EFFECTS OF LEAD (Pb) ON SOME CEREAL CROPS OF BANGLADESH AND THEIR REMEDIATION

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Submitted By

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UNIVERSITY OF DHAKA, BANGLADESH.

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BIOGRAPHICAL SKETCH

The author (Jasmin Parvin) was born on 25 November 1974 in the district of Comilla. She is the youngest daughter of Late Younus Pathan and Mrs Anowara Begum of Village-Debidwar, Upazilla-Debidwar and District-Comilla, Bangladesh. She Passed the Secondary School Certificate (SSC) examination in 1989 from Debidwar Pilot Girls High School in first Division and the Higher Secondary Certificate (HSC) examination in 1991 from Debidwar S.A. Govt College in first division. She obtained B. Sc. (Hon's) degree in Soil Science in 1994 from Dhaka University with first class 4^{th} position and M. Sc. (Thesis group) in 1995 (held in 1997) from the same department and university with first class 5th position. The author started her professional career on 11 April 2001 as a Scientific Officer in Soil Resource Development Institute (SRDI) under the Ministry of Agriculture. Then after qualifying 22nd BCS (Bangladesh Civil Service) she joined Govt. BM College as a lecturer of Soil Science on 10^{th} December 2003 under the Ministry of Education. Now she is working as an associate professor of Soil Science in Dhamrai Govt. College, Dhaka, Bangladesh.

She is happily married to Md Abdus Salam Munshi and blessed with one daughter Samayala Binte Salam and one son Shadman Sahil.

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The Author

November, 2015.

DECLARATION

I hereby declare that the work presented in this thesis entitled '**Effects of Lead (Pb) on Some Cereal Crops of Bangladesh and its Remediation'** is the result of my own investigation. I further declare that this thesis has not been submitted in any previous application for the award of any other academic degree in any university. All sources of information have been specially acknowledged by referring to the authors.

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Abstract

In recent ages, lead (Pb) poisoning in human body through soil-crop system is a serious threat to people of Bangladesh. Pot experiments were conducted with soils of belabo series at the research field of the Department of Soil Science, Govt. Bangla College, Dhaka, to investigate the effect of different doses of Pb (0, 50, 100, 150 and 200 ppm) and the ameliorating effects of several amendments (cowdung, poultry manure and lime) with 100 ppm Pb on Rice (variety: BRRIdhan-49), Wheat (variety: BARI wheat-26) and Maize (variety: BARI maize-9) and the varietal remediation of soils with 200 ppm Pb using four rice varieties (BRRIdhan- 33, 49, 53 and 54) and three wheat varieties (Shotabdi, Prodip and BARI wheat-26). A field experiment was also conducted to investigate the effect of different Pb doses (0, 50 and 100 ppm) on above mentioned wheat varieties and one maize variety (BARI maize-9). All the treatment and varietal combinations with three replications were laid out in a completely randomized design in pots and plots.

Pot experiments through applying different Pb doses in rice, wheat and maize varieties showed a gradual and significant decrease in yield and growth parameters and mineral nutrient concentration, except total N concentration gradually and significantly increased and then again decreased in rice grain, maize shoot and grain respectively, while N concentration gradually and significantly increased in maize root. The highest N concentrations in rice grain, maize root, shoot, grain were obtained at 100, 200, 150 and 150 ppm Pb treatments respectively. Besides increasing Pb concentration in soil caused an increase in Pb concentration in all crops. In all cases shoot accumulated more potassium than root and grain. All the crop varieties showed higher Pb accumulation in root than in shoot and grain and Pb accumulation was in the order root > shoot > grain. For a given Pb treatment in case of root, rice root accumulates higher Pb than root of wheat and maize and Pb accumulation was in the order rice > wheat > maize while in case of shoot or grain, wheat shoot and grain accumulates higher Pb than shoot and grain of rice or maize. Field experiments through applying different Pb doses in wheat and maize varieties showed similar results as in pot experiments.

Application of 100 ppm of Pb significantly decreased the growth and yield parameters and mineral nutrient concentration in all crops, except N concentration increased in rice grain and maize root, shoot and grain and Pb concentration in root, shoot and grain of three crops, as compared with their control. Addition of different amendments (cowdung, poultry manure and lime) on soils with 100ppm Pb treatment significantly increased the growth and yield parameters and N, P, K, Ca, Mg concentration and significantly decreased the Pb concentration in rice, wheat and maize varieties in comparison to un-amended soils. Among the amendments, cowdung had greatest ability to reduce Pb toxicity and increase yield and growth parameters and mineral nutrient concentration in crops except lime treatment resulted the highest 1000 grain weight of wheat (46.43g/pot). Besides, poultry litter enhanced the K concentration in rice shoot

and grain and lime enhanced Ca concentration in root and shoot of rice and in root, shoot and grain of wheat and maize. Moreover, in case of rice and wheat Pb toxicity reducing capacity was in the order cowdung> lime > poultry litter, while in case of maize Pb toxicity reducing capacity was in the order cowdung> poultry litter > lime.

Pot experiments for varietal remediation of soils with 200 ppm Pb treatment revealed that among the respective rice and wheat varieties, BRRIdhan-49 and BARI wheat-26 accumulated the highest concentrations of Pb; so their agronomic parameters and nutrient uptakes were lesser than other respective rice and wheat varieties. Conversely, BRRI dhan-54 and Shotabdi had the ability to withstand Pb stressed soil and concentrates less amounts of Pb in root, shoot and grain, hence had a better capability to increase growth and yield parameters and mineral nutrient concentrations than other respective rice and wheat varieties.

In summary it may be stated that all investigated methods (selection of suitable plant varieties, crops, soil amendment with cowdung, poultry litter and lime) caused partly significant reductions of Pb accumulation from contaminated soils. Nevertheless, for the optimization of the reduction effects, it is necessary to select and combine the different methods according to crop specific and varietal characteristics.

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1. Introduction

Pollution control issues are relatively recent in Bangladesh, as the country over the last twenty years has been slowly shifting from agricultural economy to one more dependent on urban commerce and industry. Bangladesh has at present about 30,000 large and small industrial units. They are discharging their wastes and effluents into the natural ecosystems in most cases without any treatment, thus causing environmental pollution especially with heavy metals and organic toxins (Chamon *et al.,* 2011). In addition, fertilizers and pesticides are being randomly used in agricultural lands by the uneducated farmers. Industrial effluents and wastes lead to significant pollution of soils and plants around Dhaka city. 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) (Nuruzzaman, Gerzabek and Ullah, 1995). Long-term use of industrial or municipal wastewater in irrigation is known to have significant contribution to trace elements, such as Cr, Mn, Ni, Cu, Zn, Pb and Cd in surface soil (Mapanda *et al*., 2005). Excessive accumulation of trace elements in agricultural soils through wastewater irrigation may not only result in soil contamination but also affect food quality and safety (Muchuweti *et al.,* 2006; Sharma *et al*., 2007). Use of lead acid battery (LAB) in Bangladesh has risen with sharp rise of motor vehicles. As result, manufacture of LAB is increasing. Most of the lead used by these industries comes from recycling of LAB. Workers in LAB industry are at risk of exposure lead and thus development of lead toxicity (Ahmed *et al.,* 2014).

The term "heavy metal" is a physical one and refers to the specific gravity. Those metals which show a specific gravity >4.5 g/cm^3 are called heavy metals (Markert, 1993). Synonymous heavy metals as used in this text are trace elements, trace metals, micro-elements and trace inorganic.

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 (Kibria, 2008; Kashem and Singh, 1999). 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 (Kibria *et al.,* 2006, 2007). 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 (Seregin and Ivanov, 2001).Lead concentrations in many turmeric samples of Bangladesh were elevated, with lead concentrations as high as 483 ppm (Gleason *et al.*, 2014).

Figure-1: Lead (Pb) affected cereal crops. (Source: Web-1)

The pores in a plant's leaves let in carbon dioxide needed for photosynthesis and emit oxygen. Lead pollution coats the surface of the leaf and reduces the amount of light reaching it. This results in stunting the growth or killing the plants by reducing the rate of photosynthesis, inhibiting respiration, encouraging an elongation of plant cells influencing root development by causing pre-mature aging (Figure-1). Lead inhibits water imbalance, disturbed mineral nutrient, enzyme activities, change in hormonal status and membrane permeability alteration (figure-2).

Lead at high concentrations inhibits cellular activities thus causing cell death. Increased lead concentration hampers the synthesis of chlorophyll because of impaired uptake of Iron Magnesium through plants. The photosynthetic apparatus is damaged due to its affinity for protein N- and S- legends. At higher concentrations of lead, inhibition of respiration is observed.

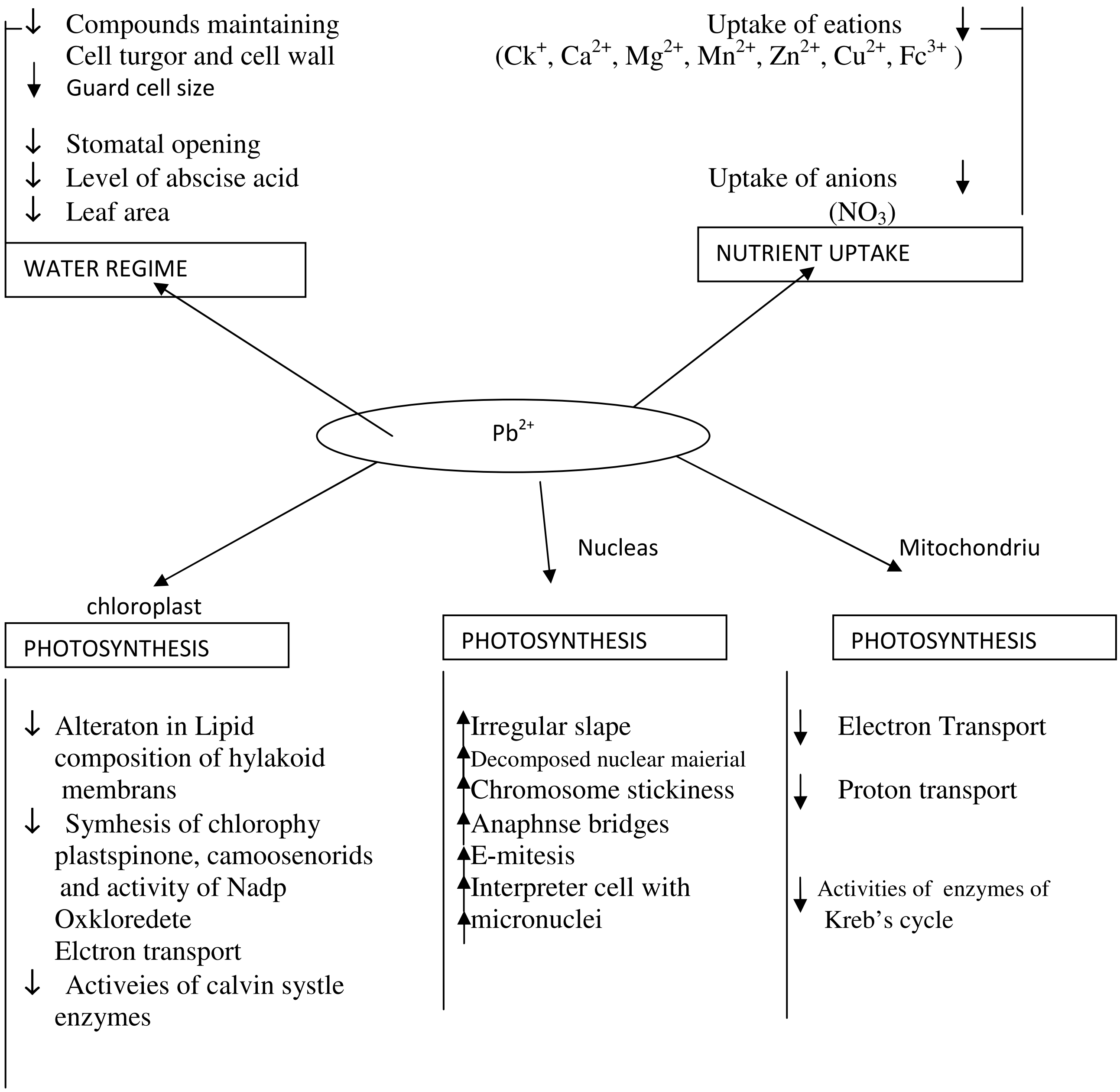


Figure-2: Effects of Pb on Photosynthesis, mitotic irregularities, respiration, water regime and nutrient uptake. ↑and ↓ signs represent enhanced and decreased activities respectively. Source: Pallavi and Dubey, 2005.

Rice, Wheat and Maize are the mandatory cereal crops of Bangladesh. Rice is the staple food of around three billion people worldwide (Mail online, 29 th October 2015). Others are uses for making flour, bread, biscuit, pizza, cream role, poultry feed, cattle feed etc. Unfortunately this cereal crop production and their mineral nutrient content are affected by contamination of lead.

Rice seed germination rate and the amount of chlorophyll decreased remarkably with increasing Pb concentration. Excess of Pb reduced the dry weight of rice pronouncedly at harvest when the grain yield also decreased (Chatterjee *et al*., 2004).Pb was effective in inducing proline accumulation and its toxicity causes oxidative stress in rice plants (Zeng *et al.,* 2006).Pb treatment had a stimulating effect on soil enzymatic activities and microbial biomass carbon at low concentration and an inhibitory influence at higher concentration and was effective in inducing proline accumulation and its toxicity causes oxidative stress in rice plants (Zeng *et al.,* (2007). The contents of N, P, K, Ca, Mg, Fe, Cu and Cd in the rice straw and grain decreased significantly with increasing level of lead, while accumulation of Pb increased both in the straw and grain with increasing lead stress (Ullah *et al.,* 2011).High concentrations of Pb caused 14 to 30% decreased germination in rice seeds and reduced the growth of seedlings by more than 13 to 45% (Verma and Dubey, 2003). Rice imported from some countries contains high levels of lead that could pose a health risk to children.US expert's detected concentrations of lead ranging from six to 12 milligrams per kilogram in rice from several sources. Infants and children consuming the rice would be exposed to lead levels 30 to 60 times higher than the tolerable safety limits, set by the US Food and Drug Administration (FDA). For Asian children, who consume more rice, exposures could be up to 120 times higher (Mail online, 29 th October 2015).

The seed germination and seedling growth of wheat could be promoted at low concentrations of Pb (under 0.5 mg/L), while they would be inhibited when the concentration of Pb was high (Weiwei *et al.,* 2009). Low concentrations of Pb in the soil stimulated seedling growth; high concentrations, however, inhibited their growth (Yau *et al.,* 2010). Lead reduced the germination, root and aerial biomass of wheat (Nedjah *et al.,* 2013).Pb reduced the morphological parameters of wheat such as shoot/root length, shoot fresh/dry weights, number of tillers (Bhatti *et al.,* 2013). Pb in soil inhibits growth and photosynthetic activity in wheat through induction of oxidative stress (Kaur *et al.,* 2012). So Pb as a heavy metal has detrimental effects on wheat growth and development.

Maize is a familiar agricultural crop that could accumulate lead when grown in contaminated soil (Wending et al., (2013). Increased Pb concentration in soil decreased Mn and Fe in shoot and elevated Fe concentration in roots of maize (Tavizi *et al*., 2014). Seed germination, early growth seedling, root-shoot length, root-shoot fresh and dry weights, total protein content of maize were reduced by the increased lead concentrations (Hussain *et al.,* 2013). Exposure of maize varieties to excess Pb resulted in a significant root growth inhibition though shoot growth remained less affected (Ghani, 2010).Pb also decreased the uptake of Ca, Mg, K and P in *Zea mays* (Walker *et al*., 1997). Pb toxicity causes leakage of K ions from root cells in corn seedlings (Malkowski *et al.,* 2002) and decreased the uptake of Ca, Mg, K and P (Walker *et al*., 1997). Increased the concentrations of lead nitrate [$(Pb(NO_3)_2$] as heavy metal reduced the early growth seedling, root-shoot length, root-shoot fresh and dry weights, total protein content of *Zea mays* (Hussain *et al.,* 2013).

Lead application in soil significantly decreased N and P concentration in shoots as well as Ca, Zn and Mn in both shoots and roots of *A. gangetius* (Kibria *et al*., 2009).Lead, copper, cadmium and mercury toxicity decreased the total chlorophyll content of the leaves of bean seedlings (Zengin *et al*., 2005). Application of both lead and chromium caused a significant reduction in all growth parameters of Mash bean as compared with that of control (Mumtaz *et al.,* 2006) and seedling growth of *A. lebbeck* (Farooq *et al.,* 2009). Seedlings vigor index of *T. populnea* gradually decreased with the increase in concentrations of lead and cadmium (Kabir *et al*., 2008).

Lead is a dangerous neurotoxin to human and animals. It has no essential function in man but has a number of adverse effects. WHO (2009) documented that Pb exposure accounts for about 0.6%of the global burden of diseases, particularly in developing nations ATSDR (2008) also classified Pb as the second most dangerous metal on the priority list of the U. S. Environmental Protection Agency .According to Bangladesh Bureau of Statistics (BBS, 2004) baseline survey, there are 12,207 battery recycling/recharging establishments all over Bangladesh and 34% of these establishments are found in Dhaka division. 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). Health of the workers in these battery recycling/recharging establishments is much neglected; there is ample chance of exposure to lead among the workers and thus the workers are at the risk of developing lead toxicity (Enayetullah *et al.,* 2006).

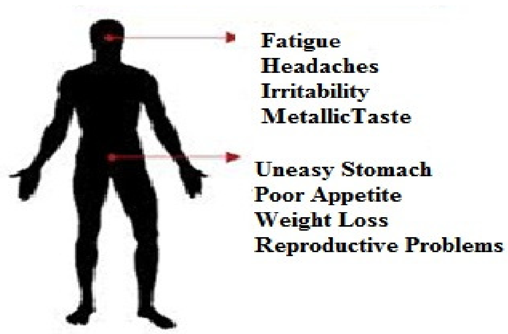


Fig-3: Early symptom of lead poisoning. (Source: Web-1).

Failure to treat lead poisoning in the early stages can cause long-term or permanent health damage, but because of the general nature of symptoms at early stages, lead poisoning is often not suspected.

In adults, lead poisoning can cause:

- poor muscle coordination
- nerve damage to the sense organs and nerves controlling the body
- increased blood pressure
- hearing and vision impairment
- reproductive problems (e.g., decreased sperm count)
- retarded fetal development even at relatively low exposure levels (figure-4).

Children are the worst sufferers as they suffer from memory loss and respiratory problem. Lead accumulates slowly in the body, and can lead to nerve and kidney damage, as well as anemia

- Although Pb was eliminated from the gasoline in Bangladesh beginning in july1999, there may be substantial accumulated lead in the dust near roadway because lead has a very long residence time in surface soil (Young *et. al*., 2002).

Although the effects of lead exposure are a potential concern for all humans, young children (less than seven years old) are most at risk.Long-term lead exposure has been linked to reduced IQ and disruptive behavior in children.

Fig-4 : Lead affected human (Source: Web-1).

Pb is a systemic poison and can induce deleterious effects in living organisms. Sever biochemical effects are:

First, as an electropositive metal Pb has a high affinity for the sulphahydryl (SH) group. Pb reacts with the SH group on enzyme molecule to form mercaptide, leading to inactivation of the enzyme.

Second, divalent Pb is similar to Ca in many aspects and may exert a competitive action on body processes such as mitochondrial respiration and neurological functions. Pb can compete with Ca for entry at the presynaptic receptor.

Third,Pb can interact with nucleic acid, leading to either decreased or increased protein synthesis.

Finally, it is widely known that Pb impairs the formation of red blood cells.

Trace metal contaminated sites are of growing concern and there is a strong need for remediation of these sites. Remediation/Ameliorations is the process involves dissolving or immobilizing the heavy metals, present as particles or adsorbed on to the soil matrix by using various agents, such as chemical, physical or organic agents. Remediation aims at protecting humans, animals and the environment from exposure to hazards and interrupting the pathways of pollutants (Tadesse *et al.*, 1994). Two main groups of remediation techniques can be distinguished. The first is the group of the so-called hard techniques like solidification (Conner, 1994), high pressure water extraction (Heimhardt,1990), and acid leaching (Palmer *et al.,* 1995). This group of techniques has the disadvantage that biological activity is impaired andor physical soil structure is destroyed. Besides, the hard techniques are quite expensive and may co-generate by-products.

Unlike organic contaminants, most metals do not undergo microbial or chemical degradation and the total concentration of these metals is soils persist for a long time after their introduction. For diffuse distribution of metals, remediation options generally include amelioration of soils to minimize the metal bioavailability (Adriano *et al.,* 1997).

Remediation strategies can be divided in two general categories; ex site and in site. Table-1 presents a summary of technologies that are currently being used or are being evaluated. Soil removal is the most common ex site method employed and is used extensively in residential areas with Pb contaminated soils. Use of the remaining ex site method is generally restricted to small sites with highly contaminated soils because of the obvious problems with dealing with large quantities of soils and the generation of waste products requiring further processing for storage. Phytostabilization is the most common in site method used, particularly for old mine sites with large areas that require remediation. Encapsulation and attenuation have been used to a limited extent. The use of soil amendments is often combined with phytostabilization. The use of P to reduce Pb bioavailability is being evaluated as an alteration to soil excavation (Adriano *et al.*, 1997). The remediation of lead affected sites is carried out by relatively narrow range of engineering based technologies (Salt *et al*., 1995). The rhizofiltration and phytoremediation provide better horizons for the utilization of such technique for the clean-up of lead contaminated soils.

Table-1: Remediation strategies currently employed or under development for metal contaminated sites in the United States (Adriano *et al*., 1997).

Method	Comments
Ex situ	
Solidification	Addition of a cementing agent to produce a hardened, nonporous, no leachablematerial
Vitrification	Heating to produce a glass-like, nonporous, no leachable material
Washing	Chelate or acid extraction
Leaching	Pile or batch leaching with Chelate or acids
Particle size segregation	Selective removal of fine particles that have the highest metal concentrations
Soil excavation	Soil removal and disposal
In situ	
Solidification	As described above
Vitrification	As described above
Encapsulation	Cover site with impermeable layer
Attenuation	Dilution with uncontaminated material
Electro kinetics	Electric current induces movement of ions to electrodes
Phytostabilization	Promote vegetative growth to immobilize metals
Phytoextraction	Removal of metals by plants
Soil Amendments	Reduce bioavailability of metals with P or other soil amendments

Organic matter amendment is 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). Different types of organic matter reduced uptake in the following way, from most to least effective, respectively: muck soil > manure > ground-up leaves >sphagnum peat. The addition of 100 ppm or more P also reduced Pb uptake.

Some heavy metals such as Pb, Cd, Zn, Cu and Cr (VI) etc. can be remediate by growing plants or vegetables, these processes of remediation is known as phytoremediation. Phytoremediation is a new technology that uses metal accumulating plants to remediate contaminated soil and water. Soil ecosystems throughout the worlds have been contaminated with heavy metals by various human activities and movement of metals up the food chain has become a human health hazard (Tu*et al*., 2000; Dahmani–Muller *et al*., 2001; Khan 2001; Qiao and Luo, 2001; McGrath *et al*., 2002). One of the most promising and potentially cost effective soil remediation techniques is phytoremediation (Ebbs and Kochain, 1997; Huang *et al*., 1997b; Blaylock, 2000). The ideal plant species to remediate a heavy metal contaminated soil would be a high biomass crop that can both tolerate and accumulate the contaminants of interest. At present only a small number of higher plant species, which can survive in metal polluted soils and extract and trans-locate metals from roots to the above ground part are used in Phytoremediation technology (Brooks, 1998). Phyto-remediation offers an attractive and economic alternative to currently practiced soil removal and burial methods. The integration especially metal accumulating crop plants (e.g. *Brassica Junceca*) with innovative soil amendments allows plants to achieve high biomass and metal accumulation rates from soils (Blaylock, 2000).

Phyto-remediation may provide an economically viable solution for remediating some of the contaminated sites. Specifically, several subsets of metal phytoremediation have been developed and targeted for commercialization.

1. Phytoextraction- in which high biomass, metal accumulating plants and appropriate soil amendments are used to transport and concentrate metals from the soil into the above ground shoots, which are harvested with conventional agricultural methods.
2. Rhizofiltration - in which plant roots grown in aerated water, precipitate and concentrate toxic metals from polluted effluents.
3. Phytostabilization – in which plants stabilize the pollutants in soils, thus rendering them harmless.
4. Phytovolatilization - in which plants extract volatile metals (e g., mercury and selenium) from soil and volatilize them from the foliage.

Bangladesh is one of the most densely populated areas in the world. Lead problem in Bangladesh is mainly city based. According to Environmentalist, Dhaka is most polluted city of all the cities in the world. The air of the city of 10 million is 5 to 8 times more polluted than the normal air. Although the government of Bangladesh adopted a policy to ban of leaded gasoline in 1999, there is no complete control over the use of leaded gasoline in the country (Boman *et al*., 2005). Sarmin (2012) reported that the range of Pb concentration in Dhaka city air was 102 to 287 ng/m^3,these indicated that these contamination was due to autoexhaugst and industrial emissions to air and consequently this metal affects human body through inhalation and ingestion.

Lead concentration above toxic limit in plants affects the growth and productivity of many crops. Its remediation should be undertaken for protecting our environment as well as human life. Unfortunately the data available on the impact of Pb pollution, their remediation by chemical means from soils and crops and phytoremediation by cereal crops are rare in Bangladesh. So it is important to initiate appropriate research program for remediation of Pb toxicity in cereal crops by using different amendments which may provide a basis for better management of Pb influenced polluted soils for cereal crop production as well as to create public awareness. Through the creation of awareness and suggestion for solution of the Pb problem in Bangladesh, expense in the health sector would be saved particularly lives of children would be protected from ingestion of Pb and diseases associated with Pb toxicity.

So, the research plan has been undertaken:

1. To study the effect of different doses of lead (Pb) on growth and yield of some cereal crops such as Rice (*Oryza saliva*), Wheat (*Triticum aestivum*) and Maize (*Zea mays L.).*

2. To investigate the effect of different doses of Pb on the nutrient concentration in root, shoot and grain of these cereal crops.

3. To identify crop (different varieties of rice and wheat), capable of accumulating lead (Pb) and to find out Pb hyper- accumulating crops.

4. To study the effect of amendments like cowdung, poultry litter and lime in remediation of Pb toxicity on these cereal crops.

5. To study the varietal effect of rice and wheat in remediation of Pb toxicity.

2. REVIEW OF LITERATURE

2.1: Preface

Pollution of the environment by heavy metals particularly Pb is already a major problem in Bangladesh and threatens environmental quality and ecosystem. Enhanced levels of heavy metals in the environment is a great concern because of their possible entry into food chain, accumulation in human body and build up with time to toxic levels.

Research on heavy metals particularly Pb from various aspects, their effect on nutrient uptake, crop production and its remediation has progressed appreciably in Bangladesh and different parts of the world. Some relevant literature is reviewed here under the following headings:

2.2: Heavy metals and their interaction

2.2.1: Heavy metals

Heavy metal is a common term in environmental pollution. There is no standard definition assigning metals as heavy metals. It mainly includes the transition metals, some metalloid, lanthanides, and actinides (Sood and Prakash, 1998). One of the common definition of heavy metals is a metal with density greater than 5 gm/cm^3 or an atomic number greater than 20 (Thakur, 2006a; Markert, 1993)

Classification of Heavy metals according to their toxicity is given in the table-2.

Table-2: Toxicity levels of Heavy metal (Thakur, 2006 b).

Heavy metal	Toxicity
Fe, Mn, Mo	Low toxicity
Zn, Ni, Cu, Co, Cr	Average toxicity
As, Ag, Sb, Cd, Hg, Pb	High toxicity

Source: (Thakur, 2006 b)

2.2.2: Heavy Metals interaction

Interaction between chemical elements may be both antagonistic and synergistic. Antagonistic effects occur most often in two ways

- The macro nutrients may inhibit trace element absorption and in turn,
- The trace element may inhibit absorption of macro nutrients.

Those reactions have been observed especially for phosphate, but also reported for other macro nutrients whose uptake and metabolic activity may be inhibited by several trace elements (Kitagishi and Yamane, 1981)

The interaction effects of Zn, Cu, and Ni in barley showed that Cu had little effects on Zn and Ni. Zinc uptake increased in presence of nickel. Sarkunan *et al.* (1991) mentioned that Zn-Cu is well reflected in yields as well as metal contents in grain and straw in rice. Lubben and Sauerbeck (1991) reported that generally the more mobile elements Cd, Zn and Ni show a pronounced rise in the grain of wheat at increasing soil contents. They found that addition of Cd to the soils resulted in higher Cd ion concentrations in all plants parts but concentrations of Pb, Zn, Cu, Mn, and Fe were low.

In addition to interactions during absorption there are others with in the plant between heavy metals and between these and some major nutrients. These interactions sometimes describe as antagonisms are discussed fully by Olsen (1972). Those between one heavy metal and another may be viewed as competition for sites in some compounds such as enzymes, or those involved in translocation. In this way Fe and Mn deficiency symptoms have been induced in plants given large amounts of Zn, Ni, or Cu (Leeper, 1978).

The response studies have demonstrated that plants to a greater extent follow the trend of interactions between amendments ($CaSO_4$ and Zn SO_4) in adsorbing Cd. For example, when Cd-Ca or Cd-Zn interactions are considered the absorption of Cd decrease in vegetative part of plants. Such a behavior can be accounted by antagonism processes and was mainly observed in the plant roots. Cd-Ca interactions were more effective than Cd- Zn interactions (Misra and Mani, 1991).

Addition of Cd plus Pb, Zn and Cu resulted in higher Cd concentrations in leaves and straw of oat plants grown in sandy loam and sandy soil. Conversely addition of Cd, Pb, Zn and Cu decrease Mn concentrations in leaves and straw more than when Cd was added separately and addition of Pb, Zn, and Cu together with Cd was shown to decrease Cd adsorption in sandy loam and sandy soil.

The antagonism between Mn and Fe is a well documented interaction in higher plants. The high amounts of Mn might have antagonistic effects on Zn uptakes (Sajwan and Lindsay, 1986). Iqbal and Halinderdeep (1992) found that nitrate uptake in the root of seven day old wheat decrease with the $CuSO_4$ salt treatments. The level of inhibition was more at higher concentrations of the heavy metals salts.

2.2.3: Heavy Metals interaction with organic matter

Organic matter can influence the solubility of heavy metals in soils in different ways. It can increase the solubility by forming soluble organic complexes, but on the other hand, the ability of organic matter to immobilize heavy metals has also been reported. Colloidal organic matter has a strong affinity for heavy metals cations and the retention of added metal is often well correlated with the amounts of soil organic matter (Misra and Mani, 1991). Organic matter provides sites for cation exchange reactions, but its strong affinity for heavy metals cations is due to legends or groups that form chelates and or complexes with the metals. The functional groups include –COOH, phenolic, alcoholic and Phenolic-OH, and carbonyl structures of various types (Stevenson and Ardakni, 1972).

Various attempts have been made to measure the stability the Organic matter complexes with different metals. In general, the stabilities of the complexes increase with increasing pH due to increase ionization of the functional groups. Amongst the metals Cu^{2+} forms very stable complexes over a wide range of pH and the order of other metals are $Fe^{2+} > Pb^{2+} > Ni^{2+} > Co^{2+} > Mn^{2+} > Zn^{2+}$ (Misra and Mani, 1991).

The presences of organic matter are known to affect metal solubility in soils (Forstner and Wittmann, 1983). Madrid *et al.* (1999) found that although most of the added metals (Zn, Cu, and Pb in NO_3 form) is still in the most soluble fraction after the studied time of reaction, their mobility, especially that of Pb, and Cu tends to decrease by the presence of the composts probably by association with the organic matter presence in them

2.2.4: Heavy Metals interaction with inorganic colloids

At trace levels, where precipitation is not a factor, other processes are involved on holding the metal cations, in form of extreme low solubility. These processes include exchange, or columbic, adsorption and specific adsorption by the solid phase components of soil. The heavy metal cations take part in exchange reactions with negatively charged surfaces of clay minerals as given below:

$$\text{Clay-Ca} + M^{2+} \rightarrow \text{Clay-M} + Ca^{2+}$$

It is notable that Pb ion were adsorbed at pH values as low as 4 to 5, on to a surface and that all the cations were adsorbed with release of H^+. The H^+ ion released into solution on adsorption could originate from the oxide surfaces or the primary hydration sheath of the adsorbing ion.

Common inorganic soil components with significant binding preferences for specific metal (Rule and Martin, 1999) become important when levels of several metals are applied to soils. With high concentrations of metal added, the capacity of specific sorption sites (strongly bound metals) could be exceeded and the metal cation would compete with the bulk cations for adsorption sites.

2.3: Uptake of heavy metals by plants

The amounts of heavy metals uptakes by plants or crops from soil are in the strictest sense, the criterion of it availability. However, plants vary greatly in the amounts of a heavy metal content taken up by a species, stage of growth and environmental conditions. The availability of a heavy metal in a soil is much a function of the plant as of the soil (Mitchell, 1964).

