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EFFECTS OF LEAD ON GROWTH AND MINERAL NUTRITION OF WHEAT (*Triticum aestivum* L.) AS INFLUENCED BY MANURE AND LIME

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Abstract

A pot experiment was conducted to evaluate the effects of four levels of lead (50, 100, 150 and 200 mg/kg) treatment on wheat (*Triticum aestivum* L.) and its amelioration by cowdung, poultry litter and lime. The lengths, fresh and dry weights of shoot and root decreased with increasing level of lead as well as the macronutrients compared to the control. The maximum reduction was observed in the pots treated with 200 mg/kg lead. The highest reduction in macronutrient content was also observed in 200 mg/kg Pb treated pot whereas N, P, K, Ca and Mg concentration was reduced by 0.41, 0.019, 1.15, 0.38 and 0.071% for shoot and 0.512, 0.071, 0.17, 0.51 and 0.122% for root, respectively. Lead concentration in roots and shoots increased with increasing level of lead treatment compared to the control. Cowdung was shown to be most effective, followed by poultry litter and lime. This particular organic manure had considerably greater decreasing impacts in lead uptake by wheat crops. Cowdung treated pots increased fresh and dry weight by 14.56 and 13.28% for grain, 7.58 and 7.08% for shoot and 2.41 and 2.06% for root compared to pot treated with 100 mg/kg lead.

***Key words*:** Amendments, Bari wheat-26, Cowdung, Lead, Lime, Poultry litter.

INTRODUCTION

In Bangladesh, heavy metals pollution from industrial wastages is one of the most burning issues nowadays due to rapid industrialization (Bhuyan and Bakar 2017). There are around 30,000 small and large industrial units in Bangladesh (Rahman 1992). Untreated waste and effluents of these industries are discharged into the natural ecosystem, thus causing environmental pollution especially with heavy metals and organic toxics. These hazardous wastes and effluents are generally discharged in open water bodies, along roadside, or in the vicinity of the industrial installation. Industrial effluents and wastes lead to significant pollution of soils and plants around Dhaka city (Chamon *et al.* 2005). The important heavy metals discharged from industries in Bangladesh are cadmium (Cd), lead (Pb), chromium (Cr), mercury (Hg), zinc (Zn), arsenic (As) and in few cases copper (Cu) and manganese (Mn) (Gerzabek and Ullah, 1990; Chamon *et al.* 2005*).* These metals, even in a trace amount, interfere with or inactivate enzymes of living cells (Kosobrukhov *et al.* 2004).

Among heavy metals, lead is one of the major contaminants found in soil, sediments, air and water. Lead (Pb) pollution in Bangladesh soils has increased because of increased disposal of municipal and industrial solid and liquid wastes, vehicle exhausts to the soils (Chamon *et al.* 2005). Lead is a toxic element that can be harmful to plants, but plants usually show the ability to accumulate large amounts of Pb without visible changes in their appearance or yield (Adriano *et al.* 1997). Heavy metals when present at an elevated level in soil are absorbed by the root system, accumulate in different parts of plants, reduce their growth and impair metabolism (Saini and Gupta 2001).

Diffuse distribution of metals, remediation also generally include amelioration of soils to minimize the metal bioavailability (Adriano *et al.* 1997). Organic matter amendments are preferred because of its effectiveness, inexpensive availability, and additional benefits for plant growth and soil structure. The addition of organic matter substantially reduces Pb uptake (Bassuk 1986). Chamon *et al*. (2005) reported that cowdung and poultry litter amendment showed a reduction of Pb content in rice. The addition of lime decreased the availability of Pb to plants (Adriano *et al.* 1997). The aim of this work as to study the effect of different doses of Pb (lead) on growth and yield of wheat (*Triticum aestivum* L.) and its amelioration by cowdung, poultry litter and lime.

