms, % organic matter: 0.79 and total lead: 10 mg kg⁻¹. (Must quote individual reference for each parameter)

Pot experiments were conducted with uncontaminated above mentioned soil to study the effects of different doses of lead (0, 50, 100, 150, and 200 mg/kg} and the ameliorating effects of cow dung, poultry litter and lime on rice (Bridhan-49). Plastic pots were filled with 8 kg soil with three replications of each treatment and arranged in completely randomized design. Basal dose of fertilizers were added at medium rate for rice (3 plants/pot, another sentence) (BARC 2012) Rewrite mentioning the rates. The crops were harvested at maturity. Treatment of lead was applied as lead acetate (dissolved in water). The treatment combinations are given in Table 1. Second pot experiment was done to follow remediation of lead by using cow dung, poultry litter and lime at the rate of 20, 20 and 5 t/ha, respectively.

Table 1. Treatment combinations for two pot experiments.

Different doses		Amendments	
Treatments		Treatments	
T ₀	0 (Control)	T ₀	0 (Control)
T ₁	50 mg kg ⁻¹ Pb	T ₁	100 mg kg ⁻¹ Pb
T ₂	100 mg kg ⁻¹ Pb	T ₂	100 mg kg ⁻¹ Pb + Cow dung (20 t/ha)
T ₃	150 mg kg ⁻¹ Pb	T ₃	100 mg kg ⁻¹ Pb Poultry litter (20 t/ha)
T ₄	200 mg kg ⁻¹ Pb	T ₄	100 mg kg ⁻¹ Pb Lime (5 t/ha)

Soil samples were digested with HCl:HNO₃ (3:1), and plant samples with a HNO₃:HClO₄ (5:1) mixture in closed systems (Blum *et al.*, 1996). All elements were measured in the extracts by Atomic Absorption Spectroscopy (AAS).

The collected data on plant parameters and mineral nutrition were statistically analyzed by using ANOVA (analysis of variance) and Duncan's Multiple Range Test (DMRT) in IBM SPSS statistics version 20 as outlined by Gomez and Gomez (1984). The letter was used for testing the significant of variation between mean values. The 0.05 level of probability was chosen for the statistical judgment.

RESULTS AND DISCUSSION

Effects of different doses of Lead (Pb) on growth, yield and mineral nutrition of rice (variety: BRRI Dhan-49)

Growth and yield parameters

The mean values of fresh and dry wt (g/pot) of rice grains were affected considerably by different lead treatments (Table 2). The highest fresh and dry weights of grains (33.01 and 23.92 g/pot) were obtained in the control treatment (T₀) where no lead was applied. The lowest values (26.57 and 19.13 g/pot) were obtained with the treatment T₄ (at 200 mg kg⁻¹ Pb). Application of 200 mg kg⁻¹ lead reduced fresh and dry weight of grain by 19.5 and 20%, respectively, compared to the control treatment. The increasing concentration of lead produced lower grain yield of rice compared to the control (Table 2). It was evident from the observed data that lead application significantly reduced the fresh and dry weight of shoot and root with increasing lead treatment from 50 to 200 mg kg⁻¹ of lead/pot.

Table 2a. Effect of different doses of lead on growth and yield parameters of rice.

Treatments	Fresh wt. (g/pot)			Dry wt. (g/pot)			Length (cm/pot)		
	Grain	Shoot	Root	Grain	Shoot	Root	Panicle	Shoot	Root
T ₀ (Control)	33.01 a	68.57 a	23.32 a	23.92 a	25.12 a	4.23 a	25.00 a	106.33 a	26.33 a
T ₁ (50 mg kg ⁻¹ Pb)	33.11 a	65.24 a	23.05 a	22.25 ab	23.17 ab	3.77 ab	23.67 ab	106.00 a	26.33 a
T ₂ (100 mg kg ⁻¹ Pb)	32.53 a	61.71 ab	20.18 b	20.30 ab	21.22 bc	3.69 ab	23.33 ab	103.67 b	22.33 ab
T ₃ (150 mg kg ⁻¹ Pb)	28.47 ab	57.84 b	19.73 b	19.13 b	20.19 c	3.34 ab	23.00 b	102.33 b	21.67 b
T ₄ (200 mg kg ⁻¹ Pb)	26.57 b	56.81 b	17.44 c	19.13 b	20.16 c	2.96 b	22.67 b	100.00 c	21.33 b

Table 2b. Effect of different doses of lead on growth and yield parameters of rice.