2.4: Lead (Pb):

Lead is one of the well-known toxic heavy metals and is a major pollutant. It primarily enters into the atmosphere and into food chain through the use of leaded gasoline in automobiles. Lead is the least mobile of the heavy metals in soils. It accumulates primarily on the surface, where its increasing presence may begin to affect soil micro flora. Lead is not readily soluble in water and is found in relatively low concentration (Pais *et al.,* 1997)

2.4.1: Sources of Lead (Pb) Pollution

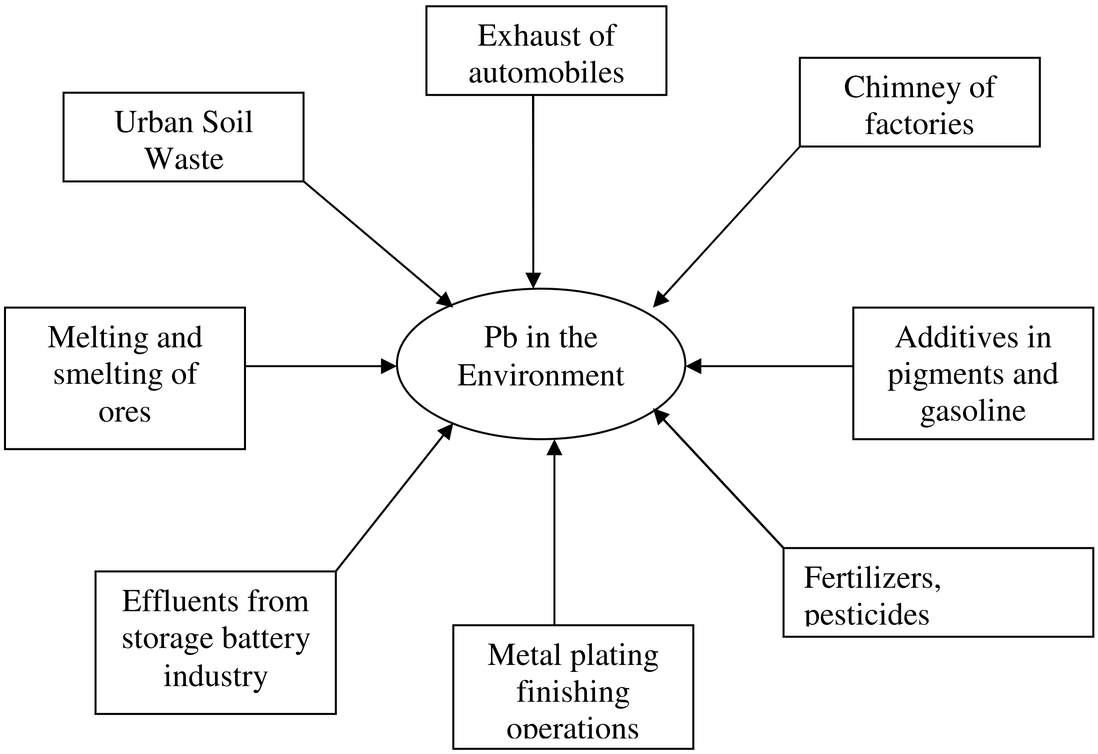


Figure-5: Sources of lead pollution in the environment (Source-web:1).

2.4.2: Lead in Soil

Lead in soils and dust in the environment has been, and will continue to be, a source of lead poisoning. The sources include flaking, chipping, or weathering paint: improper renovation of buildings and disposal of building materials; lead by the side of roads that has settled out from burned leaded gasoline; settled dust from industrial sources and lead around houses from lead paint that has been scraped off during the continuing repainting of the house.

2.4.3: Lead in Water

Water leaves the purification plant without lead in it, but by the time you turn on your tap, lead could have accumulated. This is because water may dissolve lead that is present in brass or bronze faucets, fittings, lead pipes, or lead solder. Water in Nebraska is hard, so lead is less of a problem here. However, individual homes with older fixtures may have a problem.

2.4.4: Lead in the Air

Lead in the air has come from a variety of sources. One of the largest contributors has been from leaded gasoline. Millions of tons of lead were added to gas before use was limited by EPA regulations restricting the use of lead in gasoline. Much of this lead is still present in the environment as lead in soils and lead in dust. Aside from lead paints, lead is emitted into the air from industrial emissions. These industrial sources included smelters, refineries, incinerators, power plants, manufacturing operations, recycling efforts, and hundreds of other sources.

2.4.5: Other sources of lead pollution:

- Paint
- Dust
- Vehicle
- Coal
- Wood burning
- Metal production
- Toys and jewelry
- Dishware
- Folk and traditional medicines
- Candy & food
- Old bathtubs
- Lead wicks in candles
- Drapery and window weights
- Keys
- Battery casings
- Some imported plastic mini-blinds
- Insecticides
- Turmeric, a spice commonly used in Bangladeshi cooking, is a potential source of lead exposure (Gleason *et al.,* 2014).

2.5: CHARACTERISTICS AND TOXICITY OF LEAD

2.5.1: CONTAMINATION OF SOIL, WATER AND PLANT

Most of the lead ever produced remains in soil, dust and other environs, because it does not break down. The odorless, colorless, tasteless metal so widely present in homes, yards and workplaces can only be detected through chemical analysis. The fate of anthropogenic Pb in soils has recently received much attention because this metal is hazardous to man and animals from two sources- the food chain and soil dust inhalation.

Lead has long been known as a highly toxic poison. But it is less toxic than cadmium and mercury. It primarily enters into the atmosphere and into food chain through the use of leaded gasoline in automobiles. Lead accumulates primarily on the surface, where its increasing presence may begin to affect soil micro flora. Lead is not readily soluble in water and is found in relatively low concentration (Pais, 1997).

The most general cause of the contamination of soil with lead is from the combustion of petrol containing tetraethyl and tetraethyl leads, the product of combustion being particulate lead bromochloride (PbBrCI). After emission, the very small particles are dispersed widely by the wind while coarser particles are deposited on soil and plant surfaces within 30 to 50m of the road. The amounts of lead deposited decline exponentially with distance. There is evidence that the lead bromochloride is converted mainly to lead sulfate and occasionally to lead oxide (PbO) or lead sulfide (PbS), and it has been suggested that these conversions occur either during transport or after deposition on the soil (Olson, 1975).

The solubility of lead sulfate is extremely low and although plant uptake may increase slightly as a result of deposition on the soil, most of the additional supply is retained in the roots (Jones, 1973). Only about one half of the lead deposited on the leaves can be washed off by rain or removed by washing when vegetable foods are prepared in the kitchen. The problem of ingesting food contaminated by particulate lead becomes more serious near or in towns and cities where both the road network and traffic are denser than in open country.

Automobile exhaust accounts for about 50% of the total inorganic lead absorbed by human. In Bangladesh leaded gasoline used in automobiles enhanced the concentration of Pb in roadside soils. Venkatesh and Abhimany (1998) found 45-455 ppm Pb in roadside soils, which was much higher than the background level (0-24) for normal soil. According to pollution's now permeate the Arctic environment. It was reported that 90% of the lead in snow around the South Pole was caused by industrial discharged, mainly from Eastern Europe, the central and far eastern portions of Russia and western parts of North America.

Lead can exist in both inorganic (Pb^{2+}) and organic forms in soil. Hutton and Symoon, (1987) observed that the prime median for Pb transport was air because of the fine particulates.

Lead in seawater is largely associated with colloidal inorganic particulates. In fresh water at pH 6, lead is mainly in the form of an inorganic, non-colloidal species, probably $Pb_2(OH)_2CO_3$. At the higher pH values of most surface water, Pb is more likely to be associated with colloidal matter (De, 1994). In lake water sediments the existence of $Pb(CH_3)_4$ is reported. It is interesting to note the stability of $Pb(CH_3)_4$, $Pb(CH_3)_3^+$ and $Pb(CH_3)_2^{2+}$ in aqueous media
(De, 1994).

Air borne Pb compounds is found in both gaseous and particulate matter. The presence of $PbSO_4$ $(NH_4)_2SO_4$, Pb_3O_4, $PbSO_2$ etc. in street dust and PbO, $PbSO_4$, PbS have been reported in roadside soil. Automobile Pb Compounds in roadside air are reported to be $PbSO_4$ (NH_4) SO_4, PbBrCI: $2NH_4Cl$, PbBrC: (NH_4)2BrCI etc. (De, 1994).

Lead is removed from the atmosphere by wet and dry deposition processes. Wet deposition involves incorporation is the removal from the air of particles by gravitational settling, or brownian diffusion to surfaces. As a result of these processes, street dusts and roadside soils become enriched with Pb, 1000-4000 $MgKg^{-1}$, on busy streets.

The presence and role of organolead compounds in the environment on living system has caused great concern. These originate from leaded gasoline and petrol used all over the world. The organ lead compounds are more toxic than inorganic Pb. Commercially five tetra alkyl lead (TAL) compounds are important: tetra methyl lead (TML), tri methyl ethyl lead (TMEL), dimethyldiethyl lead (DMDL) and tetraethyl lead (TEL). Most organic Pb enters the atmosphere during manufacture, transfer of leaded gasoline and use in vehicles. There are also indications of natural methylation of inorganic Pb in the environment (De, 1994).

The ionic alkyl Pb compounds are considered as highly toxic to mammals. TAL compounds in the environment decompose to form highly soluble ionic alkyl Pb. The degradation appears to follow the pathway: PbR_4-PbR_3+- PbR_2^{2+}- PbR_3^{+3}- Pb^{2+} where R is the alkyl group (De, 1994). It has been shown with several species that a large proportion of the lead taken up from solution culture is associated with the roots.

Lead uptake is passive (Bodak *et al*., 1988; Markert, 1993) and its translocation from root to other plant parts is low. Aerial deposition and foliar uptake contribute significantly to leafy concentration. Anaerobic conditions, low pH and low phosphate concentrations promote Pb uptake.

In natural ecosystems, general litter decomposing microorganisms are sensitive to lead contamination. Hence, estimation of potential ecosystem dysfunction is often done by measuring the number, respiration rates, CO_2 evolution and rates of litter decomposition by these microorganisms. As for example, the number of *Micrococcus lutens* is agricultural soils is used as an indication of lead accumulation. Since microorganisms and plants show strong tendency to bioaccumulation lead, there is a possibility that the bio accumulated lead may enter into the terrestrial food chains (Deuny *et al*., 1987).

If the concentration of lead is relatively high in water, it is found that the primary production capacity of phytoplankton decrease considerably (Pillai, 1991). *Cyanophyta, Chlorophyta* and *Chrysophyta* species of phytoplankton are found to be susceptible to the presence of high concentration of lead in aquatic environment. The critical value for one of the chlorophyta species was reported to be 5ppm. High concentration of lead in water reduces the photo-induced CO_2 fixation in certain algae. The selective elimination of some of the sensitive species of the aquatic system may affect the water quality (Pillai, 1991).

If lead concentration takes place at a fish spawning ground, the entire fish population suffers from it. An exposure of 5ppm lead for 24 to 36 hours was found to lethal to *Lenciscus phoxicus L*, a kind of minnows. Bioaccumulaton of lead takes place in Oysters and other shellfish. Molluse is particularly susceptible to lead contamination and thus is considered to be an indicator organism for monitoring lead levels in the aquatic environment.

Lead at 30 mg/L in nutrient solution has been found to be toxic to plants, with 10 mg/L slowing plants growth and 100 mg/L being lethal. In some types of plants, lead can be as high as 350 mg/kg in plant tissue without visible harm. Extremely low levels (2 to 6 µg/Kg) of lead may be necessary for plant, as there is some evidence of a stimulatory effect at low concentrations. Lead can be readily adsorbed by plant roots (the amount adsorbed greatly varies with plant type), but little (less than 3%) is translocated to the tops. Background lead level in grasses is 2.1 mg/kg and 2.5 mg/kg in clovers.

Leafy vegetables such as lettuce, spinach, potatoes and beans are likely to absorb more lead, whereas fruiting crops such as tomatoes, corn, beats, squash, eggplant and peppers do not pick up any appreciable amount of lead through their root systems.

It is not wise to grow carrots, turnips, beet root and sprouts in cities, especially near the main roads and highways because of the lead contamination from vehicular exhausts. Lead contents of plant decreases as the distance from vehicular traffic increases (Kannan, 1997).

2.5.2: REACTIONS OF LEAD (Pb) WITH SOIL COMPONENTS:

The natural Pb content of soils is strongly related to the composition of the bedrocks and Pb is reported to be the least mobile among the other heavy metals. During weathering Pb sulfides slowly oxidize and have the ability to form carbonates and also to be incorporated in clay minerals, in Fe and Mn oxides and in organic matter. The geochemical characteristics of Pb^{2+} somewhat resemble the divalent alkaline-earth group of metals, thus Pb has the ability to replace K, Ba, Sr and even Ca, both in minerals and in sorption sites.

The Pb species can vary considerably from one soil type to another. Norrish (1975) and Schnitzer and kerndorff (1981) stated that Pb is associated mainly with clay, Mn oxides, Fe and AI hydroxides and organic matter. However, in some soil Pb may be highly concentrated in Ca carbonate particles or in phosphate concentrations.

The solubility of lead can be greatly decreased by liming. A high soil pH may precipitate Pb as hydroxide, phosphate or carbonate, as well as promote the formation of Pb-organic complexes.

Hildebrand and Blume (1974) reported that illites show much greater affinity to sorbs Pb than other clay minerals. Farrah and Pickering (1977) emphasized that adsorption of Pb is highly dependent on kinds of legends involved in the formation of hydroxyl complexes of Pb [e.g. $PbOH^+$, $Pb^4 (OH_4)^{4+}$].

The characteristic localization of Pb near the soil surface in most soil profiles is primarily related to the surficial accumulation of organic matter. The greatest Pb concentrations are also often found in the organically rich top horizons of uncultivated soils, as was reported by Fleming *et al*. (1968). Therefore, organic matter should be considered as the important sink of Pb in polluted soils.

2.5.3: ABSOPTION AND TRANSPORT

Zimdahl (1975) and Hughes *et al.* (1980) extensively reviewed the findings on Pb absorption by roots and concluded that the mode of its uptake is passive and that the rate of uptake is reduced by liming and by low temperature. Pb, although not readily soluble in soil, is absorbed mainly by root hairs and is stored to considerable degree in cell walls.

When Pb is present in soluble forms in nutrient solutions, plant roots are able to take up great amounts of this metal, the rate increasing with increasing concentration in the solutions and with time. The translocation of Pb from roots to tops is greatly limited as ZimdahI (1975) described. Only 3% of the Pb in the root is translocated to the shoot.

ZimdahI and Koeppe (1977) summarized recent results of translocation and uptake studies and showed that under certain conditions Pb from a soil source is not readily translocated to edible portion of plants. These authors stated that the main process responsible for Pb accumulation in root tissue is the deposition of Pb, especially as Pb pyrophosphate, along the cell walls. Malone *et al*. (1974) identified the deposition in cell walls outside the plasma lemma as Pb precipitates and Pb crystals. Similar Pb deposition observed in roots, stems and leaves suggest that Pb is transported and deposited in a similar manner in all tissues of the plant.

2.6: Effect of Lead (Pb) on growth, mineral nutrition of rice

Hossain *et al*. (2015) suggested that Pb may influence the synthesis of cell wall polysaccharides, thereby decreasing the cell wall extensibility, resulting in growth suppression in rice roots.

Ullah *et al*. (2011) was conducted a pot experiment with 4 levels of lead (0, 100, 150 and 200 ppm) showed significant influences on plant height, number of tillers per plant, length of spikelet, dry weight of straw and grain, weight of 1000 grains, number of filled and empty grains per panicle of rice (*Oryza sativa L.*) The highest plant height and length of spikelet were found at 100 ppm lead stress treatment (Pb_{100}), while the other yield parameters were found the best in lead free treatment (Pb_0). The contents of N, P, K, Ca, Mg, Fe, Cu and Cd in the rice straw and grain decreased significantly with increasing level of lead, while accumulation of Pb increased both in the straw and grain with increasing lead stress.

Zeng *et al*. (2007) showed that Pb treatment had a stimulating effect on soil enzymatic activities and microbial biomass carbon at low concentration and an inhibitory influence at higher concentration. The results also revealed a consistent trend of increased chlorophyll contents and rice biomass initially, maximum at a certain Pb treatment and then decreased gradually with the increase in Pb concentration. Lead was effective in inducing proline accumulation and its toxicity causes oxidative stress in rice plants.

Tariq *et al*. (2007) was conducted the nutrient culture experiment with barley (*Hordeum vulgare L.*), rice (*Oryza sativa L.*) and wheat (*Triticum aestivum L.*) at control (0), 1, 5, and 10 µM of copper (Cu), zinc (Zn), lead (Pb), magnesium (Mg) and sodium (Na). Seed germination, total root numbers, root length, shoot height, and root: shoot ratio of seedlings were measured and integrated to calculate a metal tolerance index for each crop. Among the metals, cu exerted the most adverse effects on seed germination, early growth and tolerance of crop seedlings followed by Zn and Pb. Wheat and rice seedlings were more susceptible to metal toxicity than barley. The effect 10 µM Cu, Pb and Zn was more pronounced on crop seedlings especially on wheat and rice.

Zeng *et al*. (2006) showed that the application of Pb at lower level (300 mg kg^{-1}) as lead acetate resulted in a slight increase in soil microbial activities compared with the control and had an inhibitory influence at high concentration (>500 mg Pb kg^{-1} soil) which might be the critical concentration of Pb causing a significant decline in the soil microbial activities. On the other hand when the level of Pb treatments increased to 500 mg Kg^{-1} there was ecological risk for both soil microbial activities and plants. The results also revealed that there was a consistent trend that chlorophyll contents increase initially and then decreased gradually with increase in Pb concentration. Pb was effective in inducing proline accumulation and its toxicity causes oxidative stress in rice plants. In a word, soil microbial activities and rice physiological indices, therefore, may be sensitive indicators reflecting environmental stress in soil Pb rice system.

Chatterjee *et al*. (2004) stated excess of Pb reduced the dry weight pronouncedly at harvest when the grain yield also decreased. Lead accumulation reduced the concentrations of chlorophyll in leaves carotene, sugars, phenols, non protein nitrogen, iron, manganese, copper but increased the concentrations of sulphur, phosphorus, magnesium and nitrogen.

Verma *et al.* (2003) stated that when rice seedlings were grown under increasing concentrations of lead (Pb) in the growth medium, during a 5-20 day growth period increasing lead levels caused decrease in length as well as fresh weights of seedlings. With 1000 µM Pb in the medium up to 40% reduction in root length and 31% reduction in shoot length was observed in 20-day grown seedlings. Similarly up to 43% decline in fresh weight of roots and up to 29% decline of shoots was noticed in the seedlings at 20 days of growth. When rice seedlings were raised under increasing concentrations of lead, a continuous increase in the content of lead was observed in seedlings with increasing days of growth. The absorbed lead was localized to a greater extent in roots than in shoots. Seedlings grown under 1000 µM Pb (207.2 ppm) for 20 days showed up to 1.3065 µmol g^{-1} dry wt. of Pb absorbed in roots and up to 0.8008 µmol g^{-1} dry wt. Pb absorbed in shoots.

Liu *et al.* (2003) showed that the effects of lead (800 mg/kg Pb in soil) on rice growth and development varied greatly with different cultivars. The increases or decrease of the grain yields mainly resulted from the changes of the spikelets per panicle under soil lead treatment. Furthermore, the changes of spikelet are per panicle correlated significantly and positively with the change of dry straw weights. The lead concentrations decreased rapidly from roots to grains along rice plants, so the concentrations of lead in the grains were very low compared to other parts of the rice plants, but positive correlations, mostly significant, between disconnected organs, for the lead concentrations in them. Lead was not distributed uniformly in different parts of grain structure, and the lead accumulated in polished rice was only 32.88% of the total lead accumulated in grain.

Lijuan *et al.* (2000) stated rice yield was decreased by about 12-17% at lead levels of 180-720 mg/kg soil. Content of lead in rice tissue increased with increasing level in soil. Lead accumulation was highest in root and lowest in grain.

Kang *et al.* (2000) reported that rice yield was decreased by about 2-17% at lead levels of 180-720 mg/kg soil. Content of lead in rice tissue increased with increasing level in soil. Lead accumulation was highest in root and lowest in grain. To maintain lead content in rice grain less than the food hygiene standard, the critical concentration in the soil was 241 mg/kg (total) and 49 mg/kg (DTPA extractable).

Chen *et al.* (1991) studied the effects of different lead compounds on growth and heavy metal uptake of wetland rice. Rice cv. Nanjung 3714 seedlings were grown in 200ml pots containing 0.2 kg yellow brown (Alfisol) or red (Oxisol) soil mixed with 0-2000 mg Pb/kg as $PbCI_2$, $Pb(NO_3)_2$ or $Pb(OAC)_2$. Seed germination and respiration, shoot and root growth of seedlings and seedling chlorophyll content were decreased by added Pb. $PbCI_2$ was more toxic than the other Pb compounds and the toxic effects were greater on more acid Oxisol (pH 4.7) compared with pH 6.5 in the Alfisol. In another experiment, 3 weeks old rice seedlings were transplanted into pots containing 4.5 kg yellow brown soil mixed with 0-4000 mg Pb/kg as $PbCl_2$, $Pb(NO_3)_2$ or $Pb(OAC)_2$ and grown to maturity in flooded conditions. The effects of Pb on grain yield were inconsistent, although mean yields were lowest in the $PbCI_2$ treatment. All Pb compounds greatly increased Pb uptake and plant tissue concentrations. Pb $(OAC)_2$ produced the highest Pb concentrations in the roots, whereas concentration in all above ground parts were highest in (Pb $NO_3)_2$ treated plants.

Trivedi *et al*. (1992) reported that increasing Pb concentration had an adverse impact on K uptake by rice plant. Lead reduced the contents of K significantly in straw and grains of rice.

Xie- Zhengmiao *et al*. (1994) investigated the relationships between lead, zinc and arsenic contents and rice tillering in the soil-rice system. The result showed:

1. Low concentration of Pb, Zn and As in the soils could promote rice tillering, while high concentrations of the three elements could inhibit rice tillering.
2. Combined pollution of Pb, Zn and As in soils has no additive reaction on promotion of rice tillering.
3. Contents of Pb, Zn and As in rice plants are closely related to rice tillering as well.

Zhang *et al*. (1997) collected rice samples from Asia and showed a marked difference in Pb contents in rice by areas and regions in the world.

Lead treatments reduced the contents of nitrogen in rice straw and grains (Strand *et al.,* 1990).

Increasing lead concentrations had an adverse impact on potassium (K^+) uptake by rice plant. Lead reduced the contents of K^+ significantly in straw in grain (Trivedi and Frdei, 1992).

The average potassium content of tomato and eggplant is affected by different levels of lead. Lead reduced the contents of K^+ uptake significantly (Khan and Khan, 1983).

The toxic effect of lead on potassium uptake by rice plants was also observed (Kim *et al*., 1986)

An antagonistic effect on nitrogen uptake by rice plants due to applied lead was reported (Lee *et al*., 1991)

Increasing Pb concentration in soil reduced the Ca^{2+} contents significantly in straw and grain of rice (Kim *et al*., 1986).

Lead reduced the contents of Mg^{2+} significantly in rice plant (Lee and Kim, 1991)

Hirayama and Kabayashi (1989) reported that magnesium uptake in rice plant decrease due to Pb toxicity.

Mishra and Chowdhury (1998) stated germination of two rice cultivars (Ratna and IR 36) in the presence of 10 µM Pb Cl_2 decreased germination percentage, germination index, shoot/root length, tolerance index and dry mass of shoots and roots. The effects were more pronounced in tolerant cultivar IR 36 than in the relatively susceptible cultivar Ratna.

Ullah *et al.* (1999) stated that the heavy metals were high in grasses, water hyacinth and rice plants adjacent to industries. Grass accumulated more and tolerated higher amounts of heavy metals than those of water hyacinth and rice.

2.7: Effects of Lead (Pb) on growth and mineral nutrition of Wheat:

Cheng *et al,* (2015) showed that the wheat varieties of Zhengdan 958 and longping 206 have the maximum Pb tolerance, whereas Lianchuang 5's tolerance of Pb was the minimum. Pb form in roots and shoots were mainly harmfulness HAC-extractable and HCl-extractable, according for a high proportion of 60-87%. Moreover, these values in roots were slightly higher than those of shoots. Tolerance of Zhengdan 958 to Pb stress was related to its strong ability to convert toxic Pb into non-toxic Pb.

Nedjah *et al*. (2013) identified the effect of lead on germinal parameters and the antioxidant enzyme activities (lipase, peroxidase and catalase) in durum wheat *Triticum durum* variety: (waha, vitron and gta) exposed to the concentrations of 0, 0.15, 0.25 and 0.3 g/L of Pb $(NO_3)_2$ during germination process. The obtained results showed that lead reduced the germination, root and aerial biomass. The concentration of 0.3 g/L inhibited completely the germination of the three varieties. It also slowed lipase activity, the degradation of lipids of the seed's reserves and disrupted the metabolism of peroxidase and catalase. Concerning the behavior of the three varieties studied, it appears that the vitron is the best predisposed variety to stand against lead stress by its strong antioxidant defense system.

Bhatti *et al.* (2013) conducted a pot experiment to study the adverse effects of lead (Pb) on two wheat varieties i.e. Chakwal-97 and Sehar-2006. Plants were treated with Pb at 0, 40 and 60 ppm solution levels. Pb reduced the morphological parameters such as shoot/root length, shoot fresh/dry weights, number of tillers. Pb stress also decreases the photosynthetic pigments such as chlorophyll a, chlorophyll b but carotene contents were increased. Na^+, K^+ ion contents were also decreased by Pb. So Pb as a heavy metal has detrimental effect on wheat growth and development.

Lamhamdi *et al.* (2013) also investigated lead effects on nutrient uptake and metabolism, two plant species, spinach (*Spinacia oleracea*) and wheat (*Triticum aestivum*), were grown under hydroponic conditions and stressed with lead nitrate, $Pb(NO_3)_2$, at three concentrations (1.5, 3, and 15 mM) and result showed that total amounts and concentrations of most mineral ions (Na, K, Ca, P, Mg, Fe, Cu and Zn) are reduced, although Mn concentrations are increased, as its uptake is reduced less relative to the whole plant's growth. The deficiency of mineral nutrients correlates in a strong decrease in the contents of chlorophylls a and b and proline in both species, but these effects are less pronounced in spinach than in wheat. By contrast, the effects of lead on soluble proteins differ between species; they are reduced in wheat at all lead concentrations, whereas they are increased in spinach, where their value peaks at 3 mM Pb.

Kaur *et al.* (2012) reported that wheat growth measured in terms of root length, shoot length and dry weight exhibited a significant decline with increasing Pb concentrations in the soil. In addition, there was a significant reduction in the levels of photosynthetic pigments-chlorophyll a (16-66%) and b (10-24%) and total chlorophyll content (by 14-39%) in plants growing in Pb-contaminated soil. The reduction in wheat growth in Pb-contaminated soil was accompanied by induction of oxidative stress as indicated by enhanced lipid per oxidation in terms of malondialdehyde (MDA) content (by 18-40%) and hydrogen peroxide (H_2O_2) content (by 34-123%) and alterations in the activity of enzymes, superoxide dismutases (SOD) and guaiacol peroxidases (GPX) in wheat roots. The study concludes that Pb in soil inhibits growth and photosynthetic activity in wheat through induction of oxidative stress.

Lamhamdi *et al.* (2011) reported that lead accumulation in wheat seedling was positively correlated with the external concentrations and negatively correlated with morphological parameters of plant growth.

Weiwei *et al*. (2009) investigated the ecotoxicological effects of Pb and Cu on the seed germination, seedling growth and α- amylase activity of wheat. The seed germination and seedling growth of wheat could be promoted at low concentrations of Pb (under 0.5 mg/L), while they would be inhibited when the concentration of Pb was high. Cu at the germination rate, seedling growth and vigour markedly; the activity of α-amylase could be enhanced at low concentrations of Pb or Cu but could be inhibited at high concentrations and the injury became severer with the increase of concentration. The inhibitory effect of Cu on the seedling growth indices of wheat was greater than that of Pb. The stress effects of Pb or Cu was stronger on seed germination than on seedling growth.

Du *et al*. (2010) carried out a pot experiment to study the influence of soil Pb pollution on the growth of wheat seedlings. The results are as follows: (1) low concentrations of Pb in the soil stimulated seedling growth; high concentrations, however, inhibited their growth. (2) The Pb taken up by the seedlings is mostly accumulated in the roots, and only a little is transported to the shoots. (3) More Pb was accumulated in the seedlings growing on an acid soil due to the higher level of available Pb.

Saini *et al*. (2001) indicated that yield of grain, straw and root of wheat increased significantly with an application of 5 mg Pb kg^{-1} soil and it decreased at higher levels of Pb application. Application of 80 mg Pb kg^{-1} soil over control decreased mean grain yield by 21.8 and 12.3% , straw by 6.9 and 4.2% and roots by 23.4 and 8.2% in sandy and clay loam soil respectively. Grain, straw and root Pb concentration increased significantly from 0.91 to 6.23, 2.11 to 11.17 and 4.96 to 21.76 µg g^{-1} when Pb levels were raised from 0 to 80 mg kg^{-1} soil, irrespective of the soil texture. Addition of FYM @ 1.0% decreased Pb concentration by 18.3 and 18.2% in grain 14.2 and 7.1% in straw and 5.3 and 6.6% in roots when grown in sandy and clay loam soil, respectively. The result showed that FYM application reduced Pb toxicity and improved the yield significantly.

Titov *et al*. (1996) showed that lead and cadmium metals inhibited seed germination and growth of roots and shoots of wheat and barely but the toxic effect of cadmium was observed at lower concentrations. Inhibition of seedling growth was already recorded within a day after the beginning of the treatment and then increased further. The sensitivity of the processes studied to both the metals decreased in the order: root growth, shoot growth and seed germination. The resistance of barely and wheat to lead was similar, whereas the resistance to cadmium was higher in barely.

Rashid *et al*. (1993) stated that foliar applications of lead nitrate solution caused reduction in various growth indices and yield parameters of wheat.

2.8: Effects of Pb on growth and mineral nutrition of Maize:

Keawsringam *et al.* (2015) conducted a experiment to study lead accumulation and the type of rhizobacteria associated with maize grown in the lead contaminated area. The results showed that lead concentrations in different tissues were roots>Shoots>grains. The highest lead concentration was recorded on day 120 (54.31, 110.67 and 4.79 mg kg^{-1} in shoots, roots and grains, respectively). The lowest lead concentration was recorded on day 40 (27.80 and 71.90 mg kg^{-1} in shoots and roots, respectively) with no detectable lead in the grain. Results indicated that lead concentration in grains on day 120 of the experiment exceeded the standard as animal feed (30 mg kg^{-1}), which might not be safe for human consumption.

Tafvizi *et al.* (2014) investigated the effects of different levels of lead (Pb) on the concentration of iron (Fe), manganese (Mn), and zinc (Zn) in *Zea mays* and showed that the accumulation of Pb was greater in roots than shoots in the maize varieties. Increased Pb concentration in soil decreased Mn and Fe in shoot and elevated Fe concentration in roots. The Mn concentration of roots on different levels of Pb was not affected. Zinc concentration of almost all varieties increased in shoots and decreased in roots with the increase of Pb in soil.

Hussain *et al.* (2013) reported that seed germination, early growth seedling, root-shoot length, root-shoot fresh and dry weights, total protein content of maize were reduced by the increased lead concentrations. Such growth retardation was due to metals toxicity that resulted in damages to various physiological and biochemical processes.

Ghani (2010) stated that exposure of maize varieties to excess Pb resulted in a significant root growth inhibition though shoot growth remained less affected.

Jamali *et al*. (2008) examined the effect of sewage sludge on the growth and production of maize and also determined the heavy metal content in the product. They observed that a significant amount of Zn, Cu, Cd, Pb and other trace and toxic metals were present in the sewage sludge. They treated the sewage sludge with lime before application to the maize field which had a positive effect on heavy metals. The experiment showed that heavy metals were transmitted from the sewage sludge to the maize and reduced the quality of the maize. Heavy metal content was significantly reduced (30%) in the lime treated maize, as compared to the untreated sewage sludge.

Dmitrij *et al*. (2005) stated that low heavy metal concentrations (10-100 µM) had a tendency to increase root length though high amounts of heavy metals (1 and 5mM of copper, lead and nickel, respectively) resulted in root growth inhibition as compared to control plants. The growth of maize shoots was rather resistant to various heavy metal doses as a statistically significant inhibition of shoot growth was determined only for lead amounts over 5 mM. At day 21 plant growth distinction was even more pronounced. Though no obvious impact of Zn and Pb at the amount of 10-1000 µM on growth pattern was determined 5-10 mM concentrations resulted in strong plant growth suppression. Their experiments revealed that Pb present at low concentrations has a tendency to stimulate biomass accumulation only high (5-10 mM) doses of Pb significantly suppressed biomass accumulation in roots while shoots were less affected. The shoot to root weight ratio expressed on the basis of both fresh and dry weight had a tendency to increase with the amount of lead. A significant increase of the shoot to root ratio was observed under exposure of maize seedling to 10 mM Pb^{+2} solutions.

In corn seedlings Pb toxicity causes leakage of K ions from root cells Malkowski *et al,* (2002).

Eun *et al.* (2000) reported that the inhibition of root growth under Pb toxicity is as a result of Pb induced inhibition of cell division in root tips.
The adverse effects of Pb had also been reported by Kansal *et al*. (1992) in maize.
Javed and Sahar (1987) have reported reduction in germination of maize at 5-100 mM lead nitrate treatments.

In Zea mays seedlings, Obroucheva *et al.* (1998) observed strong inhibition of primary root growth and a shorter branching zone with compact lateral roots occupying a position much closer to the root tip compared with roots grown in the absence of Pb.

In Zea mays, Pb decreased the uptake of Ca, Mg, K and P (Walker *et al*., 1997).

2.9: Effects of Pb on other crops:

Kibria *et al*. (2010) conducted a pot experiment to study the effects of lead (Pb) on growth and nutrient concentration in *Spinacea oleracea L.* The levels of Pb used in study were 0, 20, 40, 60, 80, 100, mg kg^{-1}. Lead application in soil caused a gradual decrease in dry weight of both the shoot and root of *S. oleracea* with increasing Pb level. Potassium concentration in both shoots and roots and magnesium, zinc and iron concentration in roots of *S. oleracea* decreased with Pb application. On the contrary, Pb application significantly increased nitrogen, magnesium and manganese concentration in shoots as well as calcium and manganese concentration in roots. Phosphorus concentration neither in shoots nor in roots was affected by Pb application.