MATERIAL AND METHODS

Pot experiments were conducted with soils (0-15 cm depth) collected from Mirpur Govt. Bangla College belongs to Belabo series. The properties of the soil such as pH , EC, OM, textural class, total N, P, K, Ca, Mg, Pb and CEC were 6.25, 92.6 mS, 0.72%, Silt loam, 0.04%, 0.069%, 0.60%, 0.242%, 0.66%, 8 mg/kg and 5.63 meq/100 g soil, respectively. Soil organic carbon was determined volumetrically by wet oxidation method of Walkley and Black as described by Piper (1950) and Jackson (1962) and other parameters by the methods described by Black (1965) and Jackson (1962). Pots were filled with 8 kg soil. Basal dose of fertilizer was added at a low rate i.e. N as Urea 262 kg/ha, P as TSP 55 kg/ha, K as KCl 94 kg/ha, Gypsum 34 kg/ha and Boric acid 4 kg/ha for Bari wheat-26 (3 plants/pot) (BARC 2012). The soil was mixed with different doses of lead as lead acetate. Treatments with three replications were 0, 50, 100, 150 and 200 mg/kg Pb, respectively.

Together with 100 mg/kg Pb with each of cowdung 20 t/ha, poultry litter 20 t/ha, lime 5 t/ha were added as remedial measures having 3 replications in second experiment. The pots (3 plants/pot) of both the experiments were arranged in a completely randomized design. The plants were irrigated with tap water whenever required. The crops were harvested at maturity.

Soil samples were digested with $HCl+HNO_3$ (3:1) mixture under closed system (Blum 1996). Aqua regia decomposes nearly almost all complex forming soil through which most of the ions go into solution and can be measured quantitatively and plant samples were digested with a HNO_3: $HClO_4$ (5:1) mixture in a closed systems (Blum 1996). One gram of finely ground plant sample was digested with 10 ml conc. HNO_3 and 2 ml conc. $HClO_4$.

Lead was determined in the extracts by atomic absorption spectroscopy (AAS) (Varian AA 240). The results of the experiments were statistically analyzed by ANOVA and Duncan's Multiple Range Test (DMRT) in IBM SPSS statistics version 20.

RESULTS AND DISCUSSION

Growth and yield

The fresh and dry weight (g/pot) of wheat (variety: Bari wheat-26) grain varied considerably with different Pb levels (Table 1). The highest and lowest dry weight of grains (4.1 and 2.5 g/plant) was obtained where 50 and 200 mg/kg of lead was applied. At the highest dose of Pb application (200 mg/kg), dry weight of grain decreased by 24.2%, compared with that of the control. The maximum dry weight of shoot/plant was (1.9 g) obtained in the control treatment and the lowest value was (1.5 g) in the treatment T_4 (at 200 mg/kg Pb). The dry weight of shoot plant^{-1} was decreased with increasing Pb concentration and followed the sequence $T_1>T_2>T_3>T_4>T_5$. At the highest dose of Pb application (200 mg/kg), dry weight of shoot decreased by 21%, compared with the control.

The highest dry weight of root plant^{-1} was (0.47g) in the control (T_1) treatment where no lead was applied. The lowest dry weight of root plant^{-1} was (0.23 g) was obtained in the T_4 treatment, at 200 mg/kg Pb. At the highest dose of Pb application (200 mg/kg), dry weight of root decreased by 50.6%, compared with the control. The length of shoot and root ranged from 74.33 to 78.67 and 9.50 to 13.33 cm, respectively. The maximum and the minimum length of shoot and root were obtained in control and 200 mg/kg of Pb treatments. The number of tiller plant^{-1} was not varied significantly and 1000 grains weight (g) varied significantly of wheat at different levels of lead (Table 1). The highest tiller number and 1000 grains weight were found (2.2/plant and 42.39 g/pot) in the control treatment and the lowest was (2.1/plant and 39.06 g/pot) in the 200 mg/kg of Pb treatment. The above results indicated that the tiller number and 1000 grains weight of wheat declined with increasing level of Pb.