Treatments	No. of tiller/3 plant	No. of Panicle/3 plant	No. of grain/panicle	1000 grain wt. (g/pot)
T ₀ (Control)	11.33 a	10.00 a	182.00 a	18.60 a
T ₁ (50 mg kg ⁻¹ Pb)	9.66 b	9.67 a	178.00 a	17.63 ab
T ₂ (100 mg kg ⁻¹ Pb)	9.33 b	9.33 ab	167.00 b	16.90 ab
T ₃ (150 mg kg ⁻¹ Pb)	9.33 b	9.00 ab	159.33 bc	16.40 b
T ₄ (200 mg kg ⁻¹ Pb)	9.00 b	8.33 b	150.33 c	15.87 b

Means followed by the same letter (s) in a column do not differ significantly from each other at 5% level by DMRT

At the highest dose of lead (200 mgkg⁻¹) treated pots, shoot and root length of rice decreased by 6.0 and 19.0%, respectively, compared with the control. The number of tiller/pot and 1000 grains weight (g/pot) of rice differed significantly among different treatment levels. The highest tiller number and 1000 grains weight were found (11.33 and 18.60 g/pot, respectively) in the control treatment and the lowest were (9.00 and 15.87 g/pot respectively,) in the T₄ treatment (at 200 mg kg⁻¹ of Pb).

Mahmood *et al.* (2007) stated that root length of rice seedlings at both 5 and 10 mM lead was significantly less (30-50%) than that of the control seedlings. Ullah *et al.* (2011) also showed that lead toxicity significantly affected fresh and dry weights of grain yield of rice grown in pots. Similarly Kibria *et al.* (2009) found shoot and root weights of *A. gangeticus* and *A. oleracea* declined by 28 and 46% (for shoot) and 53 and 37% (for root) over control at the highest rate (100 mg kg⁻¹) of lead application. Furthermore, the inhibition of root growth may be due to a decrease in calcium in root tips, leading to a decrease in cell division or cell elongation (Eun *et al.*2000). Also Israret *et al.* (2011) found lead induced oxidative stress in *Sesbania drummondii*.

Mineral Nutrients

Application of different doses of lead decreased nitrogen concentration in root and shoot of rice (variety: Bridhan-49) but in case of grain nitrogen concentration increased significantly up to 100 mg kg⁻¹ of lead treated pots and then decreased with increasing level of lead (Table 3) because of antagonistic effect of lead with nitrogen. The maximum amount of P, K and Mg were found in the control (T₀) treatment and the lowest in the 200 mg kg⁻¹ of lead treated pots (T₄) in case of root, shoot and grain (Table 3) because of antagonistic effect of Pb with macronutrients reported by many authors (Sharma and Dubey 2005, Chamon *et al.* 2005a). Calcium concentration in root and grain of rice was significantly decreased by lead application whereas in case of shoot, calcium concentration was less affected.

Table 3a. Effects of different doses of lead on mineral nutrition of Rice.

Treatment	Nitrogen%			Phosphorus%			Potassium%		
	Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
T ₀ (Control)	0.418 a	0.353 a	0.505 d	0.408 a	0.078 a	0.239 a	0.656 a	2.09 a	0.203 a
T ₁ (50 mg kg ⁻¹ Pb)	0.386 a	0.317 b	0.591 b	0.302 b	0.069 ab	0.225 ab	0.630 a	1.83 ab	0.191 ab
T ₂ (100 mg kg ⁻¹ Pb)	0.374 a	0.302 b	0.649 a	0.241 bc	0.062 ab	0.219 abc	0.547 ab	1.80 ab	0.187 ab
T ₃ (150 mg kg ⁻¹ Pb)	0.367 a	0.253 c	0.584 b	0.223 c	0.049 ab	0.203 bc	0.540 ab	1.64 b	0.183 ab
T ₄ (200 mg kg ⁻¹ Pb)	0.297 b	0.241 c	0.558 c	0.181 c	0.041 b	0.198 c	0.410 b	1.62 b	0.171 b

Table 3b. Effects of different doses of lead on mineral nutrition of Rice.