Zengin *et al*. (2005) showed that lead, copper, cadmium and mercury toxicity decreased the total chlorophyll content of the leaves of bean seedlings. In response of heavy metal stress, the plants increased their proline, retinol, α-tocopherol and ascorbic acid content. The highest increase in proline, retinol, α-tocopherol and ascorbic acid content and greatest reduction in total chlorophyll were found in plants exposed to mercury>copper>lead.

Kibria *et al*. (2009) reported that shoot and root weight of *A. gangetius* declined by 28 and 53% and *A. oleracea* by 46 and 37%, respectively over control at the highest rate of Pb application. Lead application in soil significantly decreased N and P concentration in shoots as well as Ca, Zn and Mn in both shoots and roots of *A. gangetius.* Phosphorus, K and Fe in roots of A. *gangetius* increased with increasing rates of Pb. The contents of P, Fe and Mn in shoots and Ca, Zn and Mn in roots of *A. Oleracea* decreased with increased rates of Pb application. On the other hand, an increase of N, K and Zn concentration in shoots and K and Fe concentration in roots of *A. Oleracea* were observed. Lead application in soil significantly increased Mg concentration in both shoots and roots of *A. gangetius* and *A. Oleracea.*

Kabir *et al*. (2008) reported that seed germination, seedling growth and seedling dry weights of *Thespesia populnea L* were significantly ($p<0.05$) affected by different concentrations (10, 30, 50 and 70 µmol/L) of lead as compared to control. Lead concentration at 10 µ mol/L significantly reduced seed germination, seedling growth and dry weight as compared to control. Cd treatment at 10 µmol/L concentration also produced toxic effects on seed germination, seedling and root growth as compared to control. Increase in cadmium concentration up to 50 µmol/L produced a significant reduction in seedling dry weight of *T. populnea* as compared to control. Seedlings vigor index of *T. populnea* gradually decreased with the increase in concentrations of lead and cadmium. Lead and cadmium treatments at 70 µmol/L exhibited lowest percentage of tolerance as compared to control.

Mumtaz *et al.* (2006) reported that application of both lead and chromium caused a significant reduction in all growth parameters of Mash bean as compared with that of control. The extent of decrease in growth due to chromium compared with lead. Although high concentration of both metals in the rooting media drastically reduced all photosynthetic pigments. In addition, all yields attributes of both cultivars of mash bean reduced due to both metals in rooting medium. The sensitivity of mash bean to chromium was greater as compared to lead. In conclusion, mash bean cultivar FS-1 proved to be tolerant as it showed less reduction in growth, photosynthetic pigments and yield as compared to Mash-97.

Farooqi *et al.* (2009) reported that Lead and Cadmium treatments of 10, 30, 50, 70 and 90 µmol/L affected seed germination and seedling growth of *A. lebbeck* as compared to control. Lead treatments of 10, 30, 50, 70 and 90 µmol/L concentrations produced significant ($p<0.05$) effects on seed germination and seedling length of *A. lebbeck* while lead treatment at 50 µmol/L significantly affected root growth and seedling dry biomass as compared to control.

Wierzbicka (1994) reported that a reduction in root growth, mitotic irregularities and chromosome stickiness were observed in onion (*Allium cepa*) due to effect of different concentrations of Pb nitrate.

A considerable decrease in dry weights of plant parts is observed under Pb treatment (Kosobrukhov, 2004)

2.10: Amelioration of Pb toxicity by various treatments

Essien *et al*. (2015) conducted an experiment to evaluate the enhancement of remediation by *Eleusine indica* through augmentation of soil with cow dung. The soil was contaminated artificially with 50kg, 75kg and 100kg crude oil over 8 weeks period. The study included an assessment of the polycyclic aromatic hydrocarbons (PAHs) and heavy metal (Cd and Pb) accumulation in soil of *Eleusine indica*. More PAHs was lost from soils augmented with cow dung than from the non-augmented soil. The heavy metals (lead) were in the augmented soils than from the non augmented soil, while heavy metal (cadmium) shows an insignificant amount. Significant differences were noticed between the augmented soils and the non-augmented soil ($p<0.05$). The results obtained in this study show that augmenting crude oil polluted soils with cow dung will enhance remediation and restoration of crude oil polluted soil (web-2).

Bai *et al*. (2015) were conducted hydroponics experiments to study the effects of sodium nitroprusside (SNP, a donor of NO) on lead toxicity in ryegrass (*Lolium perenne* L.) seedlings. When the ryegrass seedlings were grown in a nutrient solution containing 500 µM Pb^{2+} for two weeks, the plant biomass as well as net photosynthetic rate, transpiration rate, chlorophyll and carotenoid content of leaves decreased. Additionally, the content of Cu in shoots and the content of K, Mg, Fe, and Zn in both shoots and roots decreased, but the content of Ca in shoots and roots increased under the Pb stress. Moreover, Pb accumulated mostly in roots, whereas a small quantity was translocated to shoots. However, the addition of 50, 100, and 200 µM SNP into the solution containing Pb increased the chlorophyll content and net photosynthetic rate, reduced Pb-induced oxidative damages, improved antioxidant enzyme activities, and inhibited translocation of Pb from roots to shoots. In particular, 100 µM SNP had the best effect on promoting growth of the ryegrass seedlings under the Pb toxicity.

Rameshkumar *et al*. (2013) conducted pot culture experiment to find out the suitable amelioration for lead toxicity by growing groundnut on leaded soil amended with cow dung and vermin compost and all morphological, growth and yield characters were analyzed on 120th DAS (Day after sowing) to find out the comparative effect between leaded soil and leaded soil with soil amendments. The germination percentage, seedling growth and dry weight of groundnut seedlings were high at amended soil when compared to lead acetate polluted soil and it might be due to the presence of optimum level of nutrients. Whereas, in higher concentrations of lead acetate, all the parameters showed negative results and it might be due to the high toxicity level of Pb present in the polluted soil.
Lee *et al*. (2011) stated that individually or combined treatment of iron–rich amendments were effectively lowered the availability of trace elements. Compared to control soil, $Ca(NO_3)_2$

extractable As, Cd, Pb and Zn were reduced by 58, 98, 98 and 99% respectively by combined treatment of limestone and red mud. The decreased availability of trace elements was accompanied by increased microbial activity and decreased plant uptake of trace elements. Compared to non amended control soil, only 13, 28, 47 and 12% of As, Cd, Pb and Zn respectively, detected in combined treatment of limestone and red mud. These results suggest that iron–rich industrial by–products could be used for remediation of soils co-contaminated with metals and arsenic.

Ahmed *et al.* (2011) used different amendments to investigate their effect on availability concentration and uptake of Pb and Cd by wheat in texturally different soils. Crop was irrigated with water containing Cd and Pb at 20 mgL^{-1}, thereby adding 260 mg pot^{-1} of each metal. Amendments included calcium carbonate at 6 or 12%, gypsum at 50 or 100% of the soil gypsum requirement, farm manure at 7.50 or 15g kg^{-1} soil and a control. Amendments decreased ammonium bicarbonate diethylenetriamine penta acetic acid (AB-DTPA) extractable Cd and Pb conc. and uptake by wheat dry matter, concentration, uptake and extractability of Cd and Pb were greater in sandy loam soil compared with those in sandy clay loan soil irrespective of amendments. Sequential extraction should that more metals were extracted from the control in all functions and that predominantly metals were found in the carbonate function.

Alamgir *et al*. (2011) reported that 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. 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. 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.

The liming of soils has been very effective in controlling heavy metal mobility in soils (Matos *et al*., 2001). Lime amendments buffer the pH of soil in order to reduce the mobility of Pb and other metal also. The application of lime may also be a cost effective form of remediation and may be applied by the range owners themselves (USEPA, 2001). Liming metal contaminated sewage sludge reduced the DTPA extractable Pb by as much as 8 to 14% (Fang and Wong, 1999). However it is important to monitor the conditions before lime application, as well as the amount of lime applied due to the possible mobilization of organic Pb complexes.

Plants may be used to control contamination via surface run off. Planting grass is an important and easy erosion control method (USEPA, 2004). Vegetation may also help to stabilize Pb. Turpeinen *et al*. (2000) reported that pine roots played an important role of immobilization of Pb in a former shooting range soil. In addition, some species of plants have been reported to accumulate Pb in the above ground biomass. Manninen and Tanskanen (1993) reported total Pb concentration as high as 70 mg Kg^{-1} in the leaves of *Betula Pendula*. However, Pb uptake by plants is typically at a minimum and the highest concentration of Pb typically remains in the roots.

Better performance of rice by applying cowdung in Tongi soil was also reported earlier (Chamon *et al*., 2005 a). In tomato shoots, cowdung and poultry litter amendment showed a reduction of Pb content. Fresh and dry weight of shoot of wheat was enhanced by 24% and 38% and shoot length of wheat was significantly higher by 39% in limed pot than unlimed pots. Liming did not significantly affect yield parameters but significantly ameliorated heavy metal concentration in rice (BR-28).

Garau *et al*. (2007) compared the efficiency of different amendments, notably red mud, natural Zeolite and lime to immobilize the heavy metals present in a polluted soil. They stated that addition of all the amendments decreased significantly the solubility of Pb, Cd, and Zn and the increase the soil pH was identified as a common mechanism of action for both red mud and lime. All the amendments reduced number of heterotrophic fungi while only the lime addition influenced negatively the number of free living N_2 fixing bacteria. Furthermore, the addition of red mud and lime caused a significant change of the dominant cultivable bacterial community.

Gray *et al.* (2006) evaluated the effectiveness of lime and red mud to reduce metal availability to *Festuca rubra* and to allow re-vegetation on a highly contaminated brown field site. Application of both lime and red mud (at 3 or 5%) increased soil pH and decreased metal availability. *Festuca rubra* failed to establish in the control plots but grew to a near complete vegetative cover on the amended plots. In an additional pot experiment, P application in combination with red mud or lime decreased the Pb concentration but not total uptake of Pb in *Festuka rubra* compared to red mud alone. The results show that both red mud and lime can be used to remediate a heavily contaminated acid soil to allow re-vegetation.

Chamon *et al*. (2006a) stated that Fresh and dry weight of shoot was enhanced by 24% and 38% in lime treated pots compared with the unlimed pots. Also shoot length of wheat was significantly higher by 39% in limed pots than the unlimed pots with Tejgaon soil. Liming did not affect significantly P and K contents in the shoots of wheat but it influenced significantly N, S, Ca and Mg contents in shoots. Nitrogen and sulphur in shoots were 18 and 70% higher due to liming, respectively. Pb content in wheat grain was reduced 56% by lime application compare to unlimed Tejgaon soil. They stated that Fe present in red mud and form complex with metal ions and lime increase pH and metal become unavailable.

Parvin *et al*. (2003) indicated that the toxic level of Pb in grain was ameliorated by cowdung, redmud and $CaCI_2$; while $CaCI_2$ eliminated the toxicity of Pb both in straw and grain and showed transfer co-efficient of lead into straw and grain is zero. Results also indicated that Pb significantly increased the Pb and N content but reduced the P, S and K content both in straw and gain of BRRIdhan-30. Soil amendments significantly reduced the content of Pb but amongst them $CaCI_2$ has greater ability to ameliorate Pb toxicity.

Chen and Lee (1997) and Hussain (2000) stated that the extensively used immobilizing agents include Ca salts such as gypsum, dolomite and phosphates and incorporation of some nontoxic organic materials into polluted soils to decrease solubility of heavy metals in soils through precipitation, adsorption, or complication. Application of calcium carbonate containing amendment sufficiently decreased the solubility of heavy metals in contaminated soils (Liu *et al*., 1998; Isoyams and Wada, 2007) and increased soil pH and all these combined to decrease the metal uptake by rice, wheat and cabbage (Chen *et al*., 2000). Many reports indicated that sulfur containing amendments and organic waste application to contaminated soils lowered the concentration of soluble Cd and Pb in soils (Kaplan *et al*., 2005).

Chamon *et al*. (2006b) was conducted a pot experiment with soils from an industrially contaminated site to test the ameliorate toxicity in tomato (*Lycopersicon esculentum*) plants showed that almost all treatments had positive effects on crop productivity and reduced heavy metal uptake. The results also showed that the dry matter yield of tomato was the highest in the pots receiving cow-dung and city wastes followed by poultry litter, control, water-hyacinth and oil cake

Nuruzzaman *et al*. (1995) reported that application of cowdung in the polluted soil has increased slightly N, P and K content of all crops (rice, wheat) but the effect was not significant. The treatment with water hyacinth did not show any difference. The dry matter yield of wheat shoot and grain increased by 33 and 52% in the 40 Mt cowdung/ha and 23 and 41% in the 40 Mt/ha water hyacinth treatments. Better performance was observed in cowdung treatments. The dry matter yield of rice shoot and grain increased by 25 and 27% 40 mt/ha cowdung and 24% grain yield reduced with 40 mt/ha water hyacinth and 35% shoot increased from those with control. The increase in dry-matter yield with the application of farm manure could be attributed to the complexing properties of organic matter, which might have increased the availability of micronutrients from sparingly soluble respective hydroxides (Stevenson, 1991; Nardi *et al*., 2002).

Kabata-Pendias (2004) reported that application of greater rates of gypsum and lime decreased wheat dry-matter yield for sandy loam and sandy clay loam soils, which might be due to the antagonistic effect of Ca and P on the absorption of several metal ions, including Cd and Pb. The Cd and Pb concentrations decreased in wheat grains with the addition of farm manure and lime, which might have immobilized the Cd and Pb through adsorption, complexation and precipitation phenomena, resulting in reduced phytotoxicity and accumulation in plants (Cao *et al*., 2003; Geebelen *et al*., 2002; Seaman *et al*., 2003).

According to Bolan *et al*. (2003) Ca^{2+} addition as gypsum and lime inhibited the translocation of Cd and Pb from root to shoot as these metals are accumulated primarily on cell walls of roots with only limited amounts translocated to shoot and grains.

2.11. Phytoremediation of Lead toxicity by various crops

Zhi *et al.* (2015) indicated that *Eruca* is tolerant or moderately tolerant to Cu, Hg, Cr, Cd and highly tolerant to Zn, Ni and Pb, and can be developed as an industrial oil crop for phytoremediation of soils contaminated by heavy metals. The heavy metal of tolerant *Eruca* can also be used for cloning genes responsible for heavy metal tolerances.

Aliyu *et al*. (2014) stated that maize can be used to phytoremediate Pb, Fe and Zn metals.

Sekara *et al*. (2005 a) carried out fiield experiments with nine crops (red beet, field pumpkin, chicory, common bean, barley, white cabbage, maize, alfalfa and common parsnip) to determine the cadmium and lead accumulation and distribution in the plants' organs. Based on the obtained results, species suited for phytoremediation were selected. Within the red beet, field pumpkin, chicory, common bean, white cabbage and parsnip the maximum Cd and Pb content was found in leaves. The red beet was characterized by the highest cadmium concentration ratio (shoots/roots). The red beet and common parsnip were characterized by the highest lead concentration ratios (shoots/roots).

Gupta *et al.* (2010) conducted field experiment to study the phytotoxicity of lead on growth parameters two inbreeds of Black gram (*Vigna mungo*). In a separate experiment Black gram is intercropped with vetiver grass to study the phytoremediation through vetiver. In the first set of experiment, the growth and metabolism of Black gram were adversely affected with the increase in lead concentration and a concentration dependent decrease was noticed in all the growth parameters studied. Variety T-9 was found to be more susceptible to lead as compared to PU-35. In the second set of experiment (intercropping with vetiver) a significant recovery of this phytotoxicity was noticed in both the varieties of Black gram. Lead accumulation in roots of vetiver grown in lead treated soil is higher than growing in non contaminated soil. Results of the present study reveal that vetiver can be regarded as a potential phytoremediator plant that can be grown in a site contaminated with lead.

Ghani (2010) reported that Desi (Maize variety) withstands excess Pb with its higher Pb accumulation capacity in roots and better up regulated protective mechanisms compared to Neelam (Maize variety). Therefore, Desi is more tolerant to Pb toxicity compared to Neelam which was found to be susceptible variety.

Chamon *et al.* (2005b) stated that the highest Pb concentration was obtained in BR-11 and the lowest in rice shoot of BR-22. There was no significant difference in Pb concentration among the shoots of BR-30, BR-22 and BR-25. Pb concentration in grains were highest in BR-29 and lowest in BR-14. The wheat variety Kanchan exhibited the highest grain yield, followed by Akbar and Agrani. No significant differences of MN, Cu and Pb concentration of shoot among the wheat varieties were obtained and Pb concentration in grains were lowest in Agrani and highest in Kanchan variety.

3. Materials and Methods

Pot and field experiments were conducted in the experimental field of Soil Science Department under Govt. Bangla College, Mirpur, Dhaka during June, 2011 to June, 2012 to study the effects of Lead on some cereal crops of Bangladesh and its remediation. This chapter deals with the major information regarding materials and methods that were used in conducting the pot and field experiments.

3.1. Experimental site: The experimental site of collected agricultural soils for pot and field experiments was Mirpur, Govt. Bangla college field belongs to Belabo series under the Agro-ecological zone, Madhupur tract (AEZ-28).

3.2. Collection of Soil sample: Bulk soil samples representing 0-15 cm depth were collected from the experimental field by pit and core method with the help of a soil auger/spade.

3.3. Description of the soil series

The uncontaminated soil used in this experiment belongs to belabo soil series and comprises moderately well drained, yellow-brown, mottled clays occupying level upland sites. The brown loamy topsoil is underlain by a thin layer of yellow-brown to strong brown friable clay which becomes increasingly strong mottled reddish yellow with depth. The soil series was identified at Govt. Bangla college premises was found shallow depth due to human disturbance. It has anthropogenic problems. The area has a tropical monsoon climate. The Modhupur tract are compact clays, previously called pleistocene clays, but now thought possibly to be Dupi Tila age and now called Modhupur clay. The mean annual rainfall of the area is about 2225 mm.

Table-3: A correlation of the Belabo Soil Series with the international Soil classification system (ISCS)

Soil Series	family	Sub group	Great group	Sub order	order	Physiographic unit (P.M)	General soil type	FAO/UNESCO legend
Belaboo	Clayey kaolinitic	Typic palendalt	Palendult	Ustults	Ultisol	Modhupur Tract (Modhupur clay)	Red brown terrace soil	Dys tric nito sol

3.4: Soil Series identified by SRDI Staff: Soil series was identified by the Soil Resource Development Institute (SRDI) scientists and supportive staff (Photograph-1).

Photograph-1: Soil series identification at Govt. Bangla College, Mirpur, Dhaka by SRDI staffs.

3.5. Soil sample preparation; The collected soil samples from experimental field were air-dried for several days in a clean room avoiding direct sunlight and dust. After air-drying a portion of the larger and massive aggregates were broken by gently crushing them with a hammer and then mixed thoroughly to make it a composite sample. Dry root, grasses and other particulate materials were discarded from the sample and used for pot experiments and grown rice, wheat and maize crops. A portion of the crushed and composite soil sample was further ground and screened to pass through 2.0 mm sieve. This sample was kept in a plastic container for physical and chemical analyses and level properly showing the depth, sample name and the date of collection. Collected soil samples were analyzed and shown in (Table-4).

3.6. Collection of Fertilizers: All fertilizers (Urea, TSP, MP, Gypsum, $ZnSO_4.H_2O$, Boric acid

were procured from the Bangladesh Agricultural Development Corporation (BADC) sale centre, Motijheel, Dhaka.

3.7. Collection of Cowdung, Poultry litter and Lime: Well decomposed cowdung was collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. Poultry litter was collected from poultry farm, Savar and was well decomposed. Then Cowdung and Poultry Litter was grinned in a blender and was applied to rice, wheat, maize varieties at a rate of 20 t/ha. Lime (CaO) was collected from the Dept. of Soil, Water and Environment, University of Dhaka.

3.8 Collection of Seedling: Thirty days old rice seedlings of BRRIdhan-33, BRRIdhan- 49, BRRIdhan-53 and BRRIdhan-54 were collected from the seedbed of Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. Seedlings were kept in water pots submerging their roots in several centimeters for few days before transplantation.

3.9. Collection of seeds: Certified seeds of wheat (*Triticum aestivum*) and maize (*Zea mays L.*) were collected from Bangladesh Agricultural Research Institute), Joydebpur, Gazipur.

3.10. Pot and Field experiment: Pot and field experiments were conducted with uncontaminated soils of Govt. Bangla college field, Mirpur, Dhaka. Different cereal crops such as rice, wheat and maize were the test crops. To study the effects of different doses of Pb (0, 50, 100, 150, and 200 ppm) and ameliorating effects of cowdung, poultry litter and lime, pot experiment was conducted with BRRIdhan-49 (rice variety), BARI wheat-26 (wheat variety) and BARI maize-9 (maize variety). For investigation of phytoremediation of lead toxicity by rice and wheat varieties, four rice varieties and three wheat varieties were grown in pots with addition of

200 ppm of Pb. To study the effects of Pb, three wheat varieties and one maize variety were also grown in field. All details of pot and field experiments are presented in the next section:

3.10.1: Pot Experiment

3.10.1.1: Experiment-1: Effects of different doses of lead (Pb) on rice (variety: BRRIdhan-49).

Soil: Govt. Bangla college field, Mirpur, Dhaka

Fertilizer: Urea 60 Kg/ha, TSP 10 Kg/ha, KCl 40 Kg/ha (60% K_2O) and Gypsum 10 Kg/ha.

Pots: 8 Kg soil/pot, 3 replication

Crop: Rice (3 plants/pot)

Date of transplanting: 30/07/2011

Date of harvesting: 03/11/2011

Treatments: Lead as Lead Acetate (0, 50, 100, 150 and 200 ppm respectively).

Denotation	Treatments
T_o	BRRIdhan-49+0 ppm Pb
T_1	BRRIdhan-49+50 ppm Pb
T_2	BRRIdhan-49+100 ppm Pb
T_3	BRRIdhan-49+150 ppm Pb
T_4	BRRIdhan-49+200 ppm Pb

3.10.1.2: Experiment-2: Effects of soil amendments in remediation of Pb conc. in rice (Variety: BRRIdhan-49).

Soil: Govt. Bangla college field, Mirpur, Dhaka

Fertilizer: Urea 60 Kg/ha, TSP 10 Kg/ha, KCl 40 Kg/ha (60% K_2O) and Gypsum 10 Kg/ha

Pots: 8 Kg soil/pot, 3 replication

Crop: Rice (3 plants/pot)

Date of transplanting: 30/07/2011

Date of harvesting: 03/11/2011

Treatments: 100 ppm Lead as Lead Acetate, Cowdung 20 t/ha, Poultry litter 20 t/ha and Lime 5 t/ha.

Denotation	Treatments
T_o	BRRIdhan-49
T_1	BRRIdhan-49+100 ppm Pb
T_2	BRRIdhan-49+100 ppm Pb +cowdung
T_3	BRRIdhan-49+100 ppm Pb + poultry litter
T_4	BRRIdhan-49+100 ppm Pb + lime

3.10.1.3: Experiment-3: Varietal effects of rice grown on soil contaminated with 200 ppm of Pb

Soil: Govt. Bangla college field, Mirpur, Dhaka

Fertilizer: Urea 60 Kg/ha, TSP 10 Kg/ha, KCl 40 Kg/ha (60% K_2O) and Gypsum 10 Kg/ha

Pots: 8 Kg soil/pot, 3 replication

Crop: Rice (3 plants/pot)

Date of transplanting: 30/07/2011

Date of harvesting: 03/11/2011

Treatments: 200 ppm of Lead as Lead- Acetate.

Denotation	Rice variety
V_1	BRRIdhan-33 + 200 ppm Pb
V_2	BRRIdhan-49 + 200 ppm Pb
V_3	BRRIdhan-53 + 200 ppm Pb
V_4	BRRIdhan-54 + 200 ppm Pb

3.10.1.4: Experiment-4: Effects of different doses of Pb on Bari wheat -26 (wheat variety).

Soil: Govt. Bangla college field, Mirpur, Dhaka

Fertilizer: Urea 262 Kg/ha, TSP 55 Kg/ha, KCl (60% K_2O) 94 Kg/ha, Gypsum 34 Kg/ha and Boric acid 4 Kg/ha

Pots: 8 Kg soil/pot 3 replication.

Crop: Wheat (3 plants/pot)

Date of sowing: 25/11/2011

Date of harvesting: 15/03/2011

Treatments: Lead as Lead Acetate (0, 50, 100, 150 and 200 ppm respectively).

Denotation	Treatments
T_o	BARI wheat -26+ 0 ppm Pb
T_1	BARI wheat -26 + 50 ppm Pb
T_2	BARI wheat -26 + 100 ppm Pb
T_3	BARI wheat -26 + 150 ppm Pb
T_4	BARI wheat -26 +200 ppm Pb

3.10.1.5: Experiment-5: Effects of soil amendments in remediation of Pb conc. in Bari wheat -26 (wheat variety).

Soil: Govt. Bangla college field Mirpur, Dhaka

Fertilizer: Urea 262 Kg/ha, TSP 55 Kg/ha, KCl (60% k_2O) 94 Kg/ha, Gypsum 34 Kg/ha and Boric acid 4 Kg/ha

Pots: 8kg soil/pot, 3 replication

Crop: Wheat (3 plants/pot)

Date of sowing: 25/11/2011

Date of harvesting: 15/03/2011

Treatments: 100 ppm Lead as Lead Acetate, Cowdung 20 t/ha, Poultry litter 20 t/ha, Lime 5 t/ha

Denotation	Treatments
T_o	BARI wheat -26
T_1	BARI wheat -26 + 100 ppm Pb
T_2	BARI wheat -26 + 100 ppm Pb + Cowdung
T_3	BARI wheat -26 + 100 ppm Pb +poultry litter
T_4	BARI wheat -26 +100 ppm Pb + Lime

3.10.1.6: Experiment-6: Varietal effects of wheat grown on soil contaminated with 200 ppm Pb.

Soil: Govt. Bangla college field, Mirpur, Dhaka

Fertilizer: Urea 262 Kg/ha, TSP 55 Kg/ha, KCl (60% K_2O) 94 Kg/ha, Gypsum 34 Kg/ha and Boric acid 4 Kg/ha

Pots: 8 Kg soil/pot, 3 replication

Crop: Wheat (3 plants/pot)

Date of sowing: 25/11/2011

Date of harvesting: 15/03/2011

Treatments: 200 ppm Lead as Lead Acetate

Denotation	Wheat variety
V_1	Shotabdi + 200 ppm Pb
V_2	Prodip + 200 ppm Pb
V_3	BARI wheat -26 + 200 ppm Pb

3.10.1.7: Experiment-7: Effects of different doses of Pb on BARI Maize -9 (Maize variety).

Soil: Govt. Bangla college field Mirpur, Dhaka

Fertilizer: Urea 425 Kg/ha, TSP 98 Kg/ha, KCl (60% K_2O) 116 Kg/ha, Gypsum 81 Kg/ha and Boric acid 7.16 Kg/ha

Pots: 10 Kg soil/pot 3 replication.

Crop: Maize (1 plants/pot)

Date of sowing: 02/12/2011

Date of harvesting: 14/04/2012

Treatments: Lead as lead Acetate (0, 50, 100, 150 and 200 ppm respectively).

Denotation	Treatments
T_o	BARI Maize -9 + 0 ppm Pb
T_1	BARI Maize -9 + 50 ppm Pb
T_2	BARI Maize -9 + 100 ppm Pb
T_3	BARI Maize -9 + 150 ppm Pb
T_4	BARI Maize -9 +200 ppm Pb

3.10.1.8: Experiment-8: Effects of soil amendments in remediation of Pb conc. in maize (variety: BARI Maize-9)

Soil: Govt. Bangla college field, Mirpur, Dhaka

Fertilizer: Urea 425 Kg/ha, TSP 98 Kg/ha, KCl (60% K_2O) 116 Kg/ha, Gypsum 81 Kg/ha and Boric acid 7.16 Kg/ha

Pots: 10 Kg soil/pot 3 replication.

Crop: Maize (1 plants/pot)

Date of sowing: 02/12/2011

Date of harvesting: 14/04/2012

Treatments: 100 ppm Lead as lead Acetate, Cowdung 20 t/ha, Poultry litter 20 t/ha, Lime 5 t/ha

Denotation	Treatments
T_o	Bari Maize -9
T_1	Bari Maize -9 + 100 ppm Pb
T_2	Bari Maize -9 + 100 ppm Pb +cowdung
T_3	Bari Maize -9 + 100 ppm Pb +poultry litter
T_4	Bari Maize -9 +100 ppm Pb + lime

3.10.2: Field Experiment

3.10.2.1: Experiment-1: Effects of different doses of Pb on different wheat varieties (Variety: Shotabdi, Prodip and BARI wheat-26).

Soil: Govt. Bangla college field, Mirpur, Dhaka

Fertilizer: Urea 425 Kg/ha, TSP 98 Kg/ha, KCl (60% K_2O) 116 Kg/ha, Gypsum 81 Kg/ha and Boric acid 7.16 Kg/ha

Plot size: 1 m^2, 3 replication

Crop: 25 plants/plot

Date of sowing: 12/12/2011

Date of harvesting: 05/04/2012

Treatments: Lead as Lead Acetate (0, 50, 100 ppm respectively).

Treatments	Variety
V^0_1 (control)	Shotabdi
V^1_1 (50 ppm Pb)	
V^2_1 (100 ppm Pb)	
V^0_2 (Control)	Prodip
V^1_2 (50 ppm Pb)	
V^2_2 (100 ppm Pb)	
V^0_3 (control)	BARI-what-26
V^1_3 (50 ppm Pb)	
V^2_3 100 ppm Pb	

3.10.2.2: Experiment- 2: Effects of different doses of Pb on maize (variety.Bari maize-9) in the field.

Soil: Govt. Bangla college field, Mirpur, Dhaka

Fertilizer: Urea 425 Kg/ha, TSP 98 Kg/ha, KCl (60% K_2O) 116 Kg/ha, Gypsum 81 Kg/ha and Boric acid 7.16 Kg/ha

Plot size: 1 m^2, 3 replication

Crop: 5 plants/plot.

Date of sowing: 12/12/2011

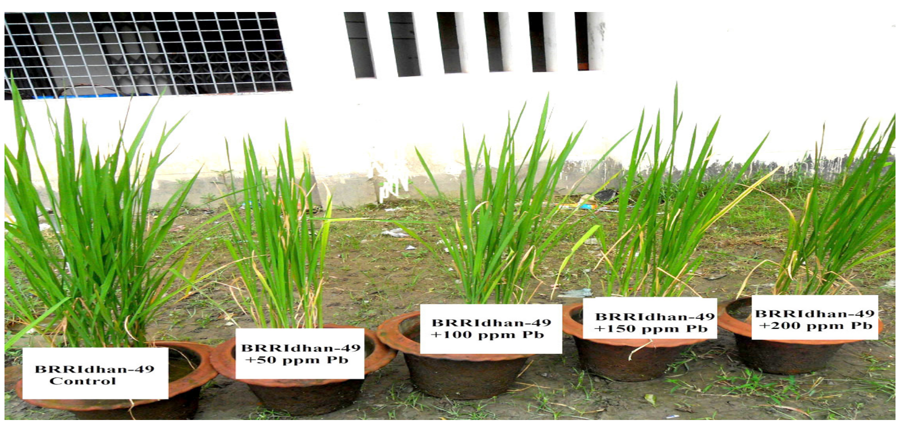
Date of harvesting: 05/04/2012

Treatments: Lead as lead Acetate (0, 50, 100 ppm respectively).

Treatments	Variety
v^0_4 control	Bari-maize-9
v^1_4 (50 ppm Pb)	
v^2_4 (100 ppm Pb)	

Photograph-2: Soil Preparation for pot experiment.

Photograph-3: Transplantation of different varieties of rice.



Photograph-4: Effects of different Pb treatments on rice (variety: BRRIdhan-49).