Dry weight of grain was decreased by the application of highest dose of Pb application (200 mg/kg). This might be due to Pb toxicity was exerted in higher concentration, which caused a significant decline in grain production of wheat. The growth inhibition under Pb-stressed condition was similar to previously reported by Mesmar and Jabber (1991) in wheat. Saini and Gupta (2001) reported that yield of grain of wheat increased significantly with an application of 5 mg Pb kg^{-1} and it decreased at higher levels of Pb application.

Table 1. Effects of different doses of lead (Pb) on growth and yield parameters of wheat.

Treatments Pb (mg/kg)	Shoot length (cm)	Root length (cm)	No. of tiller/ plant	No. of panicle/ plant	1000 grain wt. g/plant	Dry wt. of Grain g/plant	Dry wt. of shoot g/plant	Dry wt. of Root g/plant
Control	78.7a	13.3a	2.6a	2.6a	14.3a	3.3b	1.9a	0.47a
50 mg/kg	77.3b	13.3a	2.4a	2.4ab	13.6b	4.1a	1.9a	0.43a
100 mg/kg	77.0bc	10.7b	2.2a	2.2ab	13.5b	3.0b	1.9a	0.37a
150 mg/kg	75.1 d	10.3b	2.2a	2.2ab	13.3bc	2.7b	1.6b	0.26b
200 mg/kg	74.3e	9.5b	2.1a	2.1b	13.0c	2.5b	1.5c	0.23b

Mean values with the same letter (s) do not differ significantly from each other at 5% level by DMRT

The reduction of biomass by Pb toxicity could be the direct consequences of the inhibition of chlorophyll synthesis and photosynthesis (Chatterjee *et al.* 2004). Similar phenomena were also described by Kosobrukhov *et al.* (2004) and Bhatti *et al.* (2013) in wheat. Du *et al*. (2010) also reported the treatments of low Pb concentrations which was <100 mg/kg, stimulate the growth of wheat shoot seedlings and the high Pb concentrations, which was >200 mg/kg, inhibit seedlings growth. Bhatti *et al.* (2013) reported that Pb treatment had reduced the fresh and dry weight of wheat root significantly at both treatments (40 and 60 mg/kg) as compared to the control. Shoot and root length decreased due to reduction of meristematic cells in the shoot and root region by the accumulation of Pb. Significant inhibition of root length of wheat seedling at higher Pb was also reported (Chamon *et al.* 2005). Bhatti *et al.* (2013) reported that Pb treatment had reduced the number of tillers in wheat varieties and the results of this experiment are in agreement with above. The decline in nitrogen concentration due to Pb may be as a result of moisture stress and antagonistic effect created by Pb (Burzynisky 1984).

Mineral nutrition of wheat

The chemical analysis of shoot, root and grain of wheat clearly reflected the lead toxicity due to application of high lead concentration. Nitrogen, P, K, Ca and Mg concentration in wheat shoot, root and grain were decreased significantly (Table 2). The concentration of N, P, K, Ca, and Mg ranged from 0.41-0.83, 0.02-0.06, 1.15-1.99, 0.38-0.53 and 0.71-0.09% respectively in shoot; 0.51-0.64, 0.07-0.13, 0.17-0.46, 0.51-0.79 and 0.12-0.19% respectively in root and 1.21-2.02, 0.21-0.47, 0.45-0.58, 0.02-0.03 and 0.07-0.09% respectively in grain. The concentration of lead increased in shoot, root and grain due to increasing application of lead (Table 2).