Treatment	Calcium%			Magnesium%			Lead (mg/kg)	
	Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot
T ₀ (Control)	0.446 a	0.403 a	0.028 a	0.213 a	0.152 a	0.096 a	42.5 d	7.5 d
T ₁ (50 mg kg ⁻¹ Pb)	0.392 ab	0.393 ab	0.028 a	0.192 ab	0.117 b	0.090 ab	206 c	7.5 d
T ₂ (100 mg kg ⁻¹ Pb)	0.323 bc	0.360 ab	0.025 a	0.178 ab	0.107 b	0.084 bc	341 c	20.00 c
T ₃ (150 mg kg ⁻¹ Pb)	0.278 cd	0.319 b	0.022 ab	0.174 ab	0.105 b	0.086 cd	613 b	30.00 b
T ₄ (200 mg kg ⁻¹ Pb)	0.226 d	0.315 b	0.018 b	0.164 b	0.104 b	0.075 d	1577 a	43.17 a

Means followed by the same letter (s) in a column do not differ significantly from each other at 5% level by DMRT

Kibria *et al.* (2009) reported that lead application in soil significantly increased Pb concentration in shoot of *A. oleracea*. On the contrary Ullah *et al.* (2011) reported an antagonistic effect on nitrogen uptake by rice due to application of lead. These variation in N concentration in root, shoot and grain of rice, probably due to difference in plant variety. In most cases, lead blocks the entry of N, P, K, Ca and Mg in the root system (Sharma and Dubey 2005, Chamon *et al.* 2005a).

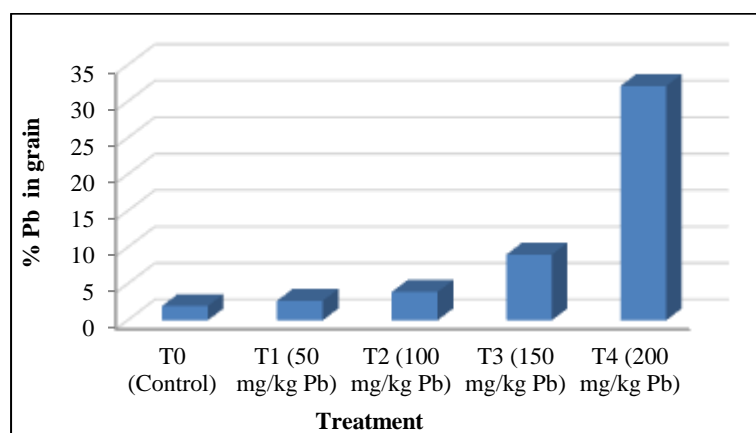


Fig. 1. Effects of different levels of lead in rice grain

Lead concentration

Lead application in soil significantly increased the lead concentration in root, shoot and grain of rice (variety: Bridhan-49) (Fig. 1). Lead concentration in root, shoot and grain appears to be very high. At 200 mg kg⁻¹ of lead treatment the Pb concentration were found to be 1577, 43.17 (Table 3) and 32.13 mg/kg (Fig. 1) in root, shoot and grain, respectively. Different parts of the plant absorb different quantities of heavy metals; the higher values were found in roots and leaves and the least amounts were found in fruits and seeds as reported by Natasa *et al.* (2015). Accumulation and distribution of lead in the plants depend on the plant species, the element species and bioavailability, pH, cation exchange capacity, atmospheric condition, vegetation period and multiple other factors (Chamon *et al.* 2005a).

Growth, yield and mineral nutrition of Rice (variety: Bridhan-49), influenced by different amendments

Growth and yield parameters

Fresh and dry weights of grain (g/pot) of rice (variety: Bridhan-49) was considerably affected by the application of different amendments which were artificially contaminated with 100 mg kg⁻¹ of lead (Table 4a).