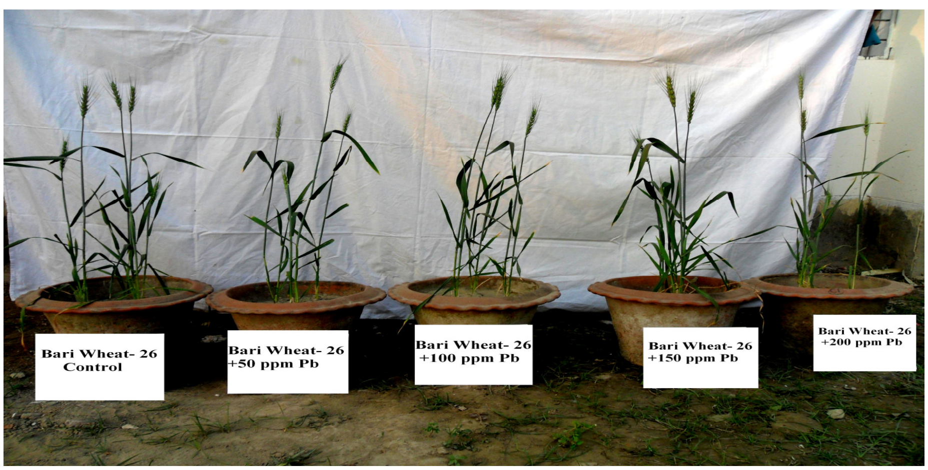
Photograph-5: **Effects of different amendments in reducing Pb conc. on rice (variety: BRRIdhan-49)**

Photograph-6: **Four varieties of rice with 200 ppm of Pb.**

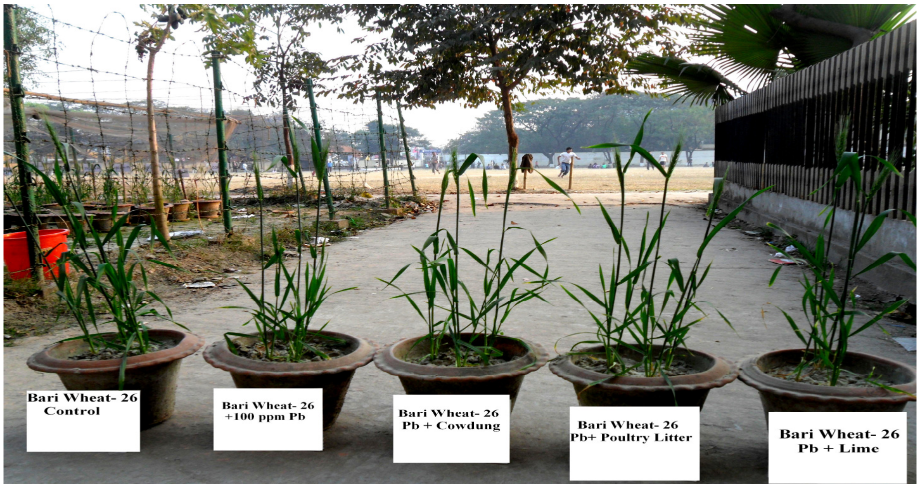
Photograph-7: **Pot experiment with different rice varieties. (My supervisors & me).**

Photograph-8: **Soil Preparation for pot experiment with wheat and maize.**

Photograph-9: **Sowing of wheat and maize varieties on pots.**

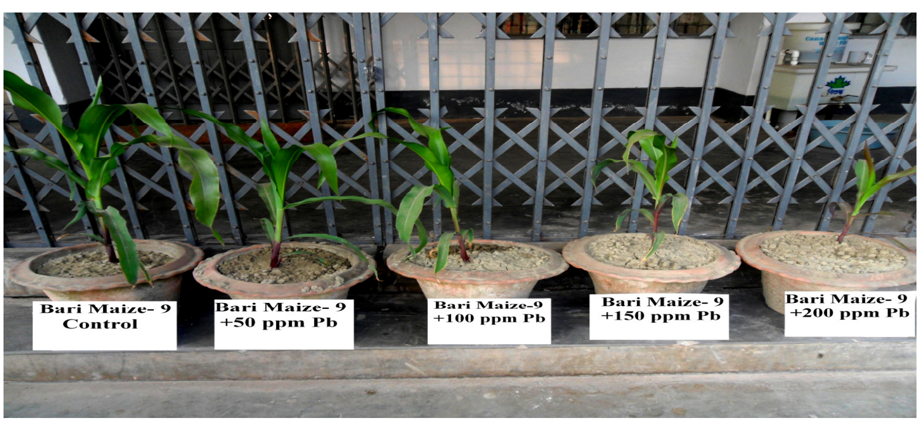


Photograph-10: **Effects of different Pb treatments on wheat (variety: BARI wheat -26).**

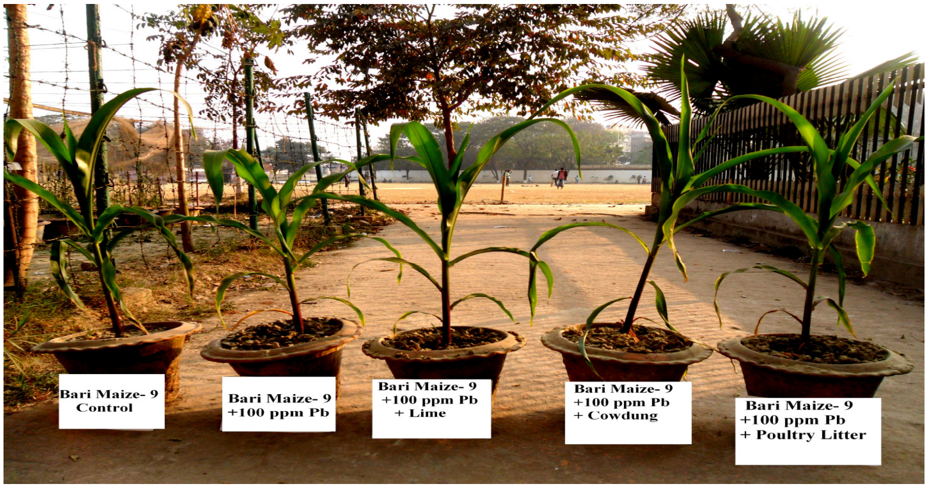


Photograph-11: Effects of different amendments in remediating Pb conc. in wheat (Variety: BARI wheat-26).

Photograph-12: Three wheat varieties with 200 ppm of Pb.



Photograph-13: Effects of different Pb treatments on maize (variety: BARI Maize-9).



Photograph-14: Effects of different amendments in reducing Pb conc. on maize (Variety: BARI Maize-9).

Photograph-15: Pot experiments with wheat and maize

Photograph-16: Sowing of wheat and maize seed in the field.

Photograph-17: **Effects of different Pb treatments on maize (variety: BARi Maize-9) in the field.**

Photograph-18: **Effects of different Pb treatments on wheat (variety: BARI wheat-26) in the field.**

Photograph-19: **Effects of different Pb treatments on wheat (variety: Shotabdi) in the field.**

3.11. Pot and field experiment conducting procedure:

Preparation of pots and field: Pots were well washed and dried in sunlight. Eight kg of air dried composite soil was taken in pot for rice and wheat and ten kg soil was taken for maize. In field the soils were plough 2 to 3 times and made them porous and then level. One m^2 (1*1) of plots were prepared for growing wheat and maize in field. Soils were pulverized and mixed well.

Marking of pots and plots: Every pot was marked in accordance with the treatment and variety with a marking pen and plots with hanging tag with giving the number of plot.

Fertilizers and amendments applied: One third dose of urea and all other fertilizers and amendments were mixed thorough with the soil at the beginning of the experiment. The one third of the dose of urea was applied after 30 days of transplantation and rest was applied during panicle initiation stage of plants

Selection of seedlings and seeds: Only the healthy, plump and large sized seedlings and seeds were selected for sowing.

Transplanting of seedlings and sowing of seeds: Five rice seedlings of 30 days old of uniform size were transplanted in per pot. For wheat and maize crops, the seeds were sown by spreading them over the surface of the soils in the pot and field. Then the seeds were covered by a thin layer of soil. The pots and field were covered by paper for germination.

Irrigation of pots and plots: The amount of water lost through evaporation and transpiration was supplemented through daily application of tap water in evening. In the case of rice plants, the water content of the soil was maintained at 3 cm above the soil surface throughout the growing period. The amount and frequencies of water application were different for different crops.

Spacing and thickening: In pots the 3 rice and 3 wheat seedlings and one maize seedling were keeping in each pot. In field 25 wheat seedlings and 5 maize seedlings were keeping in each plot after 15 days of germination. Besides, a knife was used to loosen the soils at a regular interval of seven days.

Intercultural Operations: Various intercultural operations such as weeding, spraying of insecticides, covering the whole field and pots by polythene and nets to protect the plant from rain and birds etc. were done as required. .

Harvesting: The straw and grain of rice, wheat and maize crops were separated and collected properly after drying in the sun. The roots of cereal crops were washed with tap water and finally by distilled water to remove the soil materials from the root surfaces. Total fresh weight of straw, grain and root of cereal crops were recorded per pot and per plot.

Collection and preservation of plant samples: The plant samples were collected at the time of harvesting of the crop up to the soil surface level. The collected straw root and grains of cereal crops were first air-dried and then oven dried at 70 ^{0}C for 48 hours then weight and ground and stored in plastic pots for chemical analyses.

3.12. Experimental design: The pots were laid out in a completely randomized Design (CRD) with three replications.

3.13. Analysis

Soil	Manures	Plants (root, shoot and grain)
Moisture content Soil Texture pH EC % OM CEC meq/100g Exchangeable K^+, Ca^+ , Mg^+, Na^+ Total N, P, K, Ca, Mg and Pb.	% N % OM pH Total N, P, K, Ca, Mg and Pb.	Yield (per pot) in FW and DW 1000 grain weight shoot length, root length Total N, P, K, C, Mg and Pb.

Table- 4: Physical, chemical and Physico- chemical properties of the experimental soils, cowdung and poultry litter:

Properties	Rice soil	Wheat soil	Field soil	Cow-dung	Poultry litter
pH	6.05	6.25	5.80	7.54	7.22
Ec	105.4 ms	92.6 ms	115 ms	1445ms	4.45 ms
% Moisture	27.46	23.12	29.10	-	-
Organic matter %	0.79	0.72	1.51	-	-
Organic carbon %	0.46	0.42	0.88	-	-
Partical size analysis	Sand 20.34 Silt 69.39% Clay 10.28%	Sand:17.80 % Silt::74.47 % Clay:17.74%	Sand 8.85% Silt 80.72% Clay 10.43	-	-
Textural class	Silt loam	Silt loam	Silt loam	-	-
Total N %	.09	0.04	0.17	1.52	1.34
Available N %	0.00316	0.00525	0.00180		
Total P %	0.069	0.069	0.073	0.69	1.05
Available P ppm	7.14	6.05	14.5		
Total K %	0.57	0.60	0.43	1.3	2.28
Total Ca %	0.175	0.242	0.082	1.10	3.15
Total Mg %	0.52	0.66	0.44	0.56	0.41
Total Pb ppm	10	8	17	05	14
Cation exchange capacity(meg/100 g soil)	10.02	5.63	11.03		
Exchangeable cations (meq/100 gm soil)					
Exchangeable Na	6.98	4.65	4.65	-	-
Exchangeable K	0.069	0.0616	0.0637	-	-
Exchangeable Ca	3.945	9.478	7.748	-	-
Exchangeable Mg	1.25	0.887	1.791	-	-

3.14. Laboratory Analyses of the original Soil Samples

A. Determination of Physical Properties:

a) Moisture percentage: The moisture percentage of collected soil samples was determined by drying a known amount of soil in an electrical oven at 105^0 C for 240 hours until constant weight was obtained and the moisture percentage was calculated from the loss of moisture from the sample as describe by Black, (1965).

% Moisture = Wt of air dried soil-Wt. of oven dry soil/Wt. of oven dry soil) ×100

b) Partical size analysis: The partical size analysis of the soil was carried out by Hydrometer method as described by Black, (1965) and the textural class was determined from the Marshalls triangular co-ordinates as described by the United States Department of Agriculture (USDA, 1951)

B) Determination of chemical and Physico-chemical Properties:

a) Soil Reaction (pH): Soil pH was determined electrochemically with the help of glass electrod pH meter (Model- SensoDirect pH 200) as suggested by Jackson, (1962). The ratio of soil to water was 1:2.5.

b) Electrical Conductivity (EC): The electrical conductivity of the soil was measured at a soil: water ratio of 1:2 by an EC meter as described by USSL Staff (1954).

c) Organic Carbon and Organic Matter: The organic carbon was determined volumetrically by wet oxidation method of Walkel and Black as described by Piper, (1950) and Jackson (1962). The organic matter content of the soils were determined by multiplying the percentage of organic carbon with the conventional "Van-Bemmelen's Factor" of 1.72 Piper, (1950).

d)**. Cation Exchange Capacity (CEC):**

The cation exchange capacity of the soil was determined by extracting the soil with 1N NH_4OAc solution (pH-7) followed by replacing Ammonium or from the exchange complex by 2M KCl. The displaced Ammonium (NH_4^+) was distilled with 40 % NaOH and Ammonium gas (NH_3) evolved was adsorbed in 2% Boric Acid containing mixed indicator. The absorbed Ammonium (NH_4^+) was titrating against H_2SO_4 solution (Black, 1965).

e). Exchangeable Na^+, K^+, Ca^{2+}, and Mg^{2+}

The changeable Cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) of soil were extracted with 1N NH_4OAC solution (pH-7) as describe by (Piper, 1950) and (Jackson, 1962). The extract was analyzed for Na and K by Flame Photometer at 589 and 767 nm, respectively and Calcium (Ca) and Magnesium (Mg) were measured by using Atomic absorption spectrophotometer (Varian-220) (Jackson, 1962).

f). Total Nitrogen:

Most of the nitrogen in soils present in organic form. More than 90% of soil nitrogen is organic nitrogen. Rest 10% is present in as NH_4^+ and NO_3 which are the available form for plant. The total nitrogen of soil was determined by "Micro Kjeldahl" distillation method following Sulfuric acid digestion Jackson, (1962). The Kjeldahl procedure generally employed for determination of total N involves in two steps:

- Digestion of samples to convert the N to Ammonium sulphate
- Determination of Ammonium in the digestion.

$$\text{Soil N} + H_2SO_4 \text{ ------------------- } (NH_4)_2\,SO_4$$

The amount of N converted to Ammonium sulphate then determined by distilled it with alkali and distilled Ammonia in a standard 4% Boric Acid and collected ammonium were treated against H_2SO_4 (Jackson,1962).

g). Available Nitrogen:

Available nitrogen of the soil was determined by "Micro Kjeldhal"s method using Devarda"s alloy described by (Black, 1965), after extraction of soil with 1 KCl solution. In this experiment 10 g soil sample were mixed with 100 ml of 1N KCL solution and shake for 30 minutes and then filtration are done. And then 10 ml of filtrate of solution, 10 ml of 40% NaOH, 0.2 g 4% Devarda"s alloy, Boric acid- a mixed indicator and 0.01 N H_2SO_4 are also used to determined the Available N.

h). Total Phosphorus: The total phosphorus of soil was determined colorimetrically in the HNO_3: HCl (1:3.5) digestion (Vdlufa, 1975) using a chemito visible spectrophotometer after developing the yellow color with vanadomolybdate as described by Jackson, (1962). The intensity of the yellow color was measured at 470 nm wavelength.

i). Available Phosphorus:

The available Phosphorus (P) of the soil was determined by colorimetric method using spectrophotometer at 660 nm after developing the Blue color with stannous chloride as describe by (Jackson, 1962).

j). Total Potassium, Calcium, Magnesium, and Lead: The total K, Ca, Mg, and Pb concentration of soil were obtained by digesting the soil sample with the HNO_3: HCl acid mixture (1: 3) (Blum *et al*., 1996). This acid mixture decomposes nearby all complexes forming soil particles (clay minerals, organic substance, oxide etc.), through which all the ions are brought into solution can be measured quantitatively. Potassium was determined by Gallenkamp Flame photometer analyzer at 767 nm (Jackson, 1962). Other metals- Ca, Mg and Pb were measured in the digest by using Atomic absorption spectrophotometer (Varian-220) (Jackson, 1962)

3.15 Plant Samples Analyses

Plant root, shoot and grain Analyses

a) Determination of Total Nitrogen: Plant nitrogen (root, shoot and grain) was determined by Micro Kjeldahl's method following H_2SO_4 acid digestion and steam distillation with 40% NaOH. Ammonia evolved was collected in boric acid containing mixed indicator and determined titrimetrically with a standard N/100 H_2SO_4 acid (Jackson, 1962).

b) Determination of total Phosphorus, Potassium, Calcium, Magnesium and Lead:

After wet oxidation with HNO3: $HClO_4$ (5:1) acid mixture, the total concentration of P, K, Ca, Mg and Pb were determined by using the procedure as described previously for the total soil analysis.

3.16. Statistical analysis

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).

4. RESULTS AND DISCUSSION

The research work presented in this chapter was conducted at the experimental field of the Department of Soil Science, Govt. Bangla College, Dhaka, to evaluate the effects of different doses of lead (Pb) and ameliorating effects of some amendments on growth, yield and mineral nutrition of some cereal crops of Bangladesh (rice, wheat and maize) and varietal effects of rice and wheat on Pb toxicity. The experimental results are presented and discussed in this chapter. The analysis of variance (ANOVA) of the data was computed to determine the F- value. Test of significance of different treatment and varietals means were computed by Duncan's New Multiple Range Test (DMRT) in IBM SPSS statistics version 20.

4.1. Pot experiments

4.1.1. Experiment-1: Rice: Effects of different doses of lead (Pb) on growth, yield and mineral nutrition of rice (variety: Bridhan-49)

4.1.1.1. Fresh and dry weight of grain

The mean values of fresh and dry weight (g/pot) of BRRIdhan-49 rice grain were affected considerably by different Pb treatments (Table-5 and Figure-6). The highest fresh and dry weight of grains/pot (33.01 and 23.92 g) was obtained in the control treatment (T_0) where no lead was applied. The lowest value (26.57 and 19.13 g) was obtained in the treatment T_4 (at 200 ppm Pb). 200 ppm Pb treated pots differed significantly from T_0, T_1 and T_2, however, no significant difference was observed between T_3, T_4 as well as T_0, T_1, T_2 treatments in case of fresh weight of grain while in dry weight of grain, there were no significant difference among T_0, T_1, T_2 as well as T_1, T_2, T_3, T_4 treatments, respectively. The results indicated that Pb toxicity was exerted significantly at 200 ppm of Pb treatment in case of fresh weight of grain and from 150 ppm Pb in case of dry weight of grains, which caused a significant decline in grain production of rice compared with the control treatment. The higher concentration of Pb, produced lower grain yield of rice as compared to control treatment where no Pb was applied. Similar results were also obtained by Kim *et al*. (1986) and Santos *et al.* (1992) in rice. Ullah *et al.* (2011) also showed that Pb toxicity affected significantly fresh and dry weight of grain yield of rice grown in pots.

4.1.1.2. Fresh and dry weight (g) of shoot

The fresh and dry weight of shoots per pot (g) of BRRIdhan-49 rice was affected notably by different levels of lead treatments (Table-5 and figure-6). The maximum fresh and dry weight of shootpot^{-1} was 68.57 and 25.12g obtained in the control treatment. The lowest values were 56.81 and 20.16g in the T_4 treatment (at 200 ppm Pb). The decrease in the fresh and dry weight of shoot followed the sequence of $T_0>T_1>T_2>T_3>T_4$. It was evident from the observed data that Pb application significantly reduced the fresh and dry weight of shoot from 150 to 200 ppm of Pb. In case of fresh weight of shoot, treatment $T_{2,}$ T_3 and T_4 were significantly differed from other treatments however, no significant difference was observed among $T_{0,}$ $T_{1,}$ T_2 as well as $T_{2,}$ $T_{3,}$ T_4 treatments, respectively. In case of dry weight of shoot, treatments T_0 and T_1 significantly differed from other treatments but there were no difference was observed among $T_{2,}$ $T_{3,}$ T_4 treatments. The higher the concentration of Pb the lower was the fresh and dry weight of shoot, being the highest with Pb @ 200 ppm which were 17.2 and 19.7% lower compared to that of control treatment. The decreased shoot biomass might be due to interference of Pb with physiological processes of the plant. The results of the present investigation support the earlier findings made by Lubis *et al.* (1988) and Lee *et al.* (1991). Kibria *et al.* (2009) found shoot weight of *A. gangeticus* and *A. oleracea* declined by 28 and 46% over control at the highest rate (100 mg kg^{-1}) of Pb application. The inhibition of shoot growth may be due to the decrease in photosynthesis; it (Pb) upsets mineral nutrition and water balance, changes hormonal status and affects membrane structure and permeability (Sharma and Dubey, 2005). Ullah *et al.* (2011) also showed that Pb toxicity affected significantly the growth parameters of rice grown in pots.

4.1.1.3. Fresh and dry weight (g) of root

Fresh weight of root was varied significantly by the different treatments (Table-5 and figure-7). The highest value of fresh weights of rootpot^{-1} was 23.32 and dry weight of rootpot^{-1} was 4.23 g in the control (T_0) treatment where no lead was applied. The lowest values 17.44 and 2.96 g were obtained in the T_4 treatment, at 200 ppm Pb. In general, Pb application caused a decrease in the fresh and dry weight of root of BRRIdhan-49 rice. However in case of fresh weight of root, treatment T_4 significantly differed from other treatment but there was no difference between $T_{0,}$ $T_{1,}$ as well as $T_{2,}$ T_3 treatments respectively. In case of dry weight of root there were no significant differences among the treatments. At the highest dose of Pb (200 ppm), fresh and dry weight of root decreased by 25.2 and 30.0% compared with the control. Kibria *et al.* (2009)

found root weight of *A. gangeticus* and *A. oleracea* declined by 53 and 37% at the highest rate (100 mg kg) of Pb application compared to the control. 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).

4.1.1.4. Shoot and root length (cm)

The length of shoot and root of rice (variety: BRRIdhan-49) appreciably affected by Pb application (Table-5 and figure-7). The length of shoot and root ranged from 106.33 to 100.00 and 26.33 to 21.33 cm respectively. The maximum and the minimum length of shoot and root were obtained in the Pb free treatment (T_0) and T_4 (200 ppm of Pb). Treatment T_4 differed significantly from other treatments in case of length of shoot; however no significant difference was observed between T_0, T_1 as well as $T_{2,}$ T_3 treatments, respectively. In case of root length there were no differences among $T_{0,}$ $T_{1,}$ T_2 and $T_{2,}$ $T_{3,}$ T_4 treatments, respectively. At the highest dose of Pb (200 ppm), shoot and root length of rice decreased by 6.0 and 19.0% compared with the control. Similar results were obtained by Strand *et al.* (1990) who demonstrated that the application of Pb decreased the height of rice plants. This reduction of height might be attributed to the toxic effect of heavy metal present in them (McCalla *et al.,* 1977). Mahmood *et al.* (2007) stated that root length of rice seedlings at both 5 and 10 mM Pb was significantly less (30-50%) than that of the control seedlings. Ullah *et al.* (2011) showed that the variation of plant height was significant among the lead treatments in rice.

4.1.1.5. Number of tiller/pot and 1000 grains weight

The number of tiller pot^{-1} and 1000 grains weight (g) of rice (variety: BRRIdhan-49) differed radically among treatment levels (Table-5 and figure-8). The highest tiller number and 1000 grains weight were found (11.33 and 18.60 g) in the control treatment (where no lead was applied). The lowest were (9.00 and 15.87 g) in the T_4 treatment (at 200 ppm of Pb). Treatment T_0 differed significantly from all other treatments however; no significant difference was observed among $T_{1,}$ T_2, T_3 and T_4 treatments in case of number of tiller/pot. In case of 1000 grains weight, there were no differences among $T_{0,}$ $T_{1,}$ T_2 and T_3 T_4 treatments. The above results indicated that the tiller number and 1000 grains weight declined with increasing level of Pb, being the highest with Pb @ 200 ppm which were 20.6 and 14.7% lower compared to that of the control plant. The results of the present investigation are analogous to the earlier findings of Strand *et al.* (1990) and Wagatsuma (1985). They reported that the number of tillers of rice decreased with increasing level of applied Pb. Lubis *et al.* (1988) and Lee *et al.* (1991) also reported the decreased weight of 1000 grains of rice due to Pb toxicity. Ullah *et al.* (2011) showed that significant influences on number of tiller pot^{-1} and 1000 grains weight (g) of rice grown on soil conducted with different lead treatments.

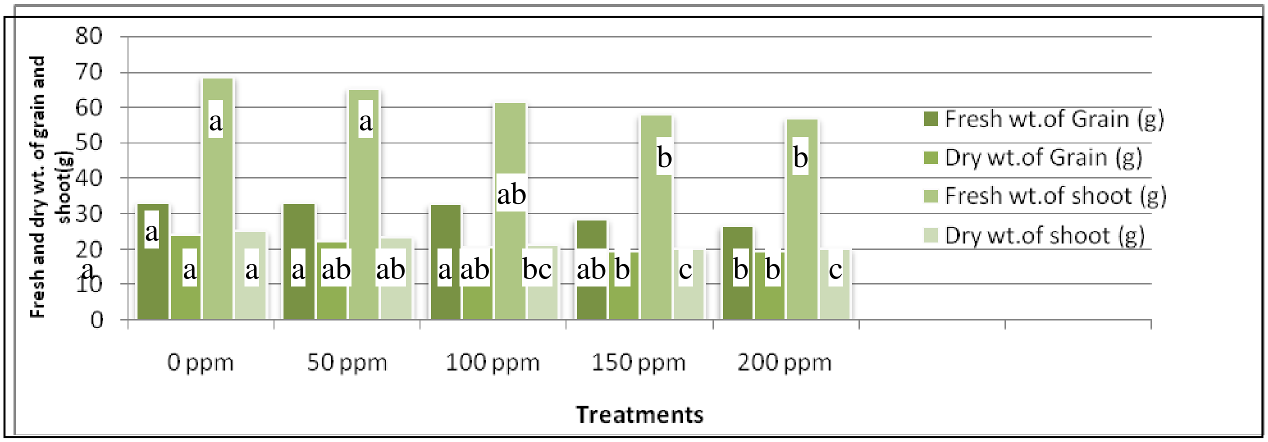


Fig-6: Effects of different doses of Pb on fresh and dry wt. of grain and shoot (g/pot) of rice (variety: BRRIdan- 49).

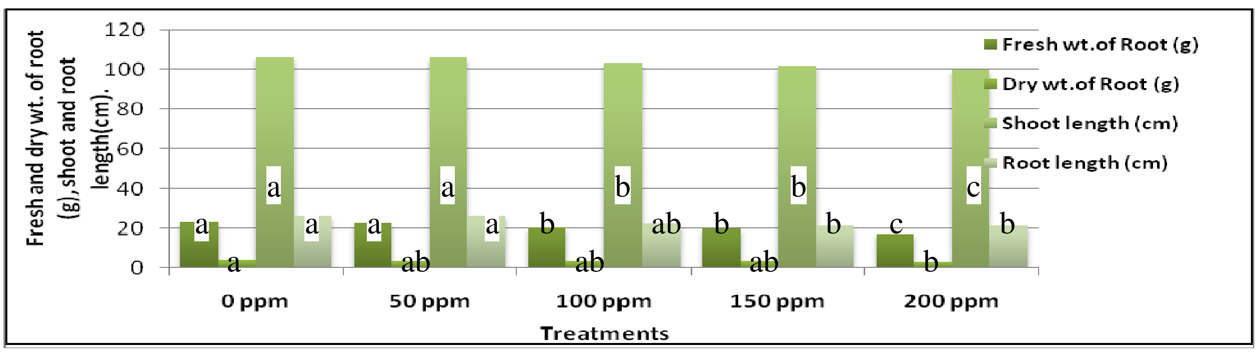


Fig-7: Effects of different doses of Pb on fresh and dry wt. of root, shoot and root length of rice (Variety: BRRIdhan- 49).

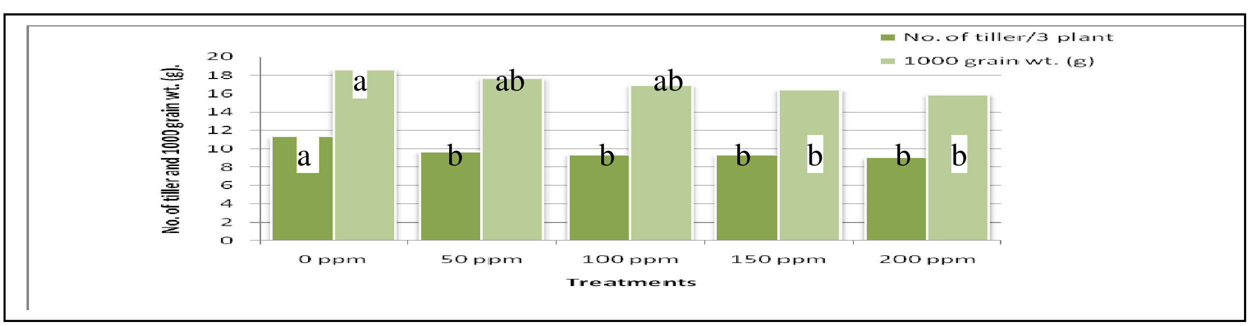


Fig-8: Effects of different doses of Pb on no. of tiller/3 plant and 1000 grain wt. (g/pot) of rice (Variety: BRRIdhan- 49)

4.1.1.6. Nitrogen Concentration:

Application of different doses of Pb decreased nitrogen concentration in root and shoot of rice (variety: Bribhan-49) but in case of grain nitrogen concentration increased significantly up to 100 ppm of Pb treated pots and then decreased with increasing level of Pb (Table-6 and Figure-9). The concentration of nitrogen ranged from 0.297 to 0.418% in root, 0.241 to 0.353% in shoot and 0.505 to 0.649% in grain. Lead treatments reduced nitrogen concentration in root and shoot of rice significantly at 200 ppm of Pb compared with the control and other treatments, however, no significant differences were observed among $T_{0,}$ $T_{1,}$ T_2 and T_3 treatments in root, between $T_{1,}$ T_2 as well as $T_{3,}$ T_4 in shoot and $T_{1,}$ T_3 in grain respectively. From the results, it was evident that the higher the concentration of Pb the lower was the concentration of nitrogen in root and shoot of rice plant, however grain N concentration increased significantly up to 100 ppm of Pb applied treatment then decreased with increasing levels of Pb. Parvin *et al.* (2003) found that application of Pb significantly increased the concentration of nitrogen in rice (BRRIdhan-30) straw and grain compared with control treatments. Kibria *et al.* (2009) also reported that Pb application in soil significantly increased concentration in shoot of *A.oleracea*. On the contrary Strand *et al.* (1990), Lee *el al.* (1991) and Ullah *et al.* (2011) reported an antagonistic effect on nitrogen uptake by rice plants due to application of Pb. These variation of N concentration in root, shoot and grain of rice, probably due to difference in plant variety. In most cases, Pb blocks the entry of N in the root system (Sharma and Dubey, 2005).

4.1.1.7. Phosphorus Concentration:

Phosphorus concentration in shoot of rice (variety: BRRIdhan-49) was not affected significantly by Pb application (Table-6 and Figure-101). The concentration of P ranged from 0.181 to 0.408% in root, 0.041to 0.078% in shoot and 0.198 to 0.239% in grain. The maximum amount of P was found in control (T_0) treatment and the minimum in the high level of Pb applied treatment T_4 (200 ppm Pb) in case of root, shoot and grain. Phosphorus concentration in root and grain decreased significantly with the increasing level of Pb however, no difference was observed among $T_{2,}$ $T_{3,}$ T_4 as well as $T_{1,}$ T_2 in case of root and $T_{0,}$ $T_{1,}$ T_2 as well as $T_{2,}$ $T_{3,}$ T_4 in case of grain. From the result it may be concluded that application of lead reduced the concentration of phosphorus in root, shoot and grain of rice. The higher the concentration of Pb, the lower was the concentration of P. This interference is due to the ability of Pb to form insoluble phosphates in plant tissue. The findings are in agreement with the results reported by Forstegard *et al.* (1993)

and Gigliotte *et al.* (1990). They reported that due to adverse or antagonistic effect of Pb, the uptake of P by rice and other plants decreased significantly. Ullah *et al.* (2011) stated that the content of phosphorus in the rice straw and grain decreased significantly with increasing level of lead.

4.1.1.8. Potassium Concentration:

Potassium concentration in shoot and grain of rice (variety: BRRIdhan-49) was not appreciably affected by Pb application though its concentration decreased with increasing Pb application (Table-6 and Figure-10). The concentration of potassium ranged from 0.410 to 0.656% in root, 1.62 to 2.09% in shoot and 0.171 to 0.203% in grain. The maximum concentration of potassium (0.656, 2.09 and 0.203% in root, shoot and grain respectively) were obtained in the control treatment and the minimum concentration (0.410, 1.62 and 0.171% in root, shoot and grain respectively) in T_4 treatment. The highest level of Pb application significantly decreased K concentration in roots of rice which was 37.5% lower as compared to control. From the results it was evident that application of lead reduced the potassium concentration in root, shoot and grain but in all cases among the treatments the differences were not statistically significant. This decrease of potassium by rice plant may be due to the saturation of soil colloids and root system by Pb replacing the potassium from exchange sites. Shoot accumulated more potassium than root and grain, which probably maintained the mobility and ion balance in shoot. Rubio et *al.* (1994) and Trivedi *et al.* (1992) observed the toxic effects of Pb on potassium uptake by rice plant. Kibria (2008) also reported that Pb application significantly decreased potassium concentration in straw and roots of rice. Ullah *et al.* (2011) stated that the conc. of potassium in the rice straw and grain decreased significantly with increasing level of lead concentration.

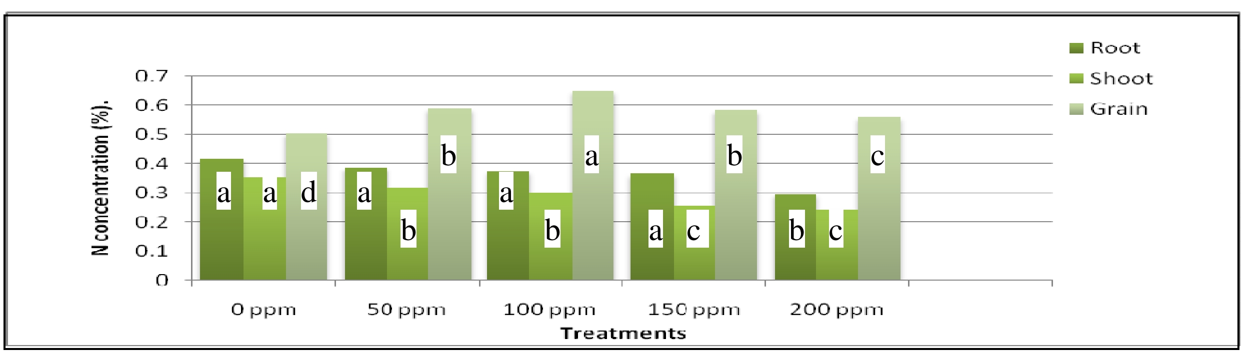


Fig- 9: Effects of different doses of Pb on N conc. (%) of root, shoot and grain of rice (variety-BRRIdhan-49).