Phosphorus concentration was lower in the pots containing higher Pb concentration due to the ability of Pb to form insoluble phosphates in plant tissue. Similar results were found by Lamhamdi *et al. (*2013) for wheat. Bhatti *et al.* (2013) observed a negative correlation between P uptake and lead concentration in the soil. Shoot accumulated more potassium than root and grain. Similar results were also found by Lamhamdi *et al. (*2013) and Bhatti *et al*. (2013) in wheat. The decrease in Ca and Mg concentration might be due to interaction of Pb with Ca in soil and Ca became less available to wheat. Similar results were also found by Lamhamdi *et al. (*2013). The absorbed Pb was localized to a greater extent in roots than in shoot and grain. Such a situation was also observed in wheat (Lamhamdi *et al.* 2013). Du *et al*. (2010) reported that the concentrations of Pb in both shoot and roots increased with the increasing treated Pb levels and the Pb taken up by the wheat seedlings was mainly accumulated in the roots, and only a little is transported to the shoots.

Table 2. Effects of different doses of lead (Pb) on mineral nutrition of wheat.

Treatments Pb (mg/kg)	Nitrogen %			Phosphorus %			Potassium %		
	Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Control	0.64a	0.83a	2.02a	0.13a	0.05a	0.47a	0.45a	1.99a	0.58 a
50 mg/kg Pb	0.59b	0.64b	1.93a	0.12a	0.04ab	0.44b	0.46a	1.99a	0.57 a
100 mg/kg Pb	0.57bc	0.51c	1.82a	0.11ab	0.04bc	0.42c	0.27b	1.85ab	0.52 ab
150 mg/kg Pb	0.56c	0.46cd	1.73a	0.01b	0.03bc	0.40d	0.21b	1.60b	0.50 ab
200 mg/kg Pb	0.51d	0.41d	1.21b	0.07c	0.02c	0.21e	0.17b	1.15c	0.45 b
Treatments Pb (mg/kg)	**Calcium %**			**Magnesium %**			**Lead %**		
	Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Control	0.79a	0.53 a	0.03 a	0.19 a	0.09a	0.09a	54.86e	19.0 c	6.72 c
50 mg/kg Pb	0.67ab	0.51ab	0.03a	0.18 a	0.09 b	0.09a	72.83 d	24.6 c	7.84 c
100 mg/kg Pb	0.61bc	0.50 ab	0.03 a	0.13 b	0.08 c	0.90 ab	183.6 c	38.0 b	15.60 b
150 mg/kg Pb	0.57bc	0.43 a	0.02 b	0.12 b	0.08 d	0.07 b	215.0 b	42.6 b	30.42 a
200 mg/kg Pb	0.51 c	0.38 b	0.02 b	0.12 b	0.07 e	0.07 b	647.8 a	54.0 a	35.67 a

Mean values with the same letter (s) do not differ significantly from each other at 5% level by DMRT

Effect of amendments

The highest shoot and root length (80.50 and 15.33 cm) were observed in cowdung treatment followed by poultry litter and lime; and for 1000 grain weight, the highest (15.48 g/plant) was noted in lime treatment followed by cowdung and poultry litter. Shoot length in cowdung was 2.3% and 4.1% higher than control and 100 mg/kg Pb treated pots respectively and for 1000 grain weight of wheat in lime, cowdung and poultry litter treatment was 8.2, 1.4 and 0.6% and 14.4, 7.2 and 6.4% for control and 100 mg/kg Pb treated pots, respectively. The effect of amendment along with and without lead on growth, yield and mineral nutrition of wheat (wheat-26) varied appreciably (Table 3). The amended pots increased significantly both fresh and dry weight of grain, shoot and root compared with control and 100 mg/kg Pb treated pots (Table 3).

Table 3. Effects of different ameliorating amendments on growth and yield parameters of wheat.