Table 4a. Effects of different amendments on growth and yield parameters of rice (variety: Bridhan-49).

Treatment	Fresh wt. (g/pot)			Dry wt. (g/pot)			Length (cm/pot)		
	Grain	Shoot	Root	Grain	Shoot	Root	Panicle	Shoot	Root
T0 (Control)	33.01 b	66.57 ab	23.32 b	23.92 b	25.12 b	4.23 a	25.00 a	106.33 ab	26.33 a
T1 (100 mg kg ⁻¹ Pb)	32.53 b	61.70 b	20.18 b	20.30 b	21.22 c	3.77 a	23.33 b	103.67 b	21.67 ab
T2 (100 mg kg ⁻¹ Pb+ cowdung (20 t/ha))	42.77 a	70.39 a	31.70 a	26.81 a	28.71 a	5.07 a	25.33 a	108.00 a	25.00 ab
T3 (100 mg kg ⁻¹ Pb+ poultry litter (20 t/ha))	36.18 b	63.84 ab	20.43 b	23.38 b	24.07 bc	3.86 a	24.33 ab	105.67 ab	21.00 ab
T4 (100 mg kg ⁻¹ Pb+ lime (5t/ha))	37.61 ab	59.80 b	19.82 b	23.02 b	21.14 c	3.48 a	25.00 a	104.64 ab	19.67 b

Application of 100 mg kg⁻¹ of lead decreased 1.5 and 15.1% fresh and dry weight of grains compared to the control. Among amendments cow dung increased by 31.5 and 32.1% fresh and dry weight of grain compared with 100 mg kg⁻¹ lead treatments. This might be due to the ameliorating effect of cow dung against lead toxicity hence increase yield of rice grain.

However, in case of fresh weight of shoot, treatment did not differ significantly. The highest fresh and dry weight was observed in cow dung (31.70 and 5.07 g/pot) and the lowest in lime (19.82 and 3.48 g/pot) treatment. Cow dung and poultry litter treatments increased fresh and dry weights of root whereas lime decreased the root biomass production (Table 4a).

Application of lead significantly declined the number of tiller/pot, panicle/pot and 1000 grain weight (g/pot) compared with the control treatment (Table 4b). The highest number of tiller/pot and panicle/pot were observed in pots treated with cow dung followed by lime and poultry litter. Cow dung treated pots also showed the highest 1000 grains weight followed by poultry litter and lime.

Overall it was evident that cow dung has a splendid role in reducing lead toxicity in rice growth parameters. Similar results were reported previously by many authors (Chamon *et al.* 2005b, Mondol *et al.* 2019, Mahajabin *et al.* 2019). Nuruzzaman *et al.* (1995) observed that the dry matter yield of rice grain was increased by 27% by 40 Mt cow dung/ha. Application of poultry litter and used tea leaves as organic amendments enhanced the growth of red amaranth (Mondol *et al.* 2019).

Table 4b. Effects of different amendments on growth and yield parameters of rice (variety: Bridhan-49).

Treatment	No. of tiller/3 plant	No. of Panicle/3 plant	No. of grain/panicle	1000 grain wt. (g/pot)
T0 (Control)	11.33 b	10.00 c	178.00 ab	18.60 a
T1 (100 mg kg ⁻¹ Pb)	9.33 c	9.33 c	167.00 b	16.93 b
T2 (100 mg kg ⁻¹ Pb+ cowdung (20 t/ha))	14.67 a	14.67 a	196.67 a	19.28 a
T3 (100 mg kg ⁻¹ Pb+ poultry litter (20 t/ha))	10.00 c	9.67 c	196.00 a	18.39 a
T4 (100 mg kg ⁻¹ Pb+ lime (5 t/ha))	12.33 b	11.67 b	189.33 ab	18.16 a

Means followed by the same letter(s) in a column do not differ significantly from each other at 5% level by DMRT

Mineral nutrients

Application of lead reduced nutrient concentration in root, shoot and grain of rice when compared with the control but with addition of amendments macronutrient concentration increased in comparison with the unamended pots (Table 5a). Nitrogen concentrations in root and shoot were decreased by 10.52 and 14.44%, respectively and increased by 28.76% in grain with application of 100 mg kg⁻¹ of lead treatment compared with the control. The highest concentration was observed with cow dung followed by poultry litter and lime in root and shoot but in grain, the highest concentration being observed with cow dung followed by lime and poultry litter, respectively.