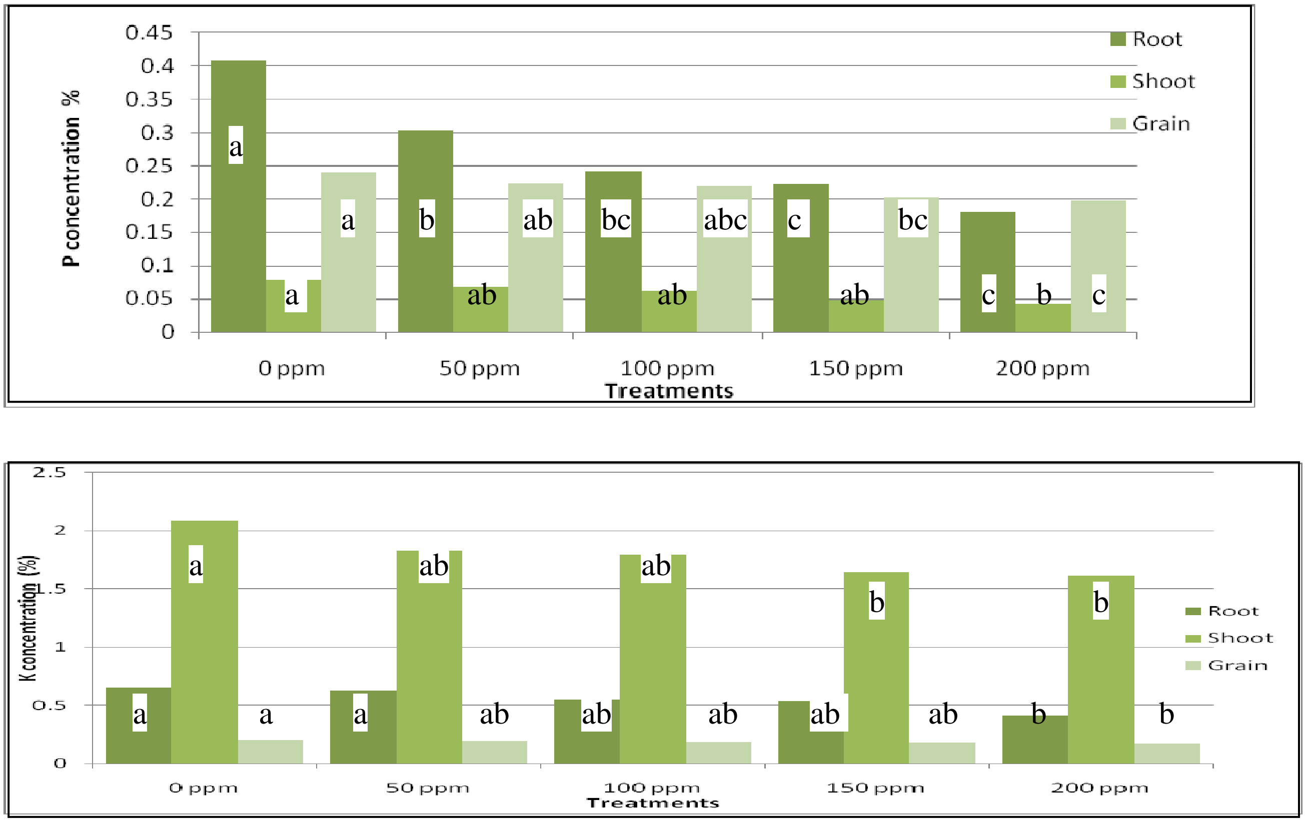


Fig- 10: Effects of different doses of Pb on P and K conc. (%) of root, shoot and grain of rice (variety: BRRIdhan-49).

4.1.1.9. Calcium Concentration

Calcium concentration in root and grain of rice (variety: BRRIdhan-49) was significantly decreased by Pb application whereas shoot Ca concentration was less affected (Table-6 and Figure-11). The concentration of calcium ranged from 0.226 to 0.446% in root, 0.315 to 0.403% in shoot and 0.018 to 0.028% in grain. The maximum amount of calcium (0.446, 0.403 and 0.028% in root, shoot and grain, respectively) was obtained in the control treatment and the minimum concentration (0.226, 0.315 and 0.0181% in root, shoot and grain of rice respectively) in T_4 treatment. Treatment T_4 was significantly different from all other treatments in case of root however, no significant difference was observed between T_0, T_1 and T_3, T_4 treatments. Ca concentration in grain of rice with Pb application up to 100 ppm was statistically similar to that of control. From the results, it was evident that the higher the concentration of Pb the lower was the concentration of calcium in root, shoot and grain of rice. The decrease in Ca conc. might be due to the interference of Pb with the physiological function of the plant and in most cases, Pb blocks the entry of Ca in the root system (Sharma and dubey, 2005). Similar results were also reported (Kim *et al.,* 1986; Xian, 1989; Trivedi and Erder, 1992 and Warter, 1992). Lee and Kim (1991) reported an antagonistic effect on calcium uptake by rice plants due to Pb toxicity. Kibria (2008) found Ca concentrations decreased in grain, straw and roots of rice, shoot and root of radish and leaf, stem and root of Indian spinach due to Pb application. Ullah *et al.* (2011) stated that the concentration of calcium in the rice straw and grain decreased significantly with increasing level of lead.

4.1.1.10. Magnesium Concentration:

Mg concentration in shoot and grains of rice (variety: BRRIdhan-49) showed to decrease notably with the increase of Pb application with the lowest values being obtained with the highest rate (200 ppm of Pb) (Table-6 and Figure-12). The concentration of calcium ranged from 0.164 to 0.213% in root, 0.104 to 0.152% in shoot and 0.075 to 0.096% in grain. The maximum concentration of calcium (0.213, 0.152 and 0.096% in root, shoot and grain of rice, respectively) was obtained in the T_0 treatment and the minimum concentration (0.164, 0.104 and 0.075% in root, shoot and grain of rice, respectively) in T_4 treatment. In case of Mg concentration in shoot, T_0 treatment differed significantly from other treatment but there was no significant difference among T_1, T_2, T_3 and T_4 treatments, respectively. However, Mg concentration in roots of rice was not significantly affected by Pb treatments in the present study. Mg concentration decreased by 18.3, 31.6 and 21.9% in the root, shoot and grain of rice at the highest rate of Pb application (200 ppm). This might be due to the antagonistic effect of Pb with Mg in rice. Similar results were also reported by many authors working in this field (Kim *et al.,* 1986; Xian, 1989). Lee and Kim (1991) also reported an adverse effect on magnesium uptake by rice plants, caused by Pb toxicity. Kibria (2008) reported that Pb application significantly decreased Mg concentration in grain, straw and roots of rice. Ullah *et al.* (2011) stated that the content of magnesium in the rice straw and grain decreased significantly with increasing level of lead.

4.1.1.11. Lead Concentration:

Lead application in soil significantly increased Pb concentration in root, shoot and grain of rice (variety: BRRIdhan-49) (Table-6 and Figure-12). The concentration of lead ranged from 42.5 to 1577 ppm in root, 7.5 to 43.17 ppm in shoot and 1.96 to 32.13 ppm in grain. The concentration of lead was the highest at 200 ppm of Pb-treated treatments and the lowest was in the control treatment. A gradual increase in Pb concentration in root, shoot and grain of rice was observed with increasing rates of Pb application. The lead concentrations of rice plant increased significantly with higher concentrations (100, 150 and 200 ppm) of Pb in root, shoot and grain. Similar results were also observed by many investigators (Kim *et al.,* 1992 and Santo *et al.,* 1992). Chen *et al.* (1991) noted that all Pb compounds greatly increased Pb uptake and plant tissue concentrations of rice plant. Ullah *et al.* (2011) stated that the accumulation of Pb increased both in the straw and grain of rice with increasing lead concentration.

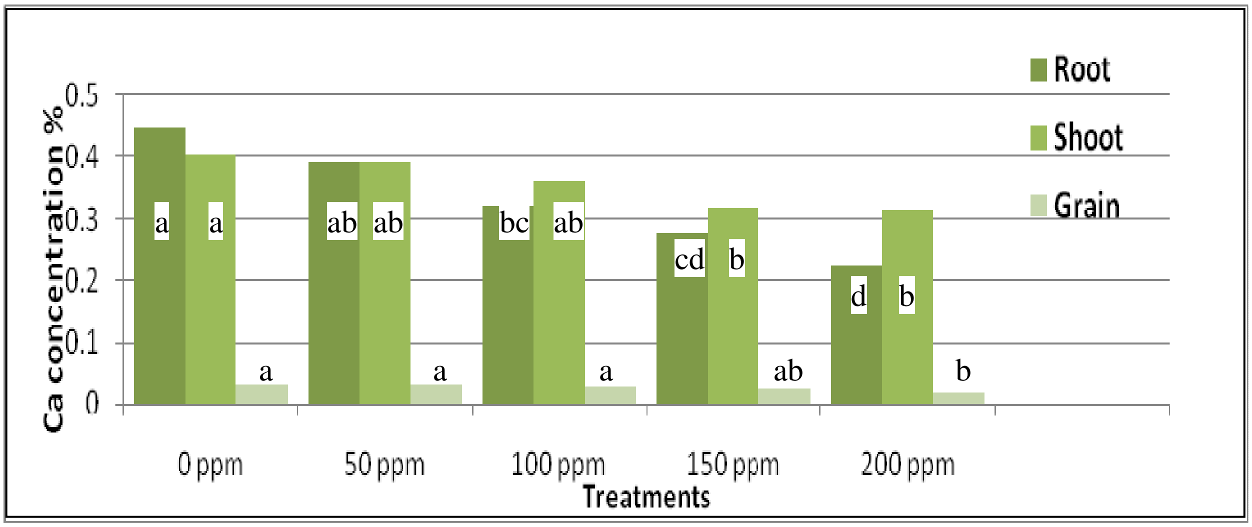


Fig-11: Effects of different doses of Pb on Ca conc. (%) of root, shoot and grain of rice (variety: BRRIdhan-49).

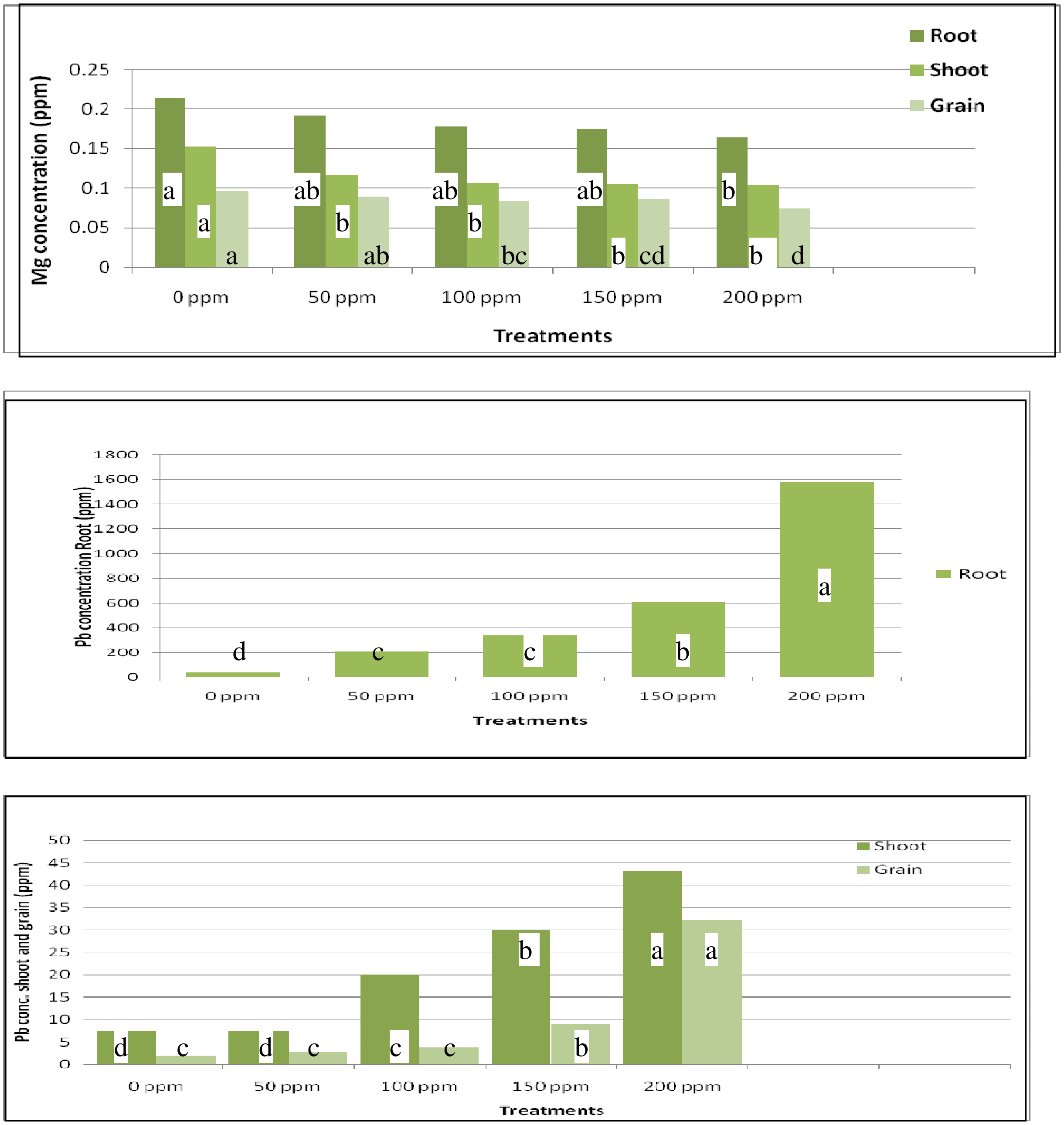


Fig-12: Effects of different doses of Pb on Mg (%) and Pb conc. (ppm) of root, shoot and grain of rice (variety: BRRIdhan-49).

4.1.2. Experiment-2: Growth, yield and mineral nutrition of rice (Variety: Bridhan-49), influenced by different amendments

4.1.2.1: Fresh and dry weight of grain

The fresh and dry weight of grain (g pot^{-1}) of rice (variety: BRRIdhan-49) was considerably affected by the application of different amendments with 100 ppm of Pb (Table-7 and Figure-13). The fresh and dry weight of grains were the highest in the pots receiving cowdung, followed by lime, poultry litter, control and 100 ppm Pb treated pots, respectively. Application of 100 ppm of Pb decreased 1.5 and 15.1% fresh and dry weight of grains compared with control. Among amendments cowdung increased by 31.5 and 32.1% fresh and dry weight of grain compared with 100 ppm Pb treatment which was significantly differed from other treatments. However, no significant differences were observed among the T_0, T_1, T_3, T_4 treatments in both cases. This might be due to the ameliorating effect of cowdung against Pb toxicity hence increase yield of rice grain. The negative growth response of rice grains and vegetables due to Pb toxicity was reported by Santose *et al.* (1992). Nuruzzaman (1995) observed that the dry matter yield of rice grains was increased by 27% at 40 Mt cowdung/ha. Better performance of rice by applying cowdung in Tongi polluted soil was also reported earlier by (Chamon *et al.,* 2005 a). Soil organic matter is known to be a predominant factor for binding heavy metals in the soil and for influencing the plant uptake. The positive influence of organic substances on plant growth is a 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 catalysts (Schnitzer and Khan, 1978; Vaughan and Malcolm, 1985).

4.1.2.2: Fresh and dry weight (g) of shoot

The dry weight of shoot (g pot^{-1}) of BRRIdhan-49 rice was varied appreciably by different amendments (Table-7 and figure-13). Application of 100 ppm of Pb reduced 7.3 and 15.5% fresh and dry weight of shoot compared with control. Among amendments cowdung and poultry litter treatment increased dry weight of shoot by 35.29 and 13.43% and lime decreased 0.45% compared with 100 ppm of Pb treated pot. Cowdung treatment significantly differed from all other treatments. However, in case of fresh weight of shoot, treatments were not differed significantly. The results showed a significant decline in fresh and dry weight of rice shoot at 100 ppm Pb. Cowdung and poultry litter increased the shoot growth of rice probably by rendering Pb less available to plants through adsorption but amongst soil amendments, cowdung was the best to reduced Pb toxicity and increased yield of rice shoot. The results of the present investigation were in agreement with the earlier findings of Patrick *et al.* (1981) who reported that the dry matter production of onion, potatoes, cabbage and lettuce was inhibited severely by Pb and Ni toxicity. Nuruzzaman (1995) reported a better performance of cowdung in dry matter production of rice, which was increased by 25% at 40 Mt/ha of cowdung.

4.1.2.3: Fresh and dry weight (g) of root

Application of organic manure resulted in significant differences in rice root biomass production (Table-7 and figure-14). The highest fresh and dry weight was observed in cowdung (31.70 and 5.07 g/pot) lowest in lime (19.82 and 3.48 g/pot) treatment and cowdung treatment was significantly different from other treatments in case of fresh weight of root. There was no significant difference among the treatments in case of dry weight of root though cowdung and poultry litter treatments increased and lime decreased the root biomass production. The results indicated that root biomass production decreased with addition of lead, but increased by the application of cowdung and poultry litter but decreased by lime treatment respectively.

4.1.2.4: Shoot, panicle and root length (cm)

The length of panicle of rice (variety: BRRIdhan-49) was varied significantly whereas shoot and root length was not varied significantly (Table-7 and figure-14). The highest shoot and panicle length was observed in cowdung treatment and root length in control treatment. Application of lead significantly decreased panicle length by 6.7% compared with control and cowdung, lime and poultry litter treatment increased by 8.6, 4.3 and 7.2% compared with 100 ppm of Pb treatments but the differences were not significant. Reduction in shoot and root length due to heavy metal toxicity was reported previously (Gerzabek and Ullah, 1990; Ullah and Gerzabek, 1991; Mondol, 1995)

4.1.2.5: Number of tiller/pot, panicle/pot and 1000 grain weight:

The number of tiller/pot**,** panicle/pot and 1000 grains weight (g pot^{-1}) of rice (variety: BRRIdhan-49) varied considerably by the different amendments (Table-7 and figure-15). Application of lead significantly declined the number of tiller/pot**,** panicle/pot and 1000 grain weight (g) compared with the control treatment. The highest number of tiller/pot and panicle/pot were observed in pots treated with cowdung followed by lime and poultry litter and were significantly differed from each other. Cowdung treated pots also showed the highest 1000 grains weight followed by poultry litter and lime. However, no significant difference in 1000 grains weight was observed among the control, cowdung, and poultry litter and lime treatments, respectively. Soil amendments with cowdung had better performance in increasing the number of tiller/pot**,** panicle/pot and 1000 grains weight (g) as compared with other amendments. Many researchers reported the importance of increased cation exchange capacity and organic matter in reducing Pb uptake (Chamon *et al.,* 2005a).

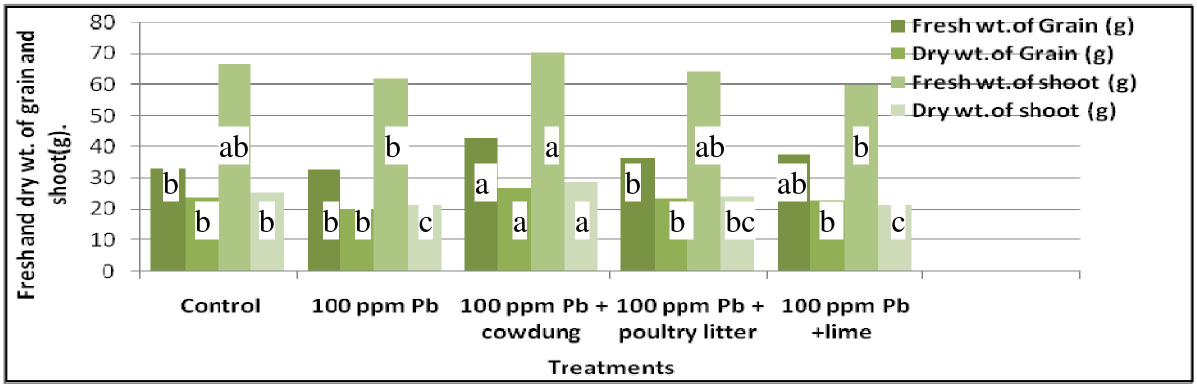


Fig-13: Effects of different amendments on fresh and dry wt. (g/pot) of grain and shoot of rice (Variety: BRRIdhan-49).

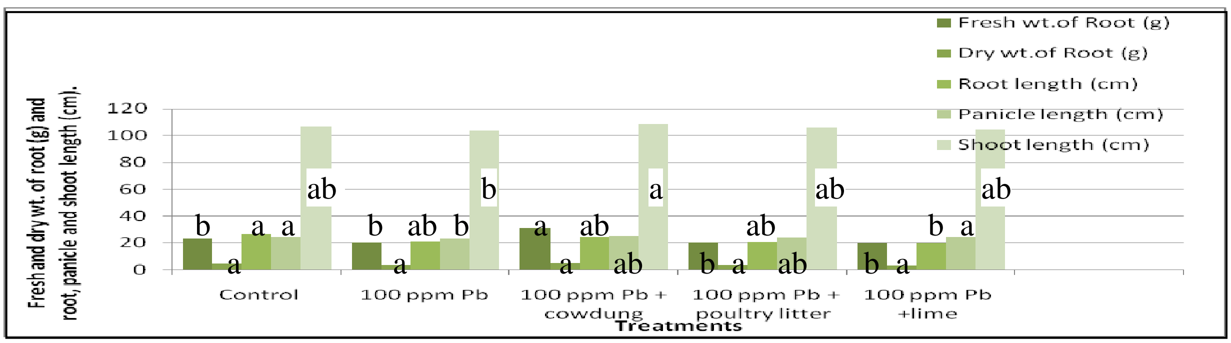


Fig-14: Effects of different amendments on fresh and dry wt. (g/pot) of rice root and length of root, panicle and shoot of rice (Variety: BRRIdhan-49).

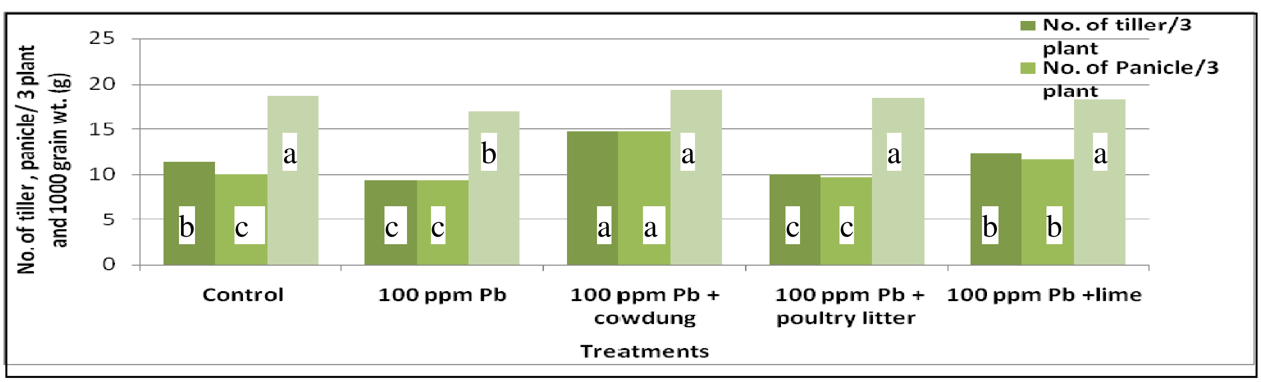


Fig-15: Effects of different amendments on no. of tiller, panicle and 1000 grain wt. (g/pot) of rice (Variety: BRRIdhan-49)

4.1.2.6: Nitrogen Concentration

Nitrogen concentrations of rice (variety: BRRIdhan-49) root, shoot and grain varied significantly with treatments (Table-8 and Figure-16). Nitrogen concentrations in root and shoot were decreased by 10.52 and 14.44% and increased by 28.76% in grain with application of 100 ppm of Pb compared with the control and these treatments were significantly different from each other in both cases. The highest concentration was observed with cowdung followed by poultry litter and lime in root and shoot but in grain, highest concentration being observed with cow-dung followed by lime and poultry litter, respectively. Cowdung treatment increased by 22.96, 15.58 and 69.44% nitrogen concentrations in root, shoot and grain compared with the control and 37.43, 35.09 and 31.58% compared with the 100 ppm Pb treatment. Cowdung, poultry litter and lime treatments did not differ significantly from each other but they were significantly different from the other treatment in case of root and shoot. In case of grain all treatments were significantly different from each other. Chamon *et al.* (2005a) reported that application of cowdung and waterhyacinth in the polluted soil enhanced the nitrogen contents in rice.

4.1.2.7: Phosphorus Concentration

Phosphorus concentration varied appreciably with the treatments (Table-8 and Figure-17). The concentration of phosphorus in root, shoot and grain of rice were decreased significantly with addition of 100 ppm of Pb. The highest being observed in cowdung treated pots (0.497, 0.133 and 0.432%) in root, shoot and grain respectively. Cowdung, poultry litter and lime treatment increased phosphorus concentration which was significantly differed from control and 100 ppm Pb treated pots. There were no difference between poultry litter and lime treatments in root and shoot however, no difference was observed between cow-dung and poultry litter treatment in grain. From the data it may be concluded that application of Pb significantly reduced the concentration of phosphorus in root, shoot and grain. Amongst soil amendments cowdung had greater ability to enhance phosphorus concentration against Pb toxicity. Due to adverse or antagonistic effect of Pb, the uptake of P by rice and other plants decreased significantly. Nurruzzaman (1995) reported that application of cowdung in the polluted soil increased phosphorus concentration of all crops (rice, wheat). Parvin *et al.* (2003) stated that application of cowdung along with Pb significantly increased P content in grain and straw of rice as compared to Pb contaminated soil. Chamon *et al.* (2005a) reported that application of cowdung and waterhyacinth in the polluted soil enhanced the phosphorus contents in rice.

4.1.2.8: Potassium Concentration

The concentration of potassium in rice root and shoot were not influenced by the amendments with Pb treated plants but in grain, potassium concentration was significantly influenced by the amendments (Table-8 and Figure-17). Application of 100 ppm of Pb decreased potassium concentration in root, shoot and grain. In root, the highest potassium concentration being observed in cowdung followed by lime and poultry litter but there were no significant difference among the treatments. In shoot, the highest potassium concentration being observed in lime followed by poultry litter and cow-dung. There were also no differences among the treatments in shoot. Straw accumulated more potassium than root and grain. In grain, the highest potassium concentration being observed in poultry litter treatment followed by lime and cowdung. All amendments significantly differed from control and 100 ppm Pb treated pots however, no difference being observed among them. Nuruzzuman (1995) reported that application of cowdung in the polluted soil increased slightly the potassium contents in rice but the effect was not significantly different. Trivedi *et al.* (1992) reported that increasing Pb concentration had an adverse impact on K uptake by rice. Chamon *et al.* (2005a) reported that application of cowdung and waterhyacinth in the polluted soil enhanced the potassium contents in rice due to binding effects of metals with organic matter. Bassuk (1986) reported the beneficial effect of the addition of organic amendments in contaminated soils on its plant growth and soil structure. It is well known that organic matter is not only an aggregating agent present in soils and sometimes the stability is related better to the "quality" than the quantity of the total soil organic carbon (Oades, 1967; Tisdall and Oades, 1980).

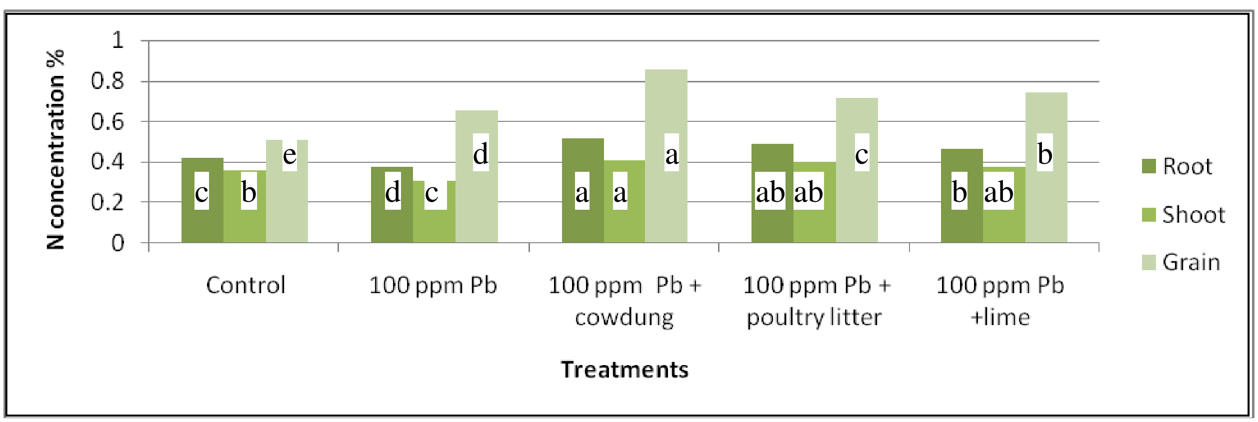


Fig-16: Effects of different amendment on N concentration (%) of root, shoot and grain of rice (Variety: BRRIdhan-49).

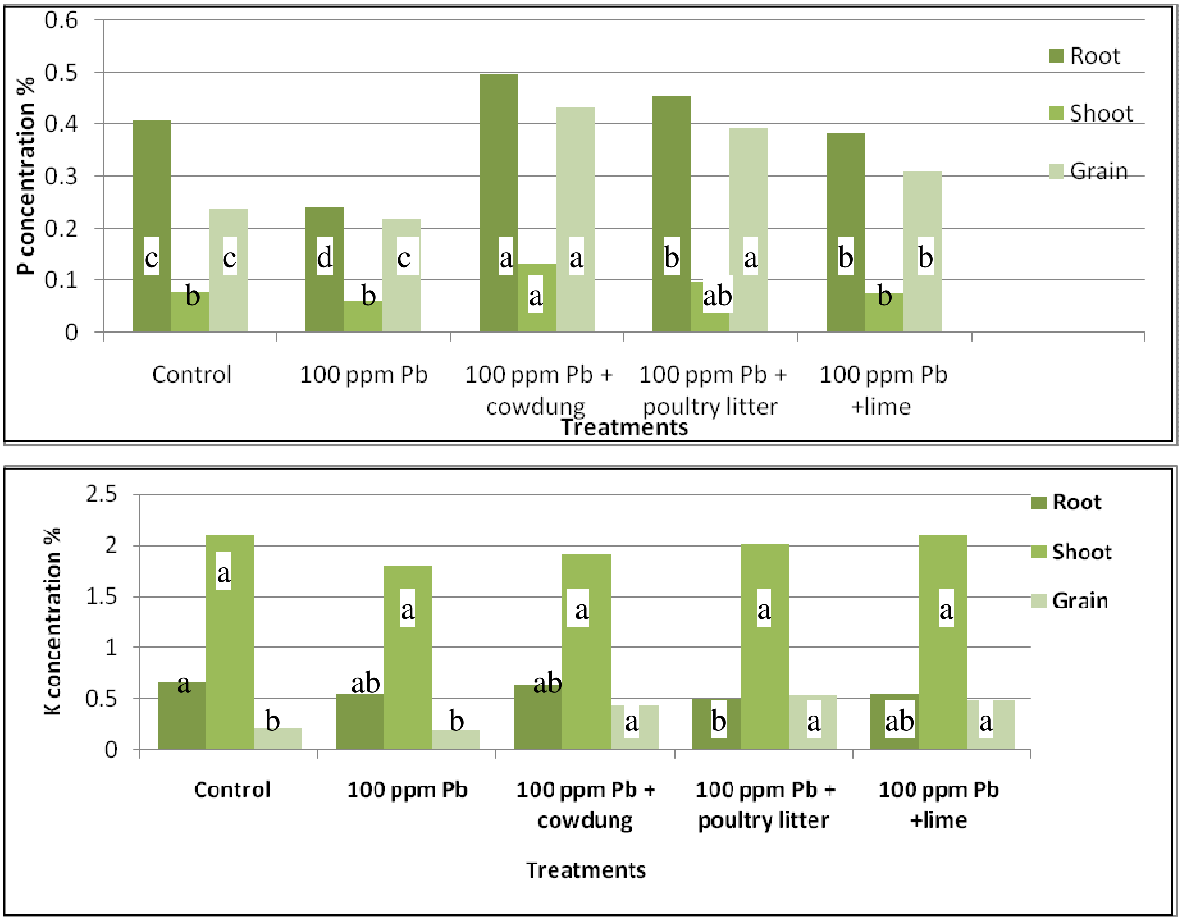


Fig-17: Effects of different amendments on P and K concentration (%) of root, shoot and grain of rice (Variety: BRRIdhan-49).

4.1.2.9: Calcium Concentration

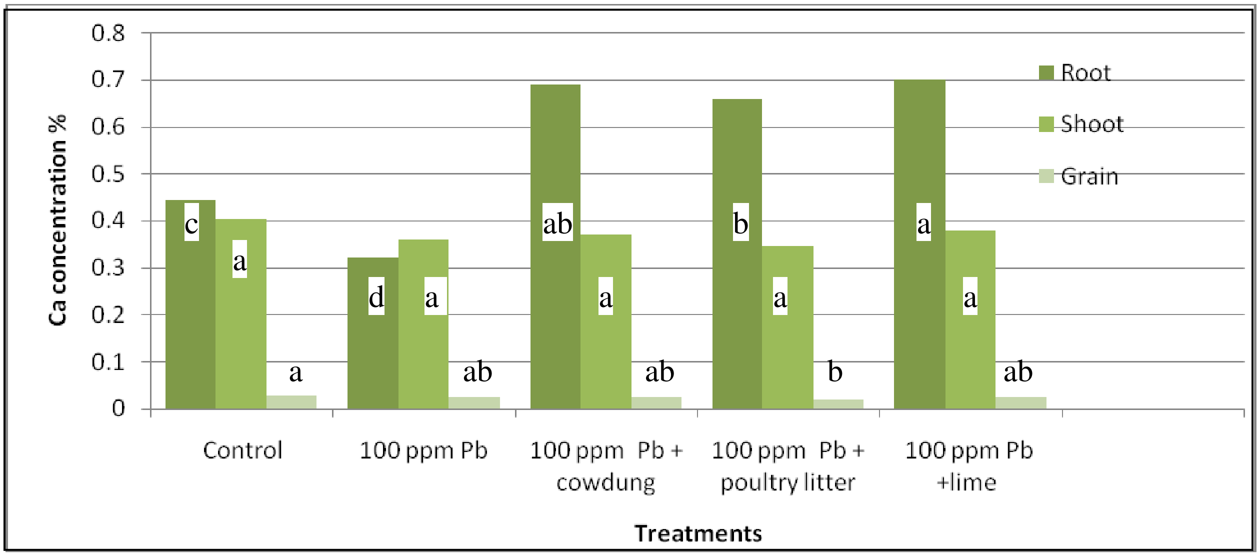
The amendments had no influence on calcium concentration in shoot and grains of rice (Table-8 and Figure-18). Application of 100 ppm of Pb reduced the calcium concentration of (BRRIdhan-49) rice root, shoot and grain. Among amendments the highest being observed in lime treatment which was 57.17% higher than control and 117.02% higher than100 ppm Pb treatment in root. Control and Pb treatment were significantly differed from other treatments however, no difference was observed between cowdung, poultry litter as well as cowdung, lime treatments respectively. In rice shoot, lime and cowdung increased and poultry litter decreased calcium concentration but among amendments there were no significant difference. The accumulation of calcium was much higher in root and shoot than grain. The reduced calcium concentration in Pb treated treatment might be due to the antagonistic effect of Pb with Ca. Lee (1991) and Kim (1991) reported an antagonistic effect on calcium uptake by rice plants due to Pb toxicity.