Treatments Pb (mg/kg)	Fresh wt. of Grain	Fresh wt. of Shoot g/plant	Fresh wt. of Root g/plant	Dry wt. of Grain	Dry wt. of Shoot	Dry wt. of Root g/plant
control	3.57 bc	2.2ab	0.60ab	3.27bc	1.88ab	0.47a
100 mg/kg Pb	3.49 c	2.0b	0.40b	3.03c	1.87b	0.37b
100 mg/kg Pb+ cowdung(20 t/ha)	4.85 a	2.53a	0.80a	4.43a	2.36a	0.69a
100 mg/kg Pb + Poultry litter (20 t/ha)	4.85 a	2.44ab	0.58ab	4.0ab	2.27a	0.38b
100 mg/kg Pb + Lime (5 t/ha)	4.09abc	2.18ab	o.45b	3.73ab	2.06ab	0.39b

Treatments Pb (mg/kg)	Shoot length (cm)	Root length (cm)	No. of tiller/ plant	No. of panicle/ plant	1000 grain wt. g/plant
Control	78.67b	13.33bc	2.56a	2.56a	14.31b
100 mg/kg Pb	77.33b	10.67d	2.22a	2.22a	13.53b
100 mg/kg Pb + cowdung (20 t/ha)	80.50 a	15.33a	2.56a	2.56a	14.51ab
100 mg/kg Pb + poultry litter (20 t/ha)	79.00ab	14.33ab	2.44a	2.50a	14.40b
100 mg/kg Pb + lime (5 t/ha)	78.01b	12.67c	2.44a	2.50a	15.47a

Mean values with the same letter (s) do not differ significantly from each other at 5% level by DMRT

Fresh and dry weight of grains, roots and shoots were the highest in the pots receiving cowdung and poultry litter followed by lime, control and 100 mg/kg Pb treated pots. Cowdung and poultry litter treated pots showed 36.1% and (25.3% and 20.4%) higher in FW (grain) and DW (shoot) respectively compared with the control and 38.9% (FW grain), (26.4%, 20.1%) for DW shoot and (85.6%, 2.7%) for DW root compared with 100 mg/kg Pb treatment.

The positive influence of organic substances on plant growth is well known phenomenon, which is due to indirect effects of humic substances acting as suppliers and regulators of plant nutrients and due to direct effects of humic substances (e.g. as respiratory catalysis) (Gerzabek and Ullah 1990). Cowdung and poultry litter were the most efficient ameliorators of Pb-toxicity with respect to fresh and dry weight of shoot (g plant^{-1}). Chamon *et al.* (2005) reported that fresh and dry weight of shoot of wheat was enhanced by 24 and 38% in lime treated than unlimed pot compared with contaminated soil. Root biomass increased by the application of cowdung, lime and poultry litter along with 100 mg/kg of Pb. Saini and Gupta (2001) reported that application of FYM enhanced root weight by 22.1 and 8.4% in sandy and clay loam soil respectively. Reduction in shoot and root length due to heavy metal toxicity was reported previously (Gerzabek and Ullah 1990). Chamon *et al.* (2005) reported that shoot length of wheat was significantly higher by 39% in limed than unlimed pots with contaminated soil.

Mineral nutrition

Nitrogen, potassium and calcium concentration increases significantly in root, shoot and grain by the application of cowdung followed by the poultry litter and lime added treatments (Table 4). The highest P concentration was observed in the cowdung amended pot followed by poultry litter in root, shoot and grain but the lime treated pots decreased P concentration in grain of wheat. Magnesium concentration in root, was increased in the cowdung, poultry litter and lime amended pots and in case of shoot Mg concentration was decreased by cowdung and poultry litter. There were no significant differences among the treatments in case of Mg concentration in grains (Table 4).

Table 4. Effects of different amendments on mineral nutrition of wheat (variety: Bari wheat).