Table 5a. Effects of different amendments on mineral nutrition of Rice (variety: Bridhan- 49).

Treatment	Nitrogen%			Phosphorus%			Potassium%		
	Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
T0 (Control)	0.418 c	0.353 b	0.504 e	0.408 c	0.078 b	0.239 c	0.656 a	2.09 a	0.203 b
T1 (100 mg kg ⁻¹ Pb)	0.374 d	0.302 c	0.649 d	0.241 d	0.062 b	0.219 c	0.540 ab	1.80 a	0.187 b
T2 (100 mg kg ⁻¹ Pb+ cowdung (20 t/ha))	0.514 a	0.408 a	0.854 a	0.497 a	0.133 a	0.432 a	0.623 ab	1.91 a	0.427 a
T3 (100 mg kg ⁻¹ Pb+ poultry litter (20 t/ha))	0.490 ab	0.396 ab	0.713 c	0.456 b	0.098 ab	0.393 a	0.496 b	2.01 a	0.530 a
T4 (100 mg kg ⁻¹ Pb+ lime (5t/ha))	0.461 b	0.371 ab	0.738 b	0.384 b	0.077 b	0.310 b	0.537 ab	2.09 a	0.483 a

Table 5b. Effects of different amendments on mineral nutrition of Rice (variety: Bridhan- 49).

Treatment	Calcium%			Magnesium%			Lead (mg/kg)		
	Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
T0 (Control)	0.446 c	0.403 a	0.028 a	0.213 b	0.152 b	0.096 a	42.5 d	7.5 b	1.96 c
T1 (100 mg kg ⁻¹ Pb)	0.323 d	0.360 a	0.025 ab	0.178 b	0.107 c	0.084 c	341 a	20.00 a	3.93 a
T2 (100 mg kg ⁻¹ Pb+ cowdung (20 t/ha))	0.691 ab	0.371 a	0.024 ab	0.333 a	0.195 a	0.098 a	210 c	7.00 b	2.01 c
T3 (100 mg kg ⁻¹ Pb+ poultry litter (20 t/ha))	0.661 b	0.348 a	0.018 b	0.213 b	0.156 b	0.093 ab	291 b	7.5 b	3.81 a
T4 (100 mg kg ⁻¹ Pb+ lime (5 t/ha))	0.701 a	0.379 a	0.024 ab	0.201 b	0.161 b	0.075 c	229 c	7.5 b	3.02 b

Means followed by the same letter(s) in a column do not differ significantly from each other at 5% level by DMRT

Cow dung treatment increased nitrogen concentrations by 22.96, 15.58 and 69.44% in root, shoot and grain, respectively, compared with the control and 37.43, 35.09 and 31.58%, respectively, compared with 100 mg kg⁻¹ lead treatment. The concentration of phosphorus in root, shoot and grain of rice were decreased significantly with addition of 100 mg kg⁻¹ of lead treatment. The highest was observed in cow

dung treated pots (0.497, 0.133 and 0.432%) in root, shoot and grain, respectively. Cow dung, poultry litter and lime treatment increased phosphorus concentration.