4.1.2.10: Magnesium Concentration:

Magnesium concentration of rice (variety: BRRIdhan-49) root, shoot and grain varied appreciably by different amendments (Table-8 and Figure-18). Application of Pb decreased 16.43, 29.60 and 12.5% magnesium concentration of rice root, shoot and grain compared with control treatment. The highest concentration of Mg was observed in cowdung treatment in root, shoot and grain and was significantly differed from other treatments. In root, cowdung increased by 56.33% and lime decreased by 5.63% magnesium concentration compared with the control and 87.07, 19.66 and 12.92% increased, in cowdung, poultry litter and lime treatments compared with 100 ppm Pb treatment. Except cowdung treatment, no difference was observed among the other treatments. Magnesium concentration increased significantly due to the application of amendments in shoot. The order was as follows: cowdung>lime>poultry litter. Cow-dung increased Mg concentration by 28.28% compared with the control and 82.24% compared with 100 ppm Pb treatment. However, in grain cowdung increased slightly Mg concentration compared with both control and 100 ppm Pb but poultry litter and lime treatments decreased Mg concentration compared with both control and 100 ppm Pb. From the result it was evident that application of 100 ppm of Pb significantly reduced Mg concentration in root, shoot and grain of rice. Amongst amendments cowdung had greater ability to ameliorate Pb toxicity and thus increased Mg concentration significantly.

4.1.2.11: Lead Concentration:

Lead concentration of rice (variety: BRRIdhan-49) root, shoot and grain as affected by different amendments are presented in Table-8 and Figure-19. Application of Pb increased 16.43, 29.60 and 12.5% Pb concentration of rice (BRRIdhan-49) root, shoot and grain compared with the control treatment and were significantly differed from other treatments. Lead concentration in root ranged between 42.5 to 341 ppm which was above the critical levels in roots (Table-31). Soil amended with cowdung, poultry litter and lime reduced the Pb concentration in rice root, shoot and grain, probably due to binding up of Pb rendering it less available to plants by organic manures or lime or there might be antagonistic effect of Ca on Pb uptake by rice plants. Cowdung, poultry litter and lime decreased 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% Pb concentration in grain compared with 100 ppm Pb treatment. From the results it may be concluded that application of lead significantly increased the concentration of Pb in root, shoot and grain of rice. All amendments decreased Pb concentration in rice. Amongst amendments cowdung had the greater ability to reduce Pb toxicity in root, shoot and grain and then lime and poultry litter. Similar results were also observed by many investigators (Kim *et al.* 1992; Santos *et al.* 1992) and Chen *et al.* (1991) reported that Pb application greatly increased Pb uptake in plant tissue of rice. Madrid *et al.* (1999) reported 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. Chamon *et al.* (2005a) reported that all organic materials can be classified as less contaminated and suitable for agricultural use according to their heavy metal concentrations. The beneficial effect of the addition of organic manures in contaminated soils on plant growth and soil structure was also reported (Bassuk, 1986). 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). Brown (1997) stated that the addition of organic matter to contaminated soil may decrease the concentration of metals in solution and decrease their leachability. Besides, many researchers reported the importance of increased cation exchange capacity and organic matter in reducing Pb uptake (Chamon *et al.,* 2005a). Soil organic matter adsorbs available Pb ions, producing and preserving forms of Pb that are less available for plant uptake or leaching (Zehetner and Wenzel, 2000). Parvin *et al.* (2003) stated that application of Pb significantly increased the content of Pb both in straw and grain of rice, soil amended with cowdung, $CaCl_2$ and Fe_2O_3 reduced the Pb content in straw; while in grains the Pb content was below detection limit, probably due to binding up of Pb rendering it less available to plants by Fe or organic manures. Cordavil *et al.* (1999) observed that applying $CaCO_3$ generally decreased Pb absorption and its translocation to plant shoots. 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 rice and cabbage (Chen, 2000; Lee and Liu, 2000).



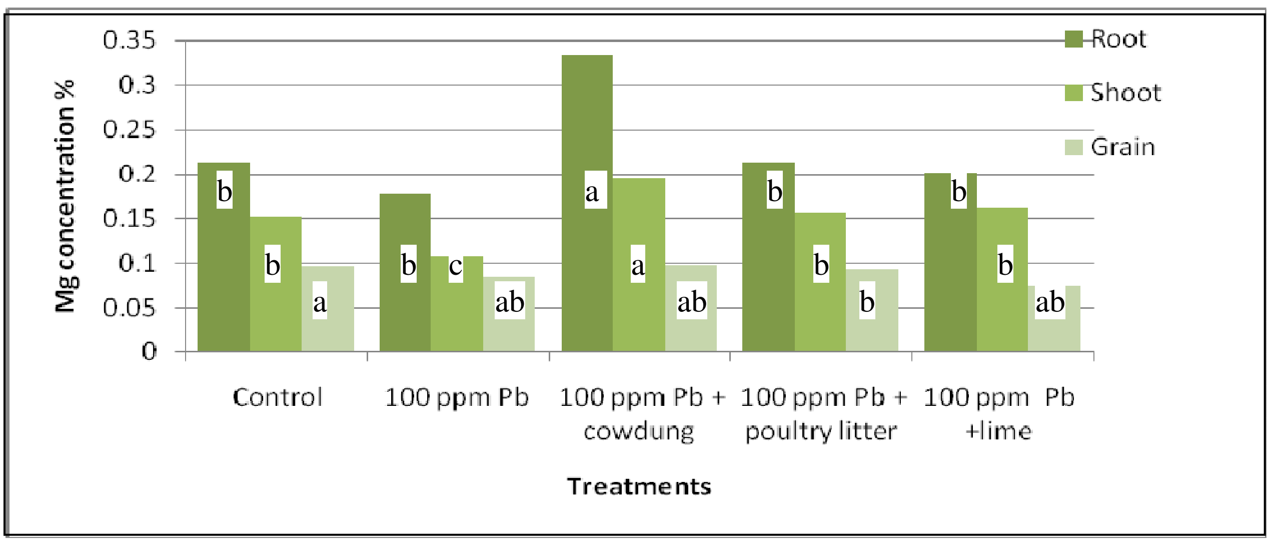


Fig-18: Effects of different amendments on Ca and Mg (%) concentration of root, shoot and grain of rice (variety: BRRIdhan-49).

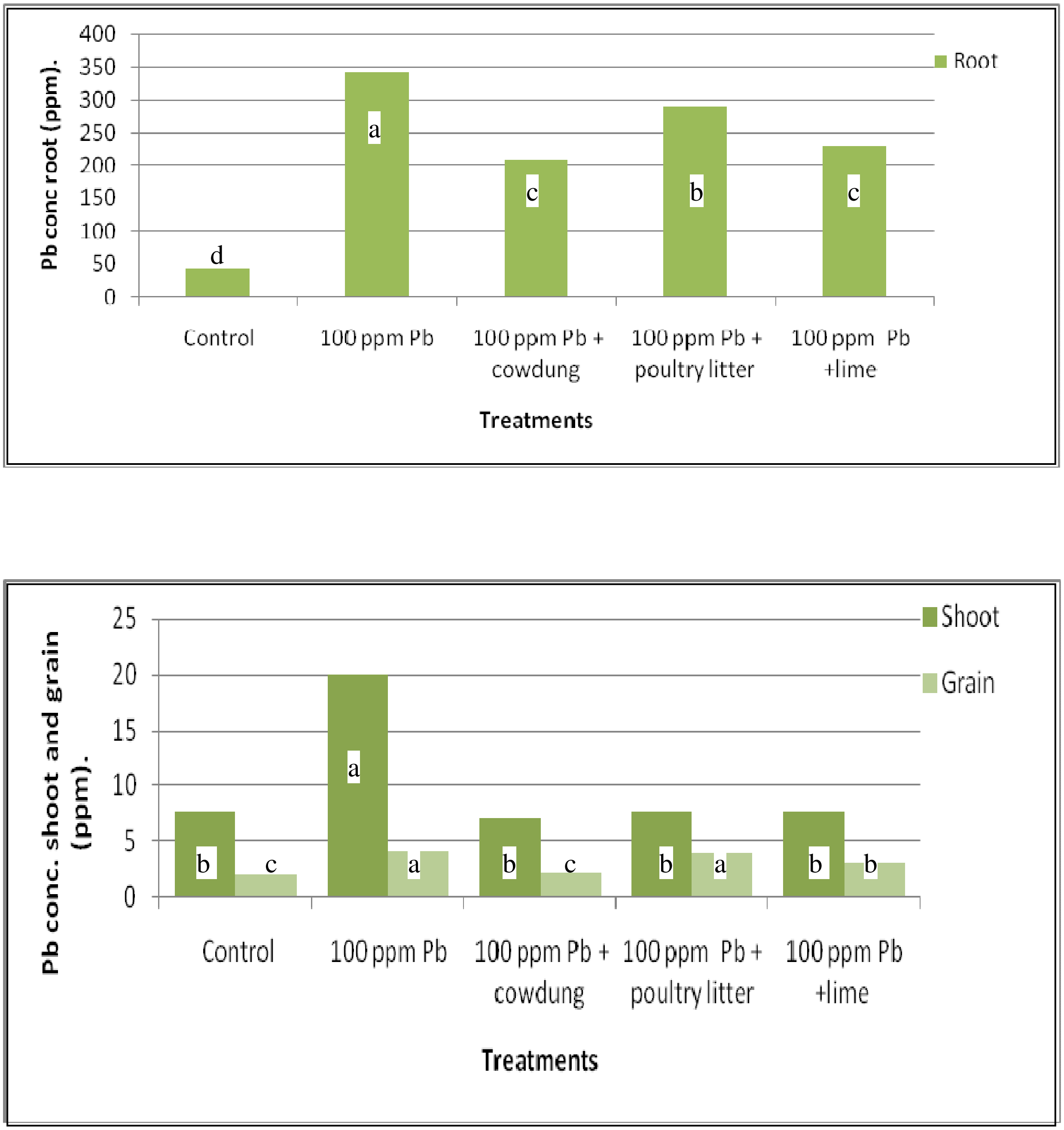


Fig-19: Effects of different amendments on Pb (ppm) concentration of root, shoot and grain of rice (variety: BRRIdhan-49).

4.1.3: Experiment-3: Growth, yield and mineral nutrition of different varieties of rice grown on soils contaminated with 200 ppm of Pb.

Significant differences in growth and mineral nutrition among different rice varieties grown on soils contaminated with 200 ppm of Pb were observed and it is discussed here:

4.1.3.1: Fresh and dry weight of grain (g)

Rice varieties of course had different fresh and dry grain yields with application of 200 ppm of Pb (Table-9 and Figure-20). Variety V_2 (BRRIdhan-49) and V_4 (BRRIdhan-54) being significantly better in fresh and dry yield production than V_1 (BRRIdhan-33) and V_3 (BRRIdhan-53). There were no significant differences in fresh and dry weight production of grains between V_1, V_3 as well as V_2, V_4 varieties, respectively. From the result it was evident that V_2 and V_4 varieties showed better tolerance against Pb toxicity in comparison with V_1 and V_3 varieties. Such reduction in fresh and dry yield of V_1 and V_3 at 200 ppm of Pb might have been caused probably by physiological disorders, impaired biochemical, physiological and enzymatic processes. The research by Xie and Huang (1994) indicated that the growth of the hybrid rice cultivar (variety: Shan you 63) was not affected by 2500 ppm of Pb in the soil because the sensitivity and tolerance of rice to soil Pb pollution are cultivar-dependent. Chamon *et al.* (2005b) also reported that BR-30 and BR-25 rice varieties being significantly better in grain dry weight production than BR-11 and BR-22.

4.1.3.2: Fresh and dry weight of shoot (g)

Significant differences in shoot biomass (fresh and dry) production existed among the four varieties of rice with addition of 200 ppm of Pb (Table-9 and Figure-20). Variety V_4 (BRRIdhan-54) exhibited the highest value in both cases followed by V_2, V_3 and V_1 and this variety (BRRIdhan-54) was significantly differed from other varieties. However, no difference was observed among V_1, V_2 and V_3 varieties in both cases. Comparison among Pb stressed varieties, highest fresh and dry weight of shoot was observed in V_4 (BRRIdhan-54) variety probably this variety is more tolerant against Pb toxicity and hence a better recovery capacity than V_1, V_2, and V_3 varieties. Chamon *et al.* (2005b) also reported that BR-22 exhibited the highest shoot biomass, followed by BR-30, BR-25 and BR-11 varieties of rice.

4.1.3.3: Fresh and dry weight of root (g)

Among the four varieties of rice, with 200 ppm of Pb, V_4 (BRRIdhan-54) exhibited the best root development in both fresh and dry wt. basis (Table-9 and Figure-21). In case of fresh weight of root, there were no significant differences among all varieties. However, in case of dry weight of root V4 (BRRIdhan-54) significantly differed from other varieties but no significant difference was observed among V_1, V_2, and V_3 rice varieties. Chamon *et al.* (2005b) also reported that among four varieties of rice, BR-11 exhibited the best root development.

4.1.3.4: Shoot, root and panicle length (cm)

The mean shoot, root and panicle lengths differed appreciably among the four varieties of rice (Table-9 and Figure-22). The highest shoot length of plant (118.50 cm) was found in V_1 (BRRIdhan-33) and the lowest (100 cm) in V_2 (BRRIdhan-49) variety. There was no difference between V_1 and V_4 varieties but they were significantly differed from V_2 and V_3. The highest root length (26.67cm) was found in V_4 (BRRIdhan-54) and the lowest (16.67cm) in V_1 (BRRIdhan-33) and they were significantly differed from V_2 and V_3 but V_2 and V_3 were not significantly different from each other. The highest panicle length (26.67cm) also found in V_4 (BRRIdhan-54) and was significantly differed from V_1, V_2, and V_3 but there were no difference among V_1, V_2, and V_3. From the result it was evident that V_1 variety exhibited better shoot length whereas V_4 (BRRIdhan-54) showed highest root and panicle length against Pb toxicity in comparison with other varieties. Chamon *et al.* (2005b) reported that shoot length of the rice variety BR-29 was significantly higher than BR-3, BR-8, BR-14, BR-16, BR-28 varieties.

4.1.3.5: No. of tiller and no. of panicle/pot

The no. of tiller and no. of panicle/pot of four varieties of rice grown on soil contaminated with 200 ppm of Pb varied considerably (Table-9 and Figure-21). The highest number of tiller and number of panicle (9.00 and 8.33) was found in V_2 (BRRIdhan-49) and the lowest (6.33 and 4.00) in V_1 (BRRIdhan-33). Variety V_1 significantly differed from V_2, V_3 and V_4. However no difference was observed among them. From the result it was evident that V_2 (BRRIdhan-49) variety had highest ability to increase no. of tiller and no. of panicle/pot against Pb toxicity as compared with other varieties.

4.1.3.6: No. of grain/panicle and 1000 grain weight (g)

Significant variation in no. of grains/panicle and 1000 grain weight (g) was observed among four varieties of rice grown on soil contaminated with 200 ppm of Pb (Table-9 and Figure-23). The highest and the lowest number of grains/panicle were (171 and 87.67) found in the V_4 and V_3 variety respectively. From the four rice varieties, V_4 (BRRIdhan-54) yielded the highest 1000 grain weight (22.98 g/pot). Variety V_2 differed significantly from other variety in case of 1000 grain weight. However, no difference was observed among V_1, V_3 and V_4 varieties in case of 1000 grain weight. From the results it was concluded that V_4 (BRRIdhan-54) variety had the highest ability to increase number of grains/panicle and 1000 grain weight (g) against Pb toxicity as compared with V_1, V_2 and V_3 varieties. Chamon *et al.* (2005b) also reported that BR-30 (rice variety) yielded the highest 1000 grain weight compared with other varieties of rice.

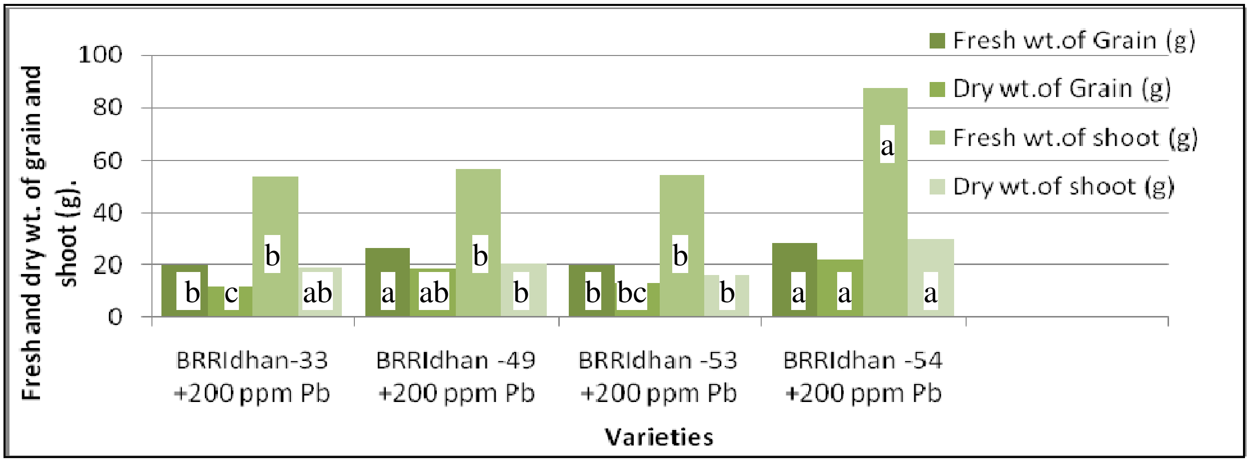


Fig 20: Effects of different varieties on fresh and dry wt .of grain and shoot (g/pot) of rice.

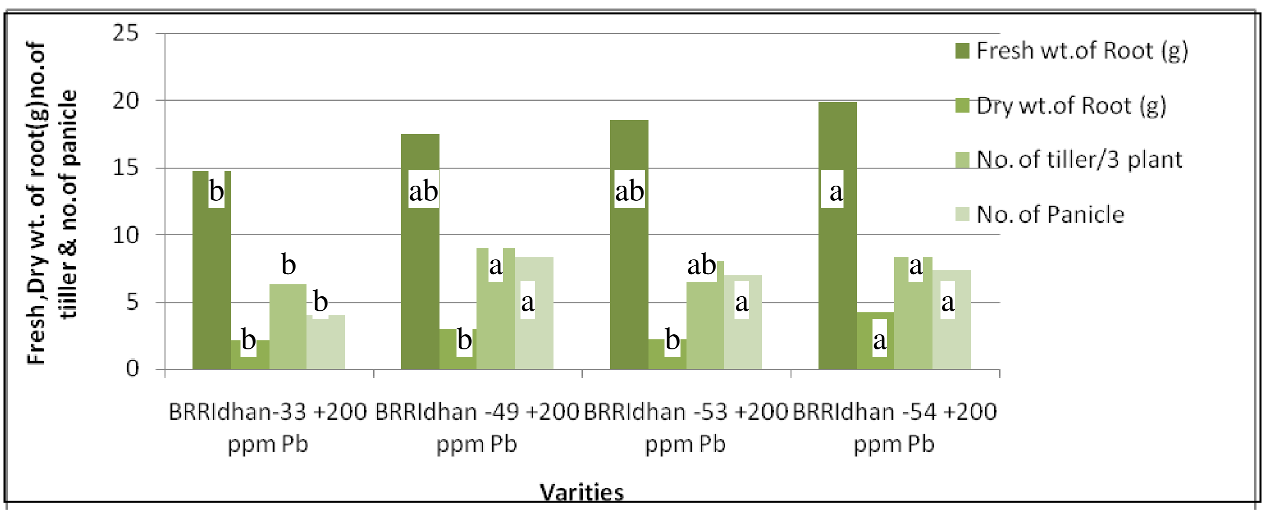


Fig-21: Effects of different varieties on fresh and dry wt. (g/pot) of root, no. of tiller and no. of panicle/pot grown on soil contaminated with Pb.

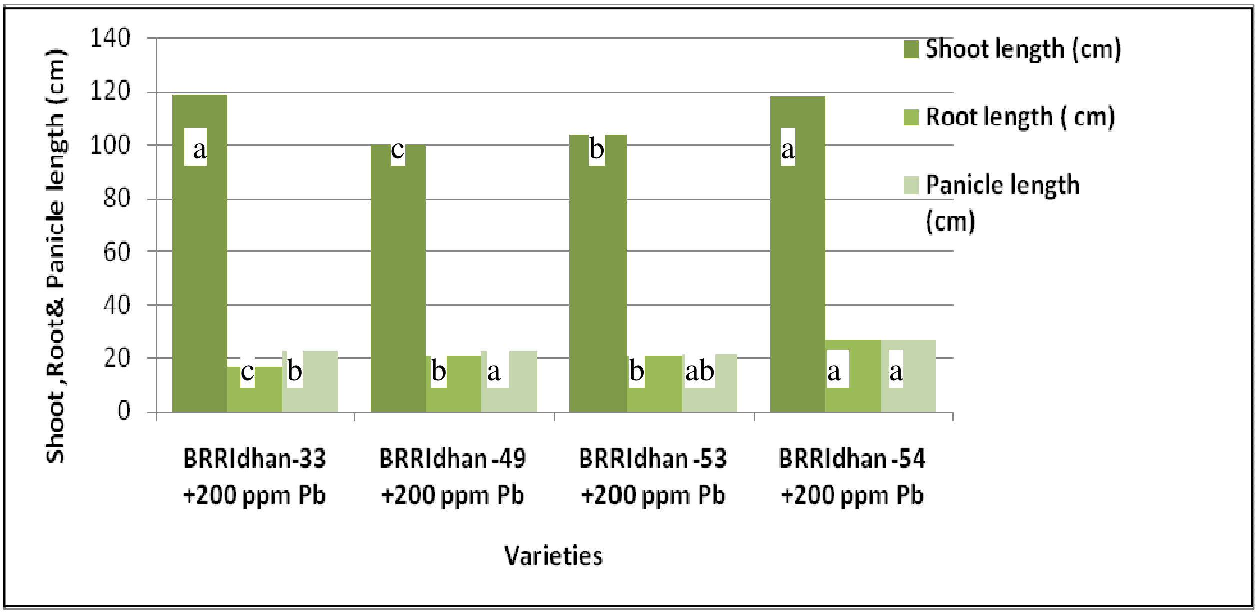


Fig- 22: Effects of different varieties on shoot, root and panicle length (cm) of rice grown on soil contaminated with Pb.

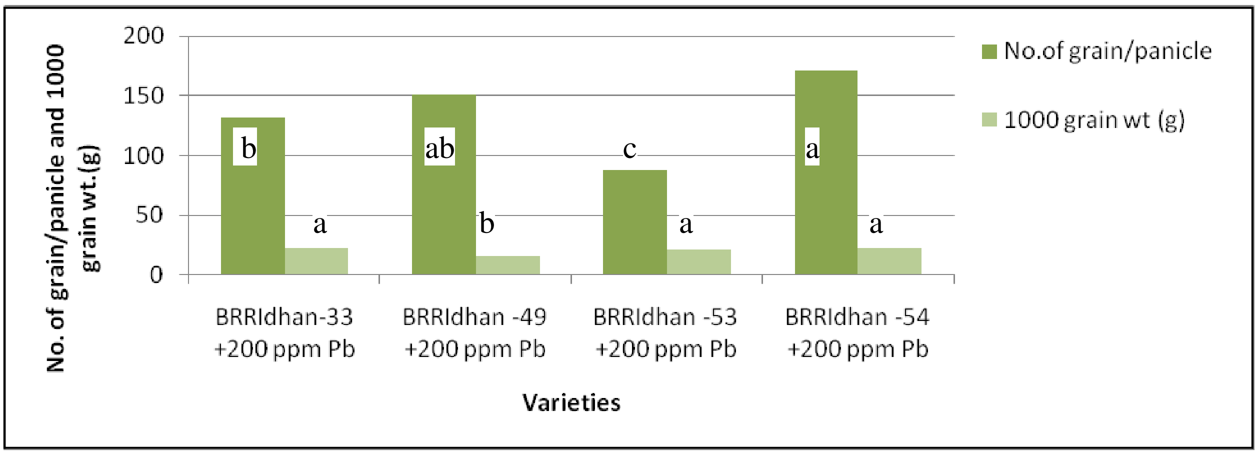


Fig-23: Effects of different varieties on no. of grain/panicle and 1000 grain wt.(g/pot) of rice grown on soil contaminated with Pb.

4.1.3.7: Nitrogen Concentration

Shoot and grain of different rice varieties showed significant differences in N concentration whereas there was no significant difference was observed among varieties in case of root N concentration (Table-10 and Figure-24). The maximum concentration of nitrogen (0.383, 0.295 and 0.703% in root, shoot and grain respectively) were obtained in V_4 (BRRIdhan-54) and the minimum concentration (0.297, 0.141 and 0.461% in root, shoot and grain) at V_2, V_3 and V_3 varieties respectively. In case of shoot, varieties V_2 and V_3 were not significantly differed from each other but differed from other varieties. In case of grain, all varieties were significantly differed from each other. From the results it was reported that only V_4 (BRRIdhan-54) variety had greater ability to absorb nitrogen in root, shoot and grain against Pb toxicity than other varieties. Chamon *et al.* (2005b) also reported that nitrogen uptake was not significantly affected by the rice varieties.

4.1.3.8: Phosphorus Concentration

Phosphorus concentration in roots did not differ significantly among the rice varieties whereas shoot and grain of P concentration in different varieties varied significantly (Table-11 and Figure-24). The maximum concentration of phosphorus (0.200, 0.133 and 0.254% in root, shoot and grain, respectively) were obtained in V_1, V_1 and V_4 and the minimum concentration (0.128, 0.041and 0.171% in root, shoot and grain, respectively) at $V_{4,}$ V_2 and $V_{1,}$ respectively. In case of shoot, varieties V_1 and V_2 were significantly differed from each other and from other varieties however, no difference was observed between V_3 and V_4 varieties. In case of grain, V_4 was significantly different from V_1 and V_2 varieties but no difference was observed between $V_{3,}$ V_4 as well as $V_{1,}$ V_2 and V_3 varieties. From the results it was observed that V_1 (BRRIdhan-33) had greater ability to absorb phosphorus in root and shoot but in grain V_4 (BRRIdhan-54) had greater ability to absorb phosphorus against Pb toxicity than other varieties.

4.1.3.9: Potassium Concentration

The concentration of K was influenced in shoot and grain but not in root of different varieties of Pb stressed rice (Table-10 and Figure-24). The maximum concentration of potassium (0.742, 1.96 and 0.560 % in root, shoot and grain) were obtained in $V_{4,}$ V_1 and V_4 varieties respectively. Varieties V_1 and V_3 were significantly different from each other but not from other varieties in case of shoot; while in grain, V_2 and V_4 were different from each other. However, no significant difference was observed between V_1 and V_3 varieties. From the results it was evident that V_4 (BRRIdhan-54) had greater ability to absorb potassium in root and grain, while in shoot V_1 (BRRIdhan-33) had the greatest ability of all the varieties to accumulate K under Pb-stressed condition. Chamon *et al.* (2005b) also reported that potassium concentration in different rice varieties were also significantly different.

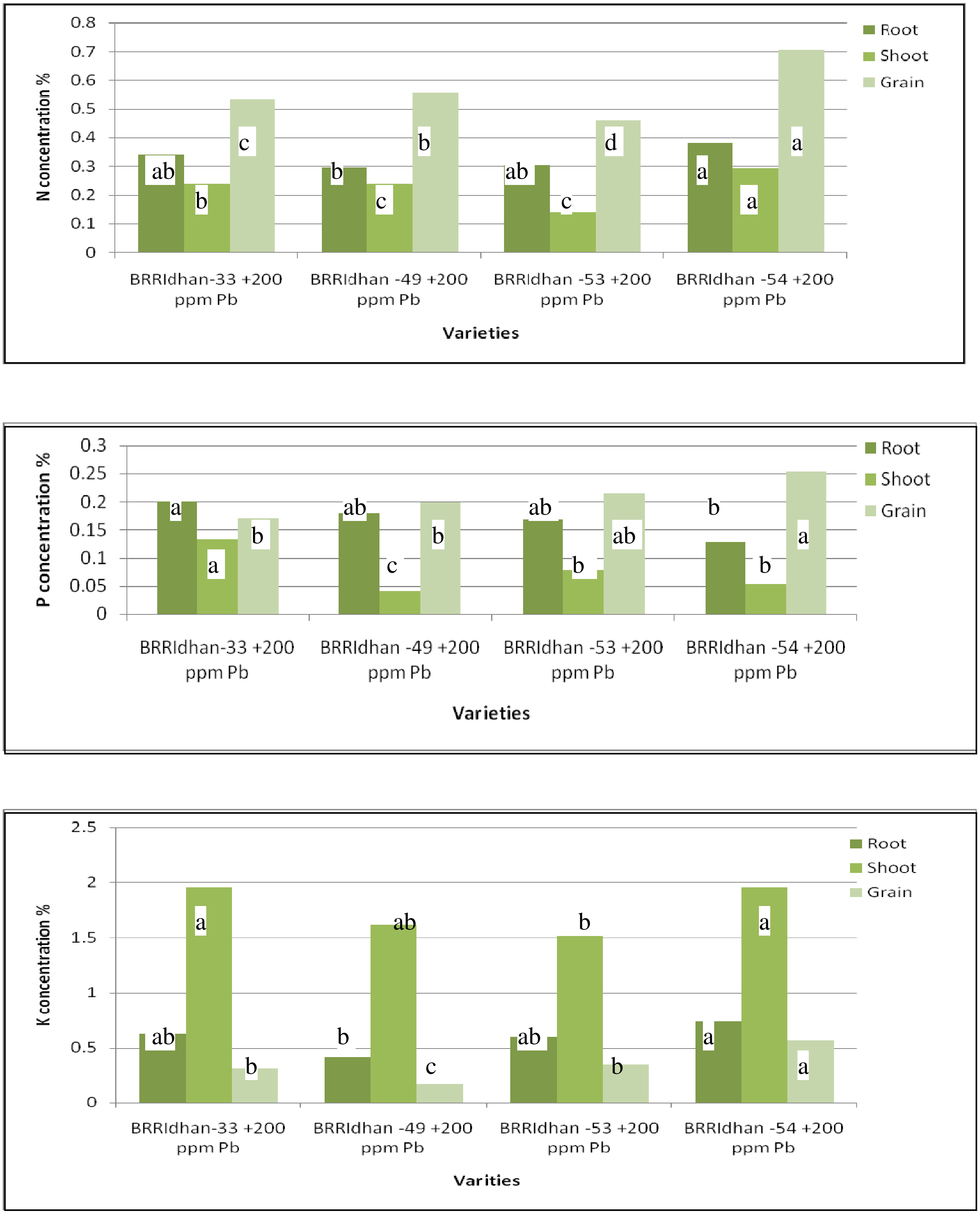


Fig-24: Effects of different varieties of rice on N, P and K conc. (%) grown on soil contaminated with Pb.

4.1.3.10: Calcium Concentration

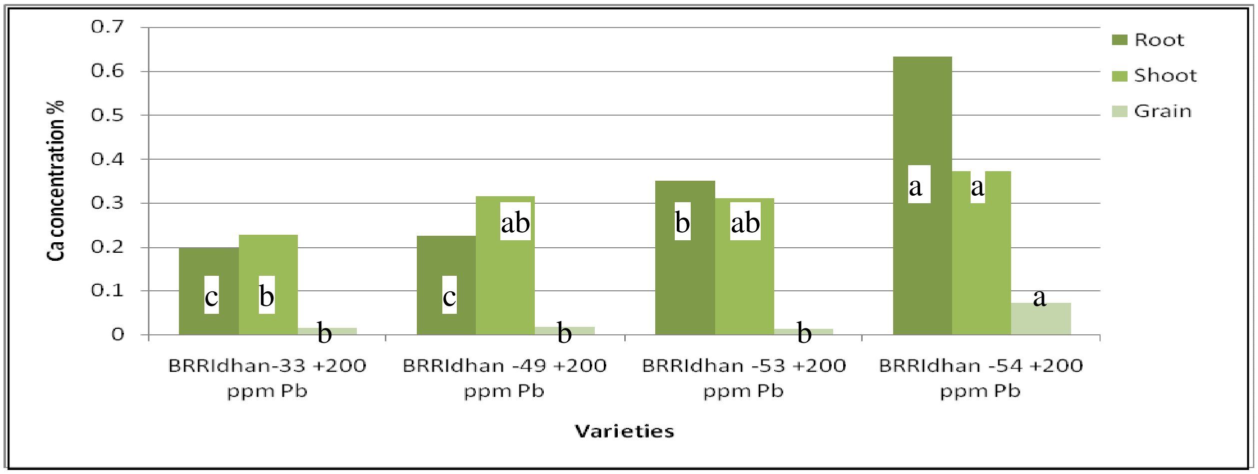
The rice varieties have different abilities to take up calcium under Pb stressed soil (Table-10 and Figure-25). The maximum concentration of calcium (0.632, 0.372 and 0.072 % in root, shoot and grain respectively) were found in V_4 (BRRIdhan-54). Varieties V_3 and V_4 were significantly different from each other and from other varieties in case of root. In case of shoot, V_1 and V_4 were significantly different from each other but not from other varieties; while in grain V_4 was significantly different from other varieties however, no significant difference was observed among V_1, V_2 and V_3 varieties. From results it was evident that V_4 (BRRIdhan-54) variety had greater ability to absorb calcium in root, shoot and grain under Pb-stressed condition. Chamon *et al.* (2005b) also reported that calcium concentration in grains was lowest in BR-25 and highest in BR-11 compared with other varieties of rice.