Treatments	**Nitrogen (N) %**			**Phosphorus (P)%**			**Potassium (k)%**		
	Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Control	0.64 c	0.83 b	2.02 b	0.13 d	0.05 b	0.47 b	0.45 a	1.99 b	0.58 b
100 mg/kg Pb	0.57 d	0.51 c	1.82 b	0.11 e	0.04 c	0.42 c	0.27 b	1.85 bc	0.52 b
100 mg/kg Pb +cowdung	0.82 a	1.01 a	2.88 a	0.19 a	0.11 a	0.53 a	0.60 a	2.93 a	0.74 a
100 mg/kg Pb + poultry litter	0.79 a	0.92 ab	2.59 a	0.18 b	0.10 a	0.47 b	0.55 a	2.78 a	0.60 b
100 mg/kg Pb + lime	0.76 b	0.85 b	2.14 b	0.16 c	0.06 b	0.41 c	0.45 a	1.69 c	0.60 b
Treatments	**Calcium (Ca)%**			**Magnesium (Mg) %**			**Lead (Pb) mg/kg**		
	Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Control	0.79 c	0.53 bc	0.03 b	0.19 c	0.09 ab	0.09 a	54.87 e	19.0 b	6.72 c
100 mg/kg Pb	0.61 d	0.50 c	0.03 b	0.13 e	0.08 c	0.09 a	183.6 a	38.0 a	15.60 a
100 mg/kg Pb +cowdung	0.69 cd	0.55 bc	0.03 b	0.24 a	0.09 b	0.10 a	105.0 d	12.77 b	5.0 c
100 mg/kg Pb + poultry litter	0.98 b	0.60 b	0.02 b	0.20 b	0.09 b	0.09 a	135.0 b	20.43 b	12.76 ab
100 mg/kg Pb + lime	1.47 a	0.74 a	0.03 a	0.18 d	0.09 a	0.09 a	117.5 c	15.67 b	10.15 b

Mean values with the same letter (s) do not differ significantly from each other at 5% level by DMRT

Nitrogen concentration increased by 43.5, 39.1 and 33.5% in root and 99.2, 81.7 and 68.0% in shoot and 58.2, 42.3 and 17.6% in grain in cowdung, poultry litter and lime treatments, respectively. Among amendments the liming enhanced Ca concentration 86.1, 39.6 and 17.9% in root, shoot and grain compared with control and 141.0, 48.0 and 26.9% compared with 100 mg/kg of Pb treatment and was differed significantly from other treatments (Table 4).

The concentration of nitrogen, phosphorus and potassium was observed highest in cowdung followed by poultry litter and lime treated pots. All amendments decreased Pb concentration in wheat. The highest being reduced in Pb amongst amendments cowdung had the greater ability to reduce Pb toxicity in root, shoot and grain and then lime and poultry litter concentration in cowdung followed by lime and poultry litter in root, shoot and grain of wheat. Chamon *et al.* (2005) reported that application of cowdung and water hyacinth in soil enhanced the N, P, K concentrations in wheat.

The reduced calcium concentration in Pb treated wheat plant might be due to the antagonistic effect of Pb with Ca and cowdung and poultry litter amendment had no ameliorating effect in case of Ca concentration. There were no significant differences among the treatments in case of Mg concentration in grain. Cowdung had the greater ability to reduce Pb toxicity due to the formation of complexes or chelate by organic matter with Pb. The addition of organic matter to contaminated soil may decrease the concentration of metal in solution and decrease their leachability. Madrid *et al.* (1999) found that the mobility and uptake of Pb tend to decrease by the presence of compost probably due to association with the organic matter present in them. Madrid *et al.* (1999) also observed that soil organic matter strongly adsorbed the heavy metals and helped in formation of insoluble organo-metal complexes. Chamon *et al.* (2005) reported that cowdung and poultry litter amendment showed a reduction of Pb content. Application of calcium carbonate containing amendment significantly decreased the solubility of heavy metals in contaminated soils and increased soil pH and decreased the metal uptake by wheat and cabbage (Chen *et al.* 2000).

It may be concluded that higher doses of Pb caused toxicity to wheat and soil amendments namely cowdung, poultry litter and lime caused significant reduction of Pb uptake.

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