Potassium concentration in grain was significantly influenced by the application of amendments. Application of 100 mg kg⁻¹ of lead decreased potassium concentration in root, shoot and grain. In root, the highest potassium concentration was observed with cow dung treatment followed by lime and poultry litter. In shoot, the highest potassium concentration was observed with lime application followed by poultry litter and cow dung. Application of 100 mg kg⁻¹ of lead reduced the calcium concentration of rice root, shoot and grain. Among amendments the highest was observed with lime treatment which was 57.17% and 117.02% higher than control and 100 mg kg⁻¹ lead treatments in root, respectively. Application of lead decreased 16.43, 29.60 and 12.5% magnesium concentration of rice root, shoot and grain, respectively, compared with the control treatment. The highest concentration of magnesium was observed with cow dung treatment in root, shoot and grain and was significantly differed from other treatments. In root, application of cow dung increased 56.33% and lime decreased 5.63% magnesium concentration compared with the control and 87.07, 19.66 and 12.92% increased, with cow dung, poultry litter and lime treatments, respectively, compared with 100 mg kg⁻¹ lead treatments (Table 5a and 5b).

Lead concentration

Lead concentration in rice (variety: Bridhan-49) root, shoot and grain as affected by different amendments are presented in Table 5. Application of lead (100 mg kg⁻¹) increased 16.43, 29.60 and 12.5% lead concentration in rice root, shoot and grain, respectively, compared with the control treatment. Lead concentration in root ranged between 42.5 to 341 mg kg⁻¹ which was above the maximum permissible limits in plants according to Sauerbeck (1982) (MPL for plants in general 10-20 mg kg⁻¹). Soil amended with cow dung, poultry litter and lime reduced lead concentration in rice root, shoot and grain, probably due to binding up of lead rendering it less available to plants by organic manures. There might be an antagonistic effect of calcium on lead uptake by rice plants due to lime addition. Cow dung, poultry litter and lime decreased lead concentration by 38.41, 14.66 and 32.84% in root and 65.0, 62.5 and 62.5% in shoot and 48.85, 3.05 and 23.15% lead concentration in grain compared with 100 mg kg⁻¹ lead treatment (Table 5).

All amendments decreased lead concentration in rice. Amongst amendments cow dung had the greatest ability to reduce lead toxicity in root, shoot and grain and followed by lime and poultry litter. The similar effects were found while reducing lead toxicity of wheat using farm yard manure (FYM) and poultry manure by Rehman *et al.* (2017). Chamonet *al.* (2005b) reported that all organic materials can be classified as less contaminated and suitable for agricultural use according to their heavy metal concentrations. The better role of organic amendment in reducing lead uptake than lime was also reported by Mahajabinet *al.* (2019).

Cow dung as an amendment worked against lead toxicity which is evident from the above findings. It is well known that organic matter is not only an aggregating agent, but also an improver of soil structure and the stability (Vaughan and Malcolm, 1985). Also soil organic matter adsorbs available lead ions, producing and preserving forms of lead that are less available for plant uptake or leaching (Zehetner and Wenzel 2000).

Different parts of the plant absorb different quantities of heavy metals; the highest were shown in roots and leaves and the least amount were found in fruits and seeds reported by Natasa *et al.* (2015). The different accumulation rate among different parts of the rice plant was most probably caused by the restricted translocation of toxic metals between roots and shoots (Brekken and Steinnes 2004). The restriction in the translocation of lead from roots to shoots and other above ground parts can be

explained by a metal exclusion mechanism in roots by which plants avoid damages in their photosynthetic processes (Borisev *et al.* 2008). It was assumed that mycorrhizal associations can greatly reduce metal translocation from roots to shoots by binding metals on cell wall components or intracellular immobilization (De Maria *et al.* 2011).

Lead contamination above toxic level in plants reduces its productivity hence its overall growth and yield. Its remediation must be undertaken for protecting our natural environment as well as to ensure a stable and toxic free food source. Therefore it is a must to conduct suitable and appropriate research programs for remedying lead induced toxicity by using various amendments (both organic and inorganic) as well as encourage public awareness to reduce the contamination.

From this study it can be concluded that the amendments used were suitable for controlling lead contamination and increasing yield. Lead contamination in the grain, shoot and root was ameliorated significantly by applying the amendments especially cow dung which is available and affordable and has positive influence in improving the physical and chemical properties of soil as well as the other two additives. Overall the inflow of metals in agricultural fields needs to avoid, otherwise it will contribute to accumulate metals in human tissues through food chain transfer. Most importantly social awareness must be encouraged to reduce lead toxicity as most of this pollution occurs through anthropogenic causes.

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