4.1.3.11: Magnesium Concentration

The rice varieties differed also with respect to the concentration of Mg in root, shoot and grain (Table-10 and Figure-25). The maximum amount of magnesium (0.172, 0.142 and 0.086% in root, shoot and grain respectively) were found in V_4, V_2 and V_3 and the minimum concentration (0.132, 0.104 and 0.069% in root, shoot and grain) in V_3, respectively. In case of root, varieties V_2 and V_4 were not significantly differed from each other but different from other varieties. In case of shoot, there were no significant differences between V_1, V_4 as well as V_2, V_3 varieties while in grain, V_1 (BRRIdhan-33) was significantly different from all other varieties however no significant difference was observed among V_2, V_3 and V_4 varieties. From the results it was evident that V_4 (BRRIdhan-54) exhibited greater ability to absorb magnesium in root and shoot but in grain, V_1 (BRRIdhan-33) had greater ability to absorb magnesium against Pb toxicity than all other varieties. Chamon *et al.* (2005b) also reported that magnesium concentration in shoots was significantly higher in BR-11 than other varieties of rice.

4.1.3.12: Lead Concentration

The rice varieties exhibited different abilities in absorbing Pb in root, shoot and grains under Pb-stressed condition of soil (Table-10 and Figure-26). The highest concentration of Pb was (1577, 43 and 32 ppm in root, shoot and grain) found in V_2 rice variety and the minimum was (574, 23.33 and 2.51 ppm in root, shoot and grain) found in V_3, V_3 and V_4, respectively. All varieties were significantly different from each other in case of root and grain, however in case of shoot, V_1 and V_2 were significantly different from each other and from other varieties but there were no significant difference between V_3 and V_4 varieties. In grain of all rice varieties, Pb concentrations exceeded limits for human consumption (0.3 mg Pb/kg) (Bangladesh Agricultural Research Council, 1997). From the results it was evident that V_4 (BRRIdhan-54) had the ability to withstand Pb-stressed soil and concentrate less amount of Pb in grain and V_2 (BRRIdhan-49) variety had a greater ability to absorb Pb in root, shoot and grain. Rice root accumulated more Pb than shoot and grains. Verma *et al. (*2003) indicated an increased uptake of Pb in rice seedlings with increase in Pb concentration in the growth medium and that the absorbed Pb is distributed in an organ specific manner with its localization greater in roots than in shoots. It has been shown that Pb is unevenly distributed in roots, where different root tissues acts as barriers to apoplastic and symplastic Pb transport and hence Pb transport to shoot and grain gets restricted (Trivedi *et al.,* 1992).



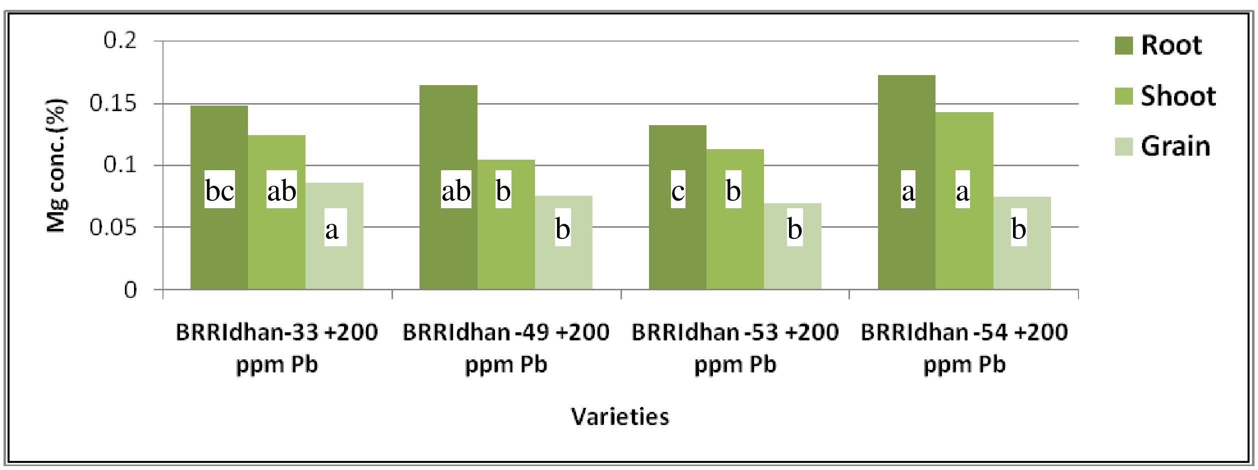


Fig- 25: Effects of different varieties of rice on Ca and Mg conc. (%) grown on soil contaminated with Pb.

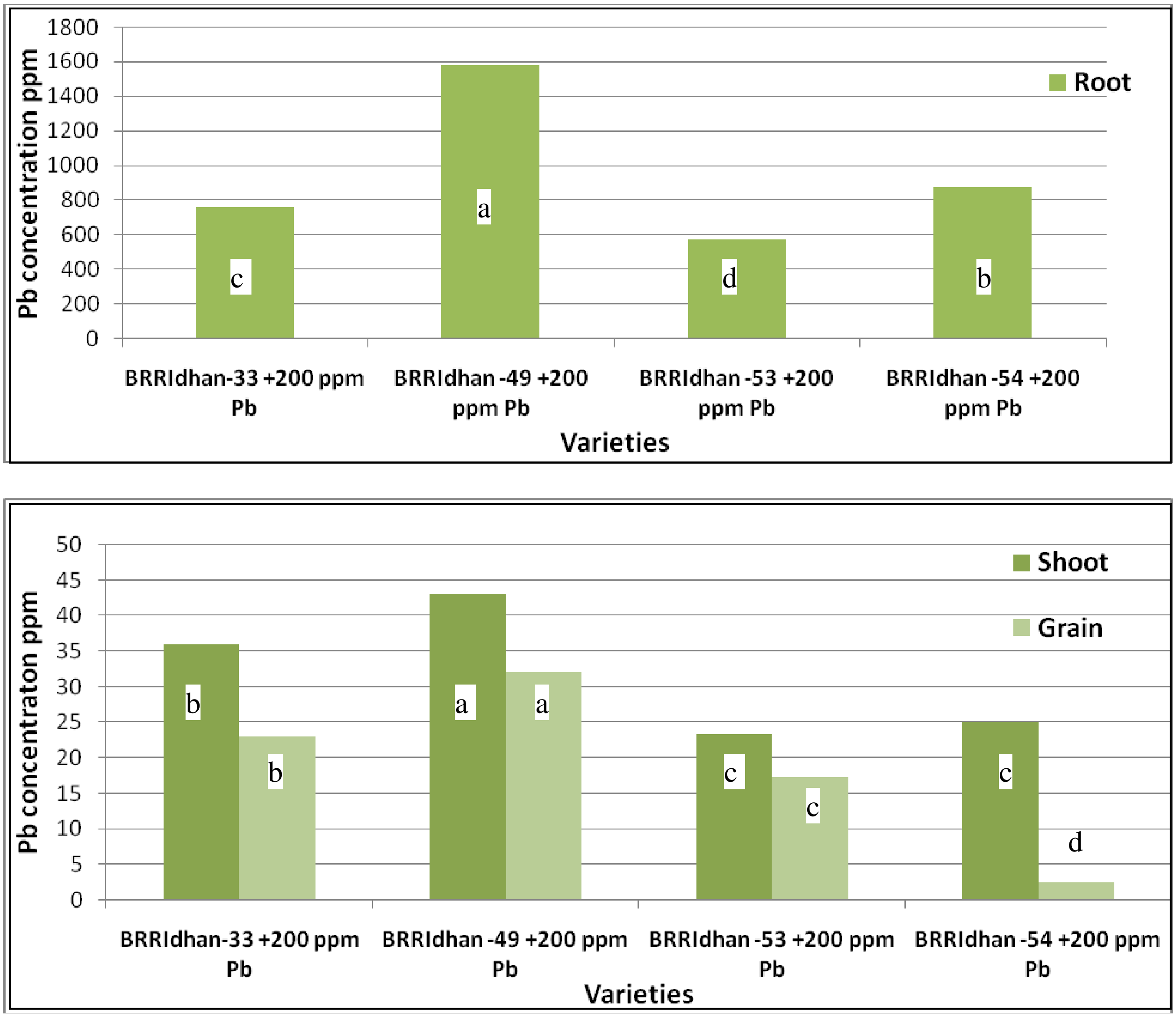


Fig- 26: Effects of different varieties of rice on Pb conc. (ppm) grown on soil contaminated with 200 ppm Pb.

4.1.4. Experiment-4: Wheat: Effects of different doses of lead (Pb) on growth, yield and mineral nutrition of wheat (variety: Bari wheat-26)

4.1.4.1. Fresh and dry weight of grain

The fresh and dry weight (g/pot) of wheat (variety: BARI wheat-26) grain varied considerably with different Pb levels (Table-11 and Figure-27). The highest fresh and dry weight of grains/pot (13.7 and 12.36 g) was obtained in the T_1 treatment where 50 ppm of lead was applied. The lowest value 9.12 and 7.50 g were obtained in the T_4 treatment (at 200 ppm Pb). 50 ppm Pb treated pots differed significantly from $T_{0,}$ $T_{2,}$ T_3 and T_4 treatments but there were no differences among $T_{0,}$ $T_{2,}$ T_3 and T_4 treatments in both fresh and dry weight (g/pot) of wheat. The results indicated that application of 50 ppm of Pb increased the fresh and dry weight of wheat grains then decreased with increasing Pb concentrations. At the highest dose of Pb application (200 ppm), fresh and dry weight of grain decreased by 14.8 and 23.5% respectively, compared with that of the control. This might be due to Pb toxicity was exerted in higher concentration, which caused a significant decline in grain production of wheat compared with the control treatment. The growth inhibition under Pb-stressed condition was similar to previously reported by Mesmar and Jabber (1991) in wheat and lentils and Kosobrukhov *et al.* (2004) in only wheat. Saini *et al.* (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 and also reported that application of 80 mg Pb kg^{-1} soil over control decreased mean grain yield by 21.8 and 12.3 % in sandy and clay loam soil, respectively.

4.1.4.2. Fresh and dry weight (g) of shoot

The fresh and dry weight of shootpot^{-1} (g) of wheat (variety: BARI wheat-26) with the different Pb treatments varied appreciably (Table-11 and figure-27). The maximum fresh and dry weight of shootpot^{-1} was (6.50 and 5.65g) obtained in the control treatment. The lowest value was (5.01 and 4.51g) in the treatment T_4 (at 200 ppm Pb). The fresh and dry weight of shoot pot^{-1} was decreased with increasing Pb concentration and followed the sequence $T_0>T_1>T_2>T_3>T_4$. In case of fresh weight of wheat shoot, treatment T_0 was significantly differed from T_3 and T_4 treatments but there were no differences among $T_{0,}$ $T_{1,}$ T_2 as well as T_3 and T_4 treatments, respectively. However, in dry weight of shoot, T_3 and T_4 treatments were significantly different from each other and from other treatments but there were no differences among $T_{2,}$ $T_{3,}$ T_4 treatments, respectively. The higher the concentration of Pb the lower was the fresh and dry weight of shoot in both cases. At the highest dose of Pb application (200 ppm), fresh and dry weight of shoot decreased by 22.9 and 20.2% respectively, compared with that of the control. The reduction of biomass by Pb toxicity could be the direct consequences of the inhibition of chlorophyll synthesis and photosynthesis (Chitterjee *et al.,* 2004). Similar phenomena were also described by Kosobrukhov *et al.* (2004) and Bhatti *et al.* (2013) in wheat. Saini *et al*. (2001) also reported that yield of straw of wheat increased significantly with an application of 5 mg Pb kg^{-1} and it decreased at higher levels of Pb application and also reported that application of 80 mg Pb kg^{-1} soil over control decreased mean straw wt. by 6.9 and 4.2% in sandy and clay loam soil respectively. Du *et al*. (2010) also reported the treatments of low Pb concentrations which is < 100 mg/kg, stimulate the growth of wheat shoot seedlings and the high Pb concentrations, which was >200 mg/kg, inhibit seedlings growth.

4.1.4.3. Fresh and dry weight (g) of root

The fresh and dry weights of root pot^{-1} (g) of wheat (variety: BARI wheat-26) was declined considerably with increasing Pb concentration (Table-11 and figure-28). The highest fresh and dry weight of root pot^{-1} was (1.80 was 1.41g) in the control (T_0) treatment where no lead was applied. The lowest fresh and dry weight of $rootpot^{-1}$ was (1.01 and 0.697g) were obtained in the T_4 treatment, at 200 ppm Pb. In case of fresh weight of root, treatments T_1 and T_4 significantly differed from each other but there were no significant differences between $T_{0,}$ $T_{1,}$ as well as $T_{2,}$ $T_{3,}$ T_4 treatments, respectively. On the contrary, there were no significant differences among $T_{0,}$ $T_{1,}$ T_2 and between $T_{3,}$ T_4 treatments in dry weight of root, respectively. At the highest dose of Pb application (200 ppm), fresh and dry weight of root decreased by 43.9 and 50.6% respectively, compared with the control. 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 ppm) as compared to the control. Saini *et al*. (2001) reported that yield of root of wheat increased significantly with an application of 5 mg Pb kg^{-1} and it decreased at higher levels of Pb application and also reported that application of 80 mg Pb kg^{-1} soil over control decreased mean root weight by 23.4 and 8.2% in sandy and clay loam soil, respectively. Du *et al*. (2010) reported that the wheat seedling roots were more severely depressed when treated with high Pb concentrations.

4.1.4.4. Shoot and root length (cm)

The length of shoot and root of wheat (variety: BARI wheat-26) were radically affected by Pb application (Table-11 and figure-29). 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 T_0 (control) and T_4 (200 ppm of Pb) treatments. In case of length of shoot $T_{0,}$ $T_{1,}$ T_3 and T_4 treatments significantly differed from each other but there were no differences between $T_{1,}$ T_2 treatments. However, in root length there were no significant differences between $T_{0,}$ T_1 as well as $T_{2,}$ $T_{3,}$ T_4 treatments, respectively. Shoot and root length decreased due to reduction of meristematic cells in the shoot and root region by the accumulation of Pb. These findings are similar to another study in which there was also reduction in shoot and root length of wheat due to Pb contaminated soil (Kaur *et al.,* 2012 and Bhatti *et al.,* 2013). Significant inhibition of root length of wheat seedling at higher Pb was also reported (Hasnian *et al*., 1993). Although Pb cannot penetrate the seed testa but Pb may have affected the root growth after radical emergence (Obroucheva *et al*., 1998). Mahmood *et al*. (2007) reported that root length of wheat seedling was significantly affected by increasing Cu, Pb and Zn and was at 5 and 10 µM Pb was significantly less (30-50%) than that of the control seedlings and also reported wheat shoots height decreased by 15% with increasing Pb.

4.1.4.5. Number of tiller/pot and 1000 grains weight

The number of tiller pot^{-1} was not varied significantly and 1000 grains weight (g) varied significantly of wheat (variety: BARI wheat-26) at different levels of lead (Table-11 and figure-29). The highest tiller number and 1000 grains weight were found (7.67 and 42.39 g) in the control treatment and the lowest was (6.33 and 39.06 g) in the T_4 treatment. In case of number of tiller pot^{-1} there were no significant differences among all treatments though the number of tiller/pot deceased with increasing Pb concentrations. However, in case of 1000 grains weight, treatment T_1 and T_4 significantly differed from each other but there were no significant differences between $T_{1,}$ T_2 as well as $T_{3,}$ T_4 treatments, respectively. The above results indicated that the tiller number and 1000 grains weight of wheat declined with increasing level of Pb. The results of the present investigation are analogous to the earlier findings of Bhatti *et al.* (2013) who reported that Pb treatment had reduced the number of tillers in wheat varieties at both treatments (40 and 60 ppm) as compared to the control.

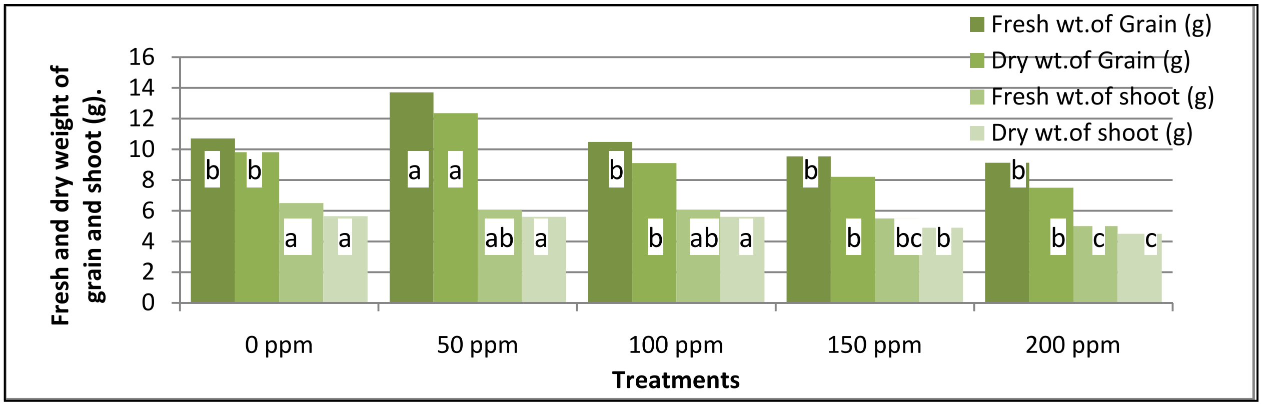


Fig- 27: Effects of different doses of Pb on fresh and dry weight of grain and shoot (g/pot) of wheat (variety: BARI wheat-26).

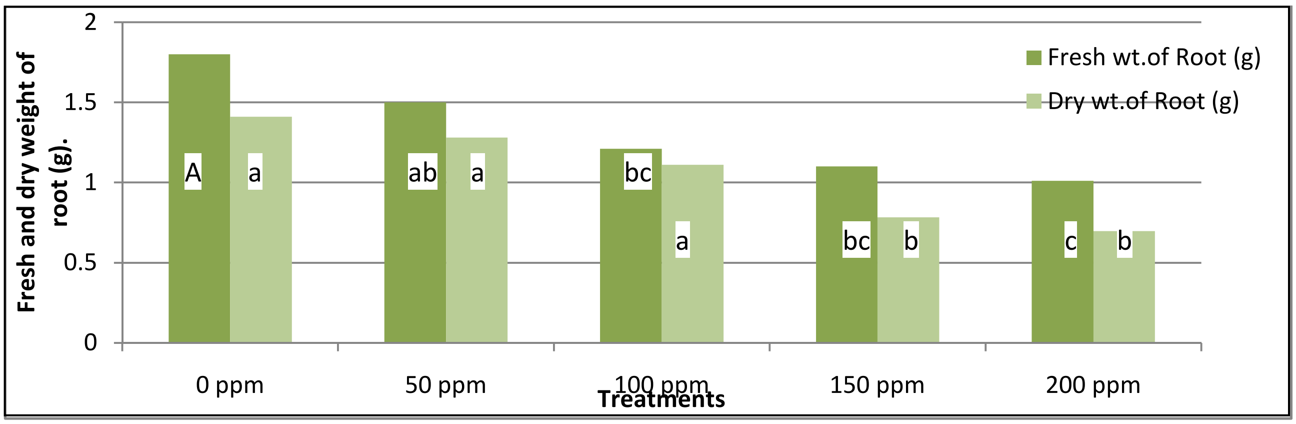


Fig- 28: Effects of different doses of Pb on fresh and dry weight of root (g/pot) of wheat (variety: BARI wheat-26).

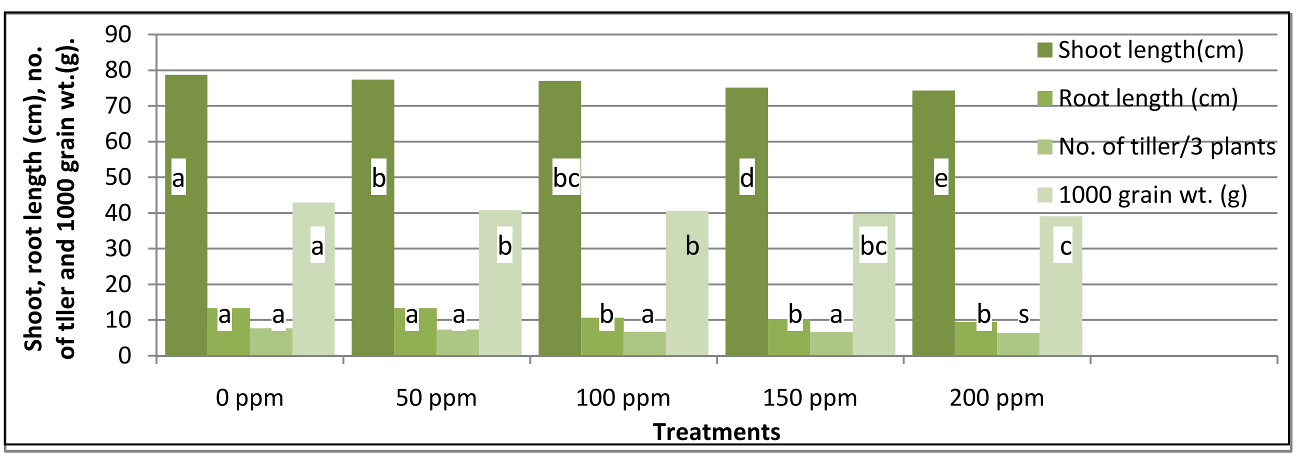


Fig-29: Effects of different doses of Pb on shoot, root length (cm), no. of tiller and 1000 grain wt.(g/pot) of wheat (variety: BARI wheat-26).

4.1.4.6. Nitrogen Concentration

Nitrogen concentrations in root, shoot and grain of wheat (variety: BARI wheat-26) were appreciably different among the treatments (Table-12 and Figure-30). The concentration of nitrogen ranged from 0.512 to 0.643% in root, 0.41 to 0.83% in shoot and 1.21 to 2.02% in grain. In case of root and shoot nitrogen concentration, all treatments differed significantly from each other except T_1, T_2 in case of root and T_2, T_3 in case of shoot. In grain nitrogen concentration, T_4 treatment differed significantly from other treatments but there were no difference among T_0, T_1 T_2, and T_3 treatments, respectively. From the results, it was evident that the higher the concentration of Pb the lower was the concentration of nitrogen in root, shoot and grain of wheat, being the highest with Pb @ 200 ppm which were 20.4, 50.6 and 40.1% lower compared to that of control treatment. The decline in nitrogen concentration due to Pb may be as a result of moisture stress and antagonistic effect created by Pb (Burzynisky and Grabowski, 1984).

4.1.4.7. Phosphorus Concentration

Phosphorus Concentrations in root, shoot and grain of wheat (variety: BARI wheat-26) considerably decreased with higher rates of Pb application in soil (Table-12 and Figure-31). The concentration of phosphorus ranged from 0.071 to 0.127% in root, 0.019 to 0.058% in shoot and 0.210 to 0.466% in grain. The maximum amount of P was found in control (T_0) treatment and the minimum in the T_4 treatment (at 200 ppm of Pb) in case of root, shoot and grain. T_4 treatment differed significantly from all other treatments in both root and shoot phosphorus concentration and other treatments were not significantly different but in case of grain, all treatments differed significantly from each other. From results, it may be concluded that application of lead reduced the concentration of phosphorus in root, shoot and grain of wheat. The higher the concentration of Pb, the lower was the concentration of P. This interference was due to the ability of Pb to form insoluble phosphates in plant tissue. Similar results were found by Lamhamdi *et al.* (2013) with wheat. It is known that lead physically blocks the access of many ions to their absorption sites on the roots (Godbold and Kettner, 1991), thus inhibiting their uptake. Akinci *et al*. (2010) and Paivok (2002) observed a negative correlation between P uptake and lead concentration in the soil.

4.1.4.8. Potassium Concentration

T□e average potassium concentration in grain of wheat (variety: BARI wheat-26) was not significantly affected by Pb application (Table-12 and Figure-31). The concentration of potassium ranged from 0.17 two 0.46% in root, 1.15 to 1.99% in shoot and 0.45 to 0.58% in grain. The maximum concentration of potassium (0.46, 1.99 and 0.58% in root, shoot and grain, respectively) were obtained in the 50 ppm of Pb and control treatment and the minimum concentration (0.17, 1.15 and 0.45% in root, shoot and grain, respectively) in T_4 treatment. K concentration in root, increased at 50 ppm of Pb application then decreased with increasing Pb. Potassium in root, shoot and grain were decreased by 62.2, 42.2 and 22.4%, respectively with the highest rate of Pb (200 ppm) application compared to that with the control. From the data it was evident that application of lead reduced the potassium concentration in root, shoot and grain but in case of grain, the treatments were not statistically significant and increased at 50 ppm of Pb application in root but not significantly different from control treatments. Treatment $T_{0,}$ T_1 was differed significantly from other treatments but there were no differences between $T_{0,}$ T_1 as well as $T_{2,}$ $T_{3,}$ T_4 in case of root K concentration. In shoot, treatment T_4 (200 ppm Pb) was differed significantly from other treatments but there were no differences among $T_{0,}$ $T_{1,}$ T_2 and T_3 treatments, respectively. Shoot accumulated more potassium than root and grain which was also observed in case of rice, probably maintained the mobility and ion balance in shoot. Similar results were also found by Lamhamdi *et al. (*2013) and Batti *et al*. (2013) in wheat.

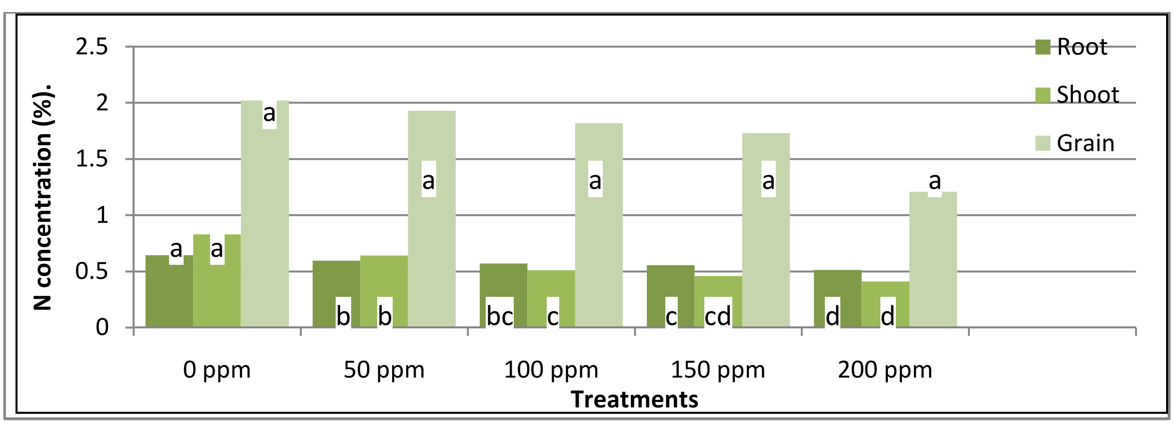


Fig-30: Effects of different doses of Pb on N conc. (%) of root, shoot and grain of wheat (variety: BARI wheat-26)

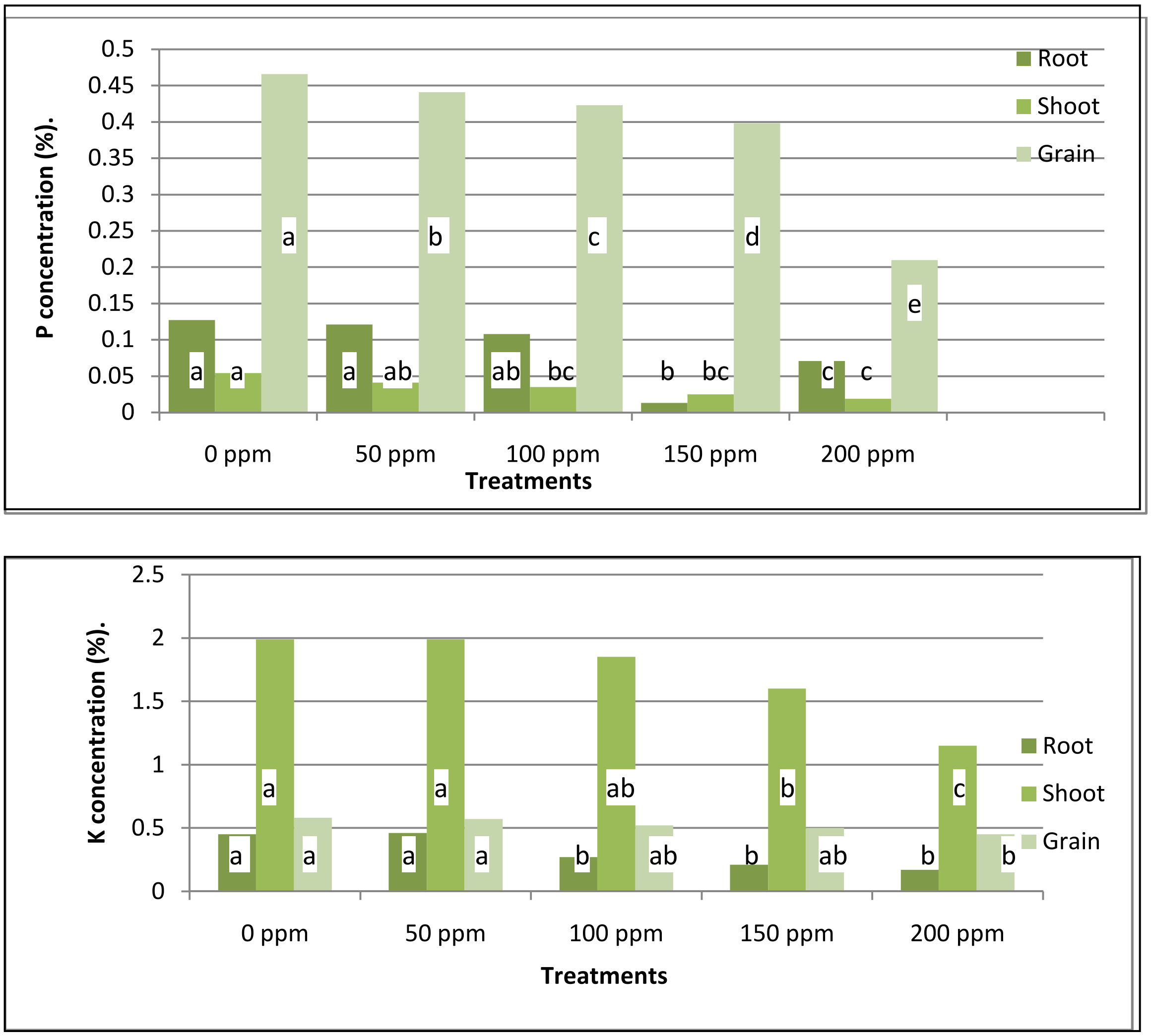


Fig-31: Effects of different doses of Pb on P and K conc. (%) of root, shoot and grain of wheat (variety: BARI wheat-26)

4.1.4.9. Calcium Concentration

Results presented in Table-12 and Figure-32 showed that the effects of different levels of lead on calcium concentration of wheat (variety: Bari wheat-29) root, shoot and grain. The concentration of calcium ranged from 0.51 to 0.79% in root, 0.38 to 0.53% in shoot and 0.018 to 0.028% in grain. The maximum calcium concentration in (0.79, 0.53 and 0.028% in root, shoot and grain, respectively) was noted in the control treatment and the minimum concentration (0.51, 0.38 and 0.018% in root, shoot and grain of wheat) in T_4 treatment. Treatment T_4 was significantly different from T_0, T_1 treatments but there were no significant differences among T_0, T_1 as well as T_2 and T_3 treatments, respectively in case of root. In shoot, there were no significant differences among all treatments though calcium concentration decreased with increasing Pb concentrations. Treatment T_3 and T_4 was significantly different from T_0, T_1, T_2 treatments but there were no significant differences among T_0, T_1, T_2 as well as T_3 and T_4 treatments, respectively in case of grain Ca concentration. From the result it may be concluded that application of lead reduced the concentration of calcium in root, shoot and grain of wheat though all treatments were not statistically different and Ca concentration decreased by 35.4, 28.3 and 35.7% in root, shoot and grain at the highest rate of Pb application (200 ppm) over that with the control. This 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) and reported that high lead concentrations in culture media caused a reduction of Ca concentration in wheat.

4.1.4.10. Magnesium Concentration

The magnesium concentration in root, shoot and grain of wheat (variety: BARI wheat-26) decreased significantly with increasing rate of Pb application showing a negative relation between Pb and Mg (Table-12 and Figure-32). The concentration of magnesium ranged from 0.122 to 0.192 % in root, 0.71 to 0.091% in shoot and 0.070 to 0.093% in grain. The maximum concentration of magnesium (0.192, 0.091 and 0.093% in root, shoot and grain of wheat respectively) was noted in the T_0 treatment whose effect was statistically similar to T_1 treatment in root and T_1, T_2 in grain. The minimum concentration (0.122, 0.071 and 0.070% in root, shoot and grain of wheat, respectively) in T_4 treatment. Treatments T_2, T_3 and T_4 were not differed significantly from each other both in case of root and grain Mg concentration but in case of shoot Mg concentration, all treatments were differed significantly from each other. From the results, it was evident that the higher the concentration of Pb, the lower was the concentration of magnesium in root, shoot and grain of wheat and this might be due to antagonistic effects of Pb with that nutrient. Similar results were also found by Lamhamdi *et al.* (2013) and reported that high lead concentrations in culture media caused a reduction of Mg concentration in wheat.

4.1.4.11. Lead Concentration

There was a lot of variation in the lead concentration of wheat (variety: BARI wheat-26) root, shoot and grain due to application of different levels of lead (Table-12 and Figure-32). The concentration of lead ranged from 54.86 to 647.8 ppm in root, 19.0 to 54.0 ppm in shoot and 6.72 to 35.67 ppm in grain. The highest concentration of lead was noted at 200 ppm of Pb-treated plants, which was differed significantly from all other treatments and the lowest was in the control treatment. In case of root Pb concentration, all treatments differed significantly from each other but in case of shoot, there were no differences between $T_{0,}$ T_1 as well as $T_{2,}$ T_3 treatments respectively. In case of grain, there was no difference between $T_{0,}$ T_1 as well as T_3 and T_4 treatments. Increasing Pb concentration in soil caused an increase in Pb concentration in root, shoot and grain of wheat. 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) and in tomato (Akinci *et al.,* 2010). Du *et al*. (2010) reported that the concentrations of Pb in both shoot and roots increase 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. Saini *et al*. (2001) reported that grain, straw and root Pb concentration of wheat increased significantly from 0.19 to 6.23, 2.11 to 11.17 and 4.96 to 21.76 $\mu g\ g^{-1}$ when Pb levels were raised from 0 to 80 mg kg^{-1} soil, irrespective of the soil texture.

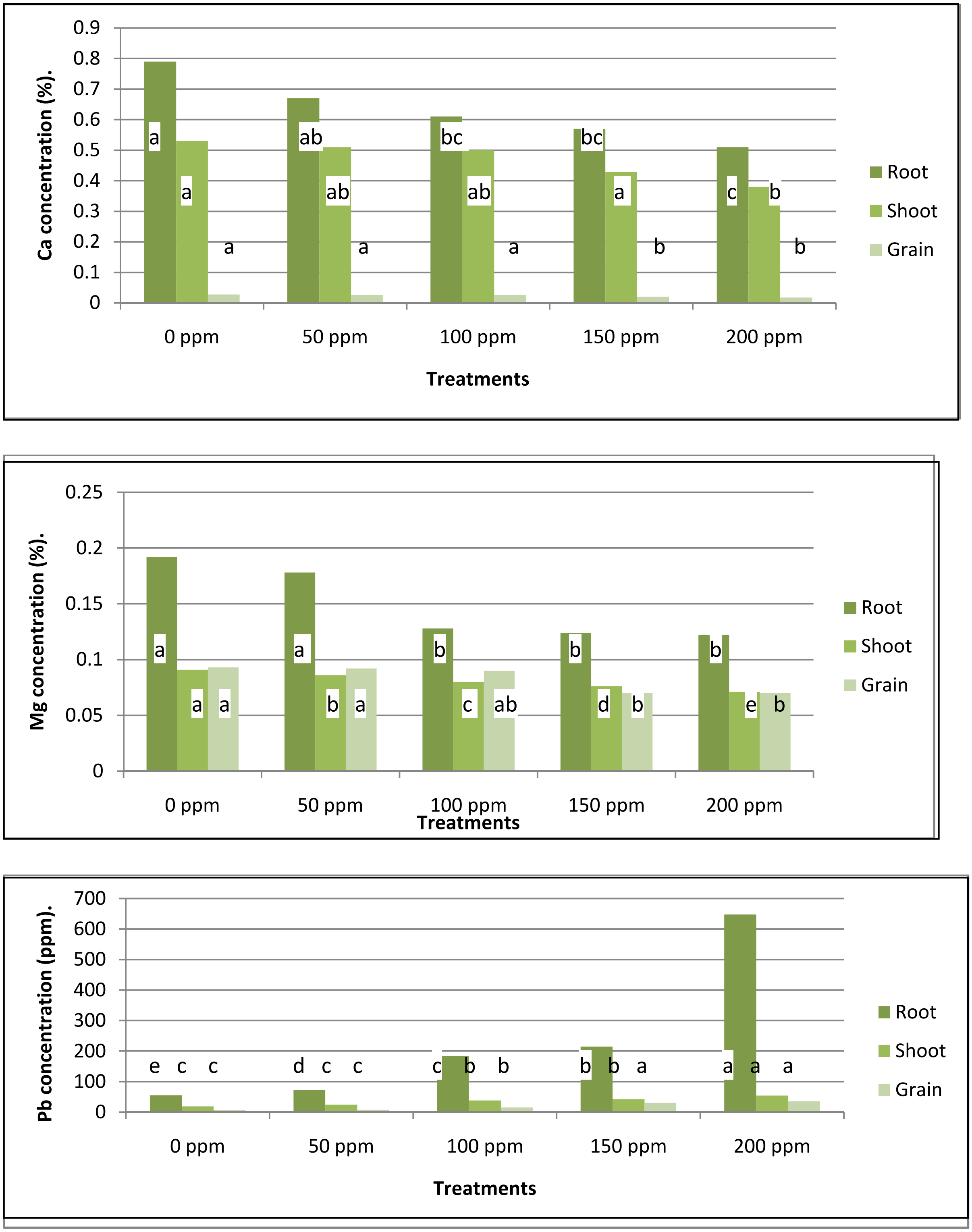


Fig-32: Effects of different doses of Pb on Ca, Mg (%) and Pb conc. (ppm) of root, shoot and grain of wheat (variety: BARI wheat-26).

4.1.5. Experiment-5: Growth, yield and mineral nutrition of wheat (variety: Bari wheat-26), influenced by different amendments

4.1.5.1: Fresh and dry weight of grain

Results presented in Table-13 and Figure-33 showed that the effect of amendments along with and without lead on fresh and dry weight of grain (g pot^{-1}) in wheat (variety: BARI wheat-26) was varied appreciably. The fresh weight of grain yields was 10.70, 10.48, 14.56, 14.56, 12.26 g/pot and dry wt. of grain was 9.81, 9.10, 13.28, 12.01, 11.2 g/pot in the control, 100 ppm of Pb, 100 ppm of Pb with cowdung, poultry litter and lime treated pots respectively. The fresh wt. of grains was the highest in the pots receiving cowdung and poultry litter followed by lime, control and 100 ppm Pb treated pots. Grain yields (FW) at cowdung and poultry litter treated pots were 36.1% higher than control and 38.9% higher than 100 ppm lead treated pot. All amendments increased significantly both fresh and dry wt. of grain compared with control and 100 ppm Pb treated pot but there were no significant difference among the amendments. This might be due to restricted solubility of Pb by amendments and consequently increase the yield of grain. Nuruzzaman (1995) observed that dry matter yield of wheat grain increased by 52% in the 40 mt cowdung/ha and 41% in the 40 mt/ha water hyacinth treatments. Better performance was observed in cowdung treatments. 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) (Schnitzer and Khan, 1978; Vaughan and Malcolm, 1985). Application of FYM enhanced grain yield by 20.5 and 11.0% in sandy and clay loam soil respectively, as compared with no manure (Saini *et al*., 2001).

4.1.5.2: Fresh and dry weight (g) of shoot

There was a variation in the fresh and dry weight of shoot (g pot^{-1}) of wheat (variety: BARI wheat-26) due to application of amendments along with 100 ppm of Pb (Table-13 and figure-33). Application of Pb decreased shoot growth (both fresh and dry) and was influenced by the organic materials. In case of dry wt. of shoot, cowdung and poultry litter treated pots along with 100 ppm Pb treatment increased by 25.3 and 20.4% compared with the control and 26.4, 21.4% compared with 100 ppm Pb treatment. Cowdung and poultry litter treated pot differed significantly from control and 100 ppm Pb treatment and were found to be the most efficient ameliorators of Pb-toxicity with respect to fresh and dry weight of shoot (g pot^{-1}). The reduction of dry matter production of onion, potatoes, cabbage and lettuce plants by Pb and Ni toxicity was also reported by Patrick *et al.* (1981). Saini *et al*. (2001) reported that application of FYM enhanced straw yield by 15.2 and 5.7% in sandy and clay loam soil respectively, as compared with no manure. Nuruzzaman (1995) reported that dry matter yield of wheat shoot increased by 33% in the 40 mt cowdung/ha and 23% in the 40 mt/ha water hyacinth treatments and are statistically significant. Chamon *et al.* (2006) repotted that fresh and dry weight of shoot of wheat was enhanced by 24 and 38% in lime treated pot than unlimed pot with contaminated soil.

4.1.5.3: Fresh and dry weight (g) of root

Root biomass production was also notably influenced by the amendments (Table-13 and figure-34). The highest dry weight of root was observed in cowdung (2.06 g/pot), followed by lime and poultry litter treatment and it was significantly different from the 100 ppm Pb treatment and lowest in100 ppm Pb (1.11g/pot) treatment. Cowdung, lime and poultry litter treatment increased by 85.6, 5.4 and 2.7% dry wt. of root compared with 100 ppm treatment. There was no significant difference among the treatments in case of fresh weight of root though cowdung, poultry litter and lime treatments increased the root biomass production. The result indicated that root biomass production decreased with addition of lead, but increased by the application of cowdung, lime and poultry litter along with 100 ppm of Pb. Saini *et al*. (2001) reported that application of FYM enhanced root weight by 22.1 and 8.4% in sandy and clay loam soil respectively, as compared with no manure.

4.1.5.4: Shoot, root length (cm) and 1000 grain wt. (g)

The length of shoot, root and 1000 grain wt. of wheat (variety: BARI wheat-26) was considerably affected by different amendments (Table-13 and figure-35). The highest shoot and root length (80.50 and 15.33 cm) were observed in cowdung treatment followed by poultry litter and lime but in case of 1000 grain weight, the highest (46.43 g/pot) was noted in lime treatment followed by cowdung, poultry litter and were significantly different from other treatments. Shoot length in cowdung treatment was 2.3% higher than control and 4.1% higher than 100 ppm Pb treated pots respectively and it was significantly different from control and 100 ppm Pb treated pot. In case of root length, cowdung and poultry litter treatment increased the length and lime treatment decreased compared with the control. 1000 grain wt. of wheat in lime, cowdung and poultry litter treatment was 8.2, 1.4 and 0.6% higher than the control and 14.4, 7.2 and 6.4% higher than 100 ppm Pb treated pots respectively. Reduction in shoot and root length due to heavy metal toxicity was reported previously (Gerzabek and Ullah, 1990; Ullah and Gerzabek, 1991; Mondol, 1995). Chamon *et al.* (2006b) reported that shoot length of wheat was significantly higher by 39% in limed pot than unlimed pots with contaminated soil.

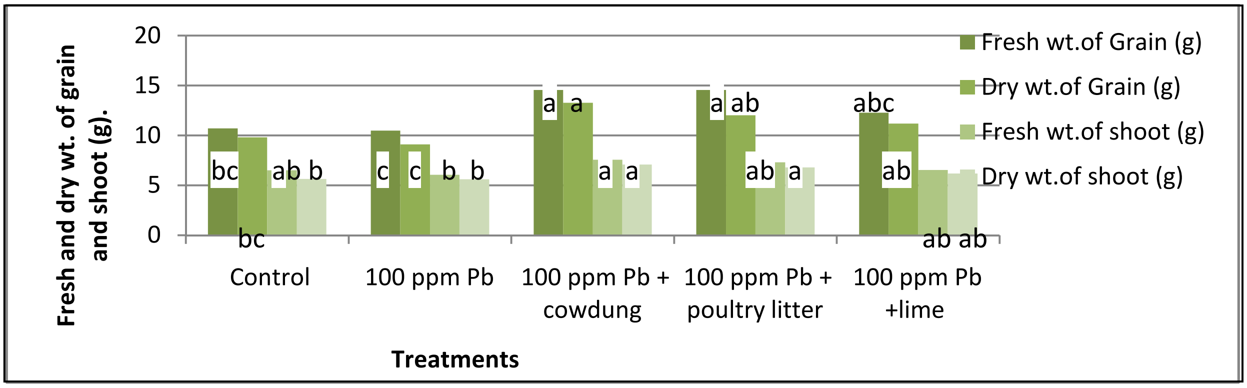


Fig-33: Effects of different amendments on fresh and dry wt. of grain and shoot (g/pot) of wheat.

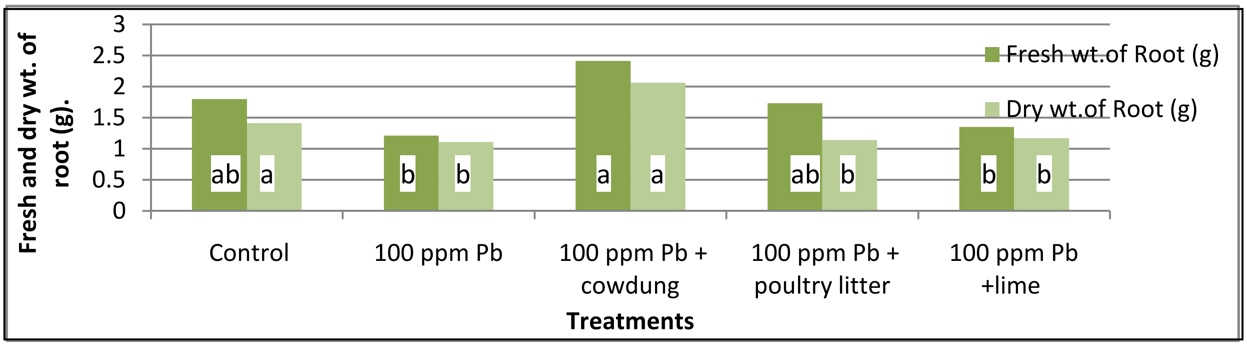


Fig-34: Effects of different amendments on fresh and dry wt. of root (g/pot) of wheat (variety: BARI wheat-26)

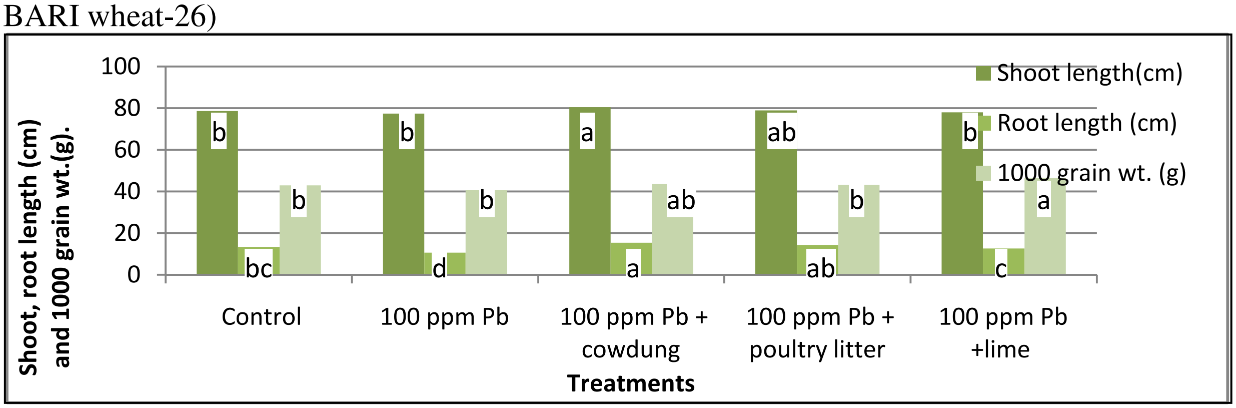


Fig-35: Effects of different amendments on shoot, root length (cm) and 1000 grain wt. (g/pot) of wheat (variety: BARI wheat-26).

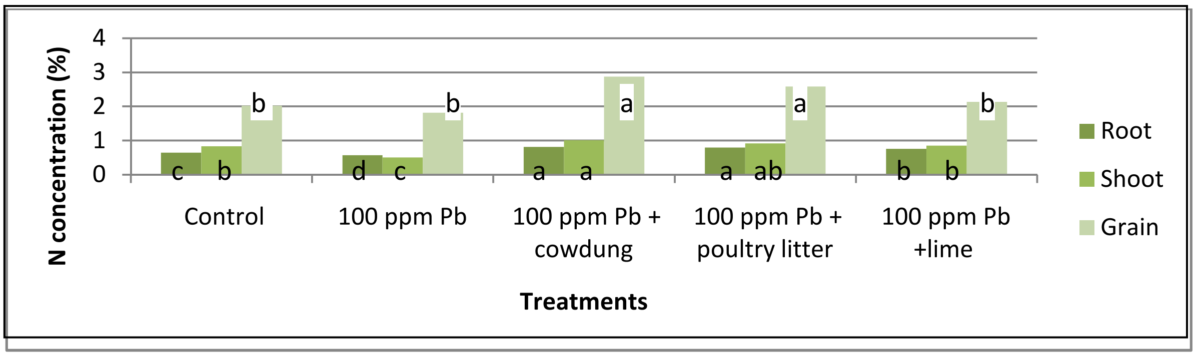
4.1.5.5: Nitrogen Concentration

Nitrogen concentrations in root, shoot and grain of wheat (variety: BARI wheat-26) varied significantly with treatments, the highest being observed in cowdung treated pots followed by the poultry litter and lime added treatments (Table-14 and Figure-36). There were no differences between cowdung and poultry litter treated pots but these treatments differed significantly from the other treatments in case of root, shoot and grain of wheat. Application of 100 ppm of Pb decreased N concentration by 11.4, 38.9 and 9.9% in root, shoot and grain compared with the control but 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, compared with the 100 ppm of Pb treatment. Nurruzzaman (1995) reported that application of cowdung in the polluted soil increased slightly nitrogen concentration of wheat crop but the effect was not significant. Chamon *et al.* (2005a) also reported that application of cowdung and waterhyacinth in soil enhanced the N contents in wheat.

4.1.5.6: Phosphorus Concentration

The lime amendment decreased phosphorus concentrations in grains of wheat (variety: BARI wheat-26) (Table-14 and Figure-36), while nitrogen concentrations in grains were increased by 14.2 and 1.1% in cowdung and poultry litter treatments compared with control and 25.8 and 11.3% compared with only 100 ppm of Pb treatments. All treatments differed significantly from each other in both case of root and grain. Cowdung, poultry litter and lime treatment increased phosphorus concentration in root and shoot of wheat which was significantly differed from control and 100 ppm Pb treated pots in case of root but in shoot there were no difference between control and lime as well as cowdung and poultry litter treatments. From the results it may be concluded that application of Pb significantly reduced the concentration of phosphorus in root, shoot and grain. Amongst soil amendments cowdung and poultry litter had greater ability to enhance phosphorus concentration against Pb toxicity. Similar findings were also reported by Muchrimsyah and Mercado (1990). Due to adverse or antagonistic effect of Pb, the uptake of P by rice and other plants decreased significantly. Nurruzzaman (1995) reported that application of cowdung in the polluted soil increased phosphorus concentration of wheat crop but the effect was not significant. Chamon *et al.* (2005a) also reported that application of cowdung and waterhyacinth in soil enhanced the P contents in wheat.

4.1.5.7: Potassium Concentration: The different treatments diverse the concentrations of potassium in wheat root, shoot and grains (Table-14 and Figure-37). Application of Pb decreased potassium concentration in root, shoot and grain of wheat. Among amendments, the highest potassium concentration being observed in cowdung followed by poultry litter and lime treated pots but there were no significant differences among the three amendments in root, cowdung and poultry litter in shoot, poultry litter and lime in grains. Shoot accumulated more potassium than root and grain which was also observed in case of rice. Nuruzzuman (1995) observed that application of cowdung in the polluted soil increased slightly the potassium contents in wheat but the effect was not significantly different. Chamon *et al.* (2005a) also reported that application of cowdung and waterhyacinth in soil enhanced the K contents in wheat.



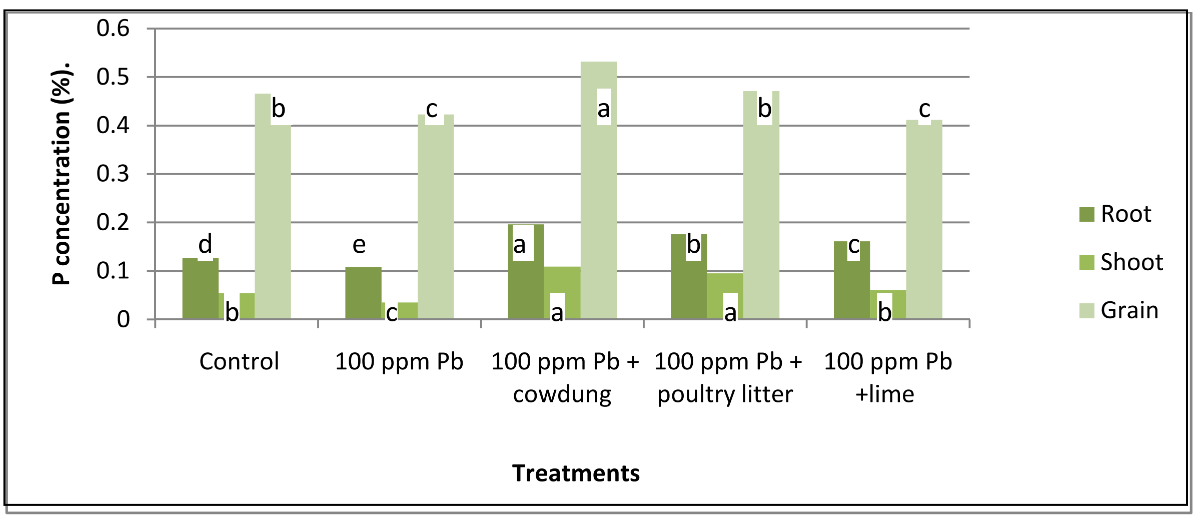


Fig-36: Effects of different amendments on N, P conc. (%) of root, shoot and grain of wheat (variety: BARI wheat-26).

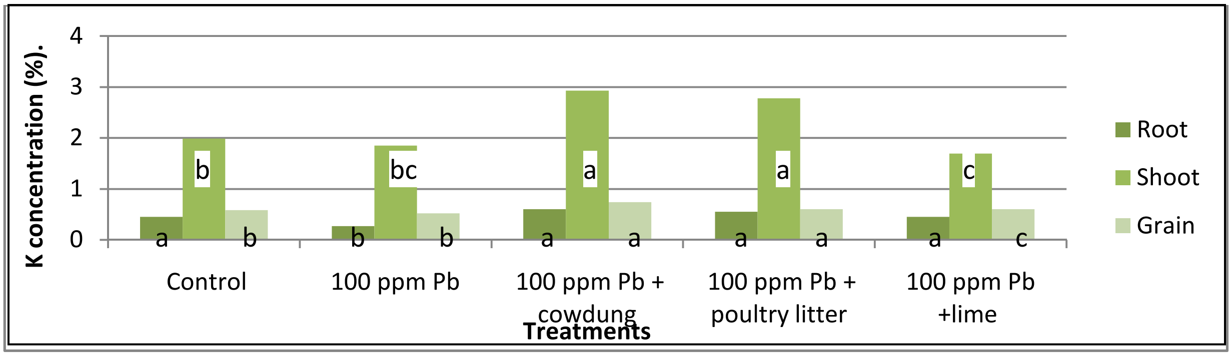


Fig-37: Effects of different amendments on K conc. (%) of root, shoot and grain of wheat (variety: BARI wheat-26).

4.1.5.8: Calcium Concentration

Calcium concentration was only influenced by liming which differed significantly from other treatment in case of root, shoot and grains of wheat (Table-14 and figure-38). Application of only 100 ppm of Pb treatment reduced the calcium concentration in root, shoot and grain as compared with the control. 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 ppm of Pb treatment and was differed significantly from other treatments. This might be due to increase soil pH by liming and thus reduce the mobility of Pb and increased calcium concentration. Cowdung and poultry litter amendment increased Ca concentration in root and shoot of wheat but decreased in case of grain as compared with the control. 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.

4.1.5.9: Magnesium Concentration

Magnesium concentrations in wheat root and shoot differed significantly with amendments but grain magnesium concentrations did not differed significantly (Table-14 and Figure-38). Application of Pb decreased by 33.3, 12.1 and 3.2% magnesium concentration of wheat root, shoot and grain compared with control treatment. The highest concentration of Mg was observed in cowdung treatment (0.243%) followed by poultry litter and lime amendments in root which themselves differed significantly. In case of shoot, cowdung and poultry litter decreased by 12.1 and 3.3% and lime increased by 4.4% Mg concentration compared with the control and 8.8, 10.0

and 18.8% increased, in cowdung, poultry litter and lime treatments compared with 100 ppm Pb treatment. There were no significant differences among the treatments in case of grains Mg concentration of wheat.

4.1.5.10: Lead Concentration

There was significant variation in lead concentration of wheat (variety: BARI wheat-26) root, shoot and grain among the different treatments (Table-14 and Figure-38). Application of 100 ppm of Pb significantly increased the Pb concentration of wheat root, shoot and grain compared with the control treatment. Lead concentration in root ranged between 54.87 to 117.5 ppm which was above the critical levels in roots (Table-31). The highest being reduced in Pb concentration in cowdung followed by lime and poultry litter in root, shoot and grain of wheat. Pb concentrations in all treatment differed significantly from each other in case of root but in case of shoot Pb concentrations, there were no significant differences among the amendments and in case of grain, there were no significant differences between control and cowdung as well as poultry litter and lime treatments. From the results it may be concluded that application of lead significantly increased the concentration of Pb in root, shoot and grain of wheat. All amendments decreased Pb concentration in wheat. Amongst amendments cowdung had the greater ability to reduce Pb toxicity in root, shoot and grain and then lime and poultry litter which was also observed in case of rice plant. This might be due to complexes or chelated by organic matter with Pb. Thus, the addition of organic matter to contaminated soil may be decrease the concentration of metal in solution and decrease their leachability (Brown, 1997). Similar results were also observed by many investigators. Judel *et al.* (1977) stated that low doses of highly soluble lead acetate increased the Pb content in plant. Madrid *et al.* (1999) reported 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. Saini *et al*. (2001) also reported that grain, straw and root Pb concentration increased significantly from 0.19 to 6.23, 2.11 to 11.17 and 4.96 to 21.76 µg g^{-1} when Pb levels were raised from 0 to 80 mg kg^{-1} soil, irrespective of the soil texture. Addition of FYM @ 1% decreased Pb concentration by 18.3 and 18.2% in grain 14.2 and 7.1% in straw and 5.3 and 6.6% in roots when grown in sandy and clay loam soil, respectively. Lagerwerff (1972) observed that soil organic matter strongly adsorbed the heavy metals and helped in formation of insoluble organo-metal complexes, suggested a possibility. Chamon *et al.* (2005a) reported that cowdung and poultry litter amendment showed a reduction of Pb content. The addition of lime has been shown to decrease the availability of Pb to plants due to the decreased solubility of Pb carbonates (Zimdahl and Skogerboe, 1977). 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). Davis and Coker (1980) reported that the availability of trace elements to plants is generally target at low pH than at high pH, and the effect of an increase in soil pH value, by liming of soil, is a reduction in metal absorption by plants.

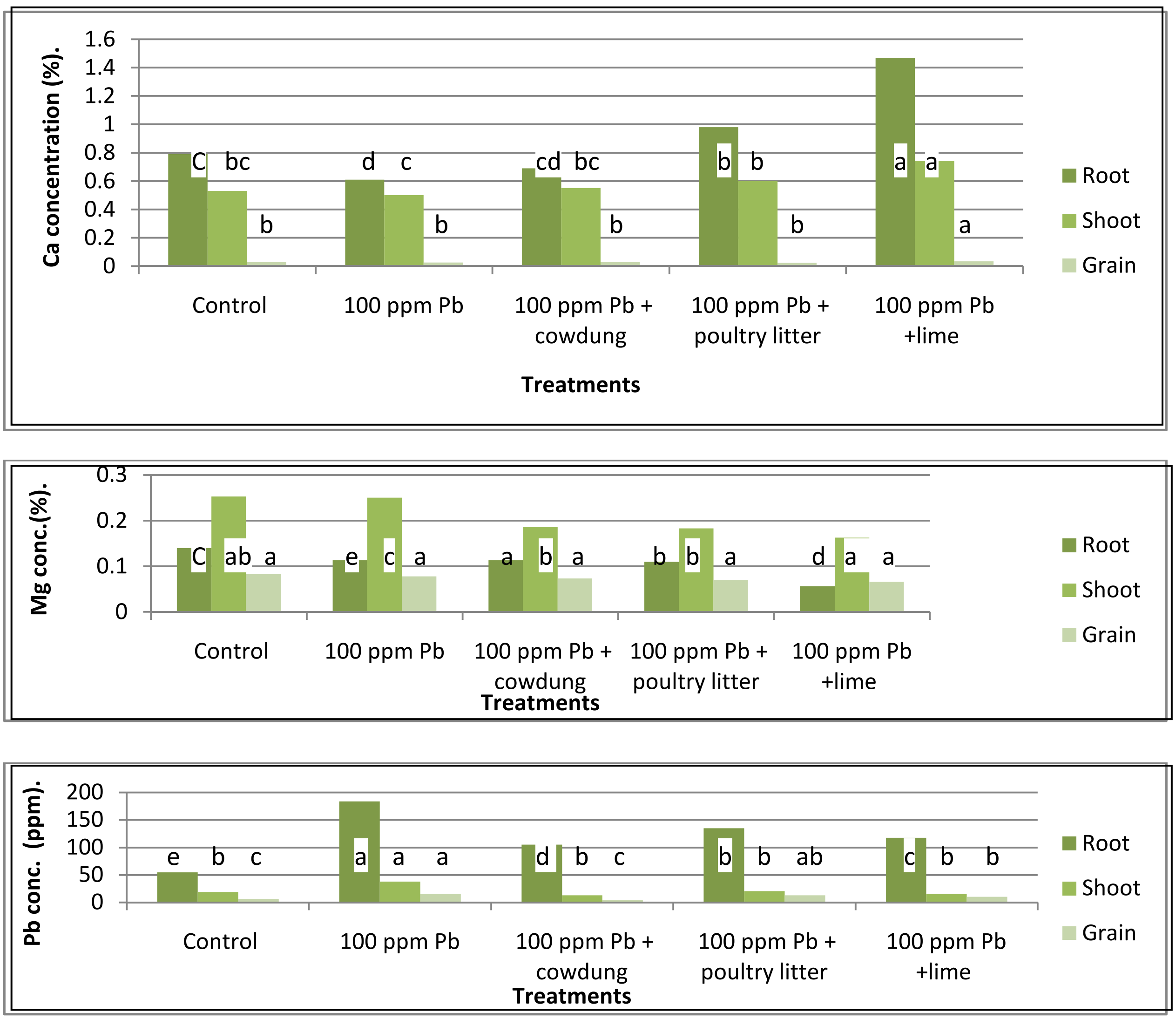


Fig-38: Effects of different amendments on Ca, Mg (%) and Pb conc. (ppm) of root, shoot and grain of wheat (variety: BARI wheat-26).

4.1.6: Experiment-6: Growth, yield and mineral nutrition of different varieties of wheat grown on soils contaminated with 200 ppm of Pb.

Significant differences in growth and mineral nutrition among different wheat varieties grown on soils contaminated with 200 ppm of Pb were observed and it is discussed here:

4.1.6.1: Fresh and dry weight of grain (g)

The wheat varieties treated with 200 ppm of Pb showed significant differences on grain yield production (Table-15 and Figure-39). The highest fresh and dry weight of wheat grain (12.31 and 11.41 g/pot) was obtained in variety V_1 (Shotabdi) and the lowest (9.12 and 7.50 g/pot) was obtained in the variety V_3 (BARI wheat-26). There were no significant differences in fresh weight of grains among the varieties. In case of dry wt. of grain, V_3 (BARI wheat-26) differed significantly from other varieties but there were no significant differences between V_1 and V_2 varieties. Comparison among Pb stressed wheat varieties, it was evident that V_1 (Shotabdi) variety showed better tolerance against Pb toxicity in comparison with V_2 and V_3 varieties. Due to differing rates of absorption among the varieties, plants often show wide differences in their growth and yield production (John, 1973; Jarvis and Jones, 1978). Generally the growth rates of different varieties are different (Chino *et al*., 1997). Chamon *et al*. (2006a) reported that the wheat variety: Khanchan exhibited the highest grain yield, followed by Akbar and Agrani.

4.1.6.2: Fresh and dry weight of shoot (g)

Momentous differences in shoot biomass (fresh and dry) production were observed among the three varieties of wheat (Table-15 and Figure-39). Variety V_1 (Shotabdi) exhibited the highest fresh and dry weight (7.86 and 6.93 g/pot) and the lowest (5.01 and 4.51 g/pot) being observed in V_3 (BARI wheat-26) variety and was significantly differed from each other. There were no significant differences between V_1 and V_2 varieties in both cases. From the results it was evident that V_1 (Shotabdi) variety is more tolerant against Pb toxicity and hence a better recovery capacity than V_2 and V_3 varieties. Chamon *et al*. (2006a) reported that the straw biomass of wheat variety: Khanchan was significantly lower on normal soil (Bajitpur soil) than Akbar and Agrani.

4.1.6.3: Fresh and dry weight of root (g)

Wheat varieties with addition of 200 ppm of Pb had different fresh and dry weight of root (Table -15 and Figure-40). Among the three varieties of wheat, variety V_2 (Prodip) exhibited the best root development (2.18 and 1.16 g/pot) in both (fresh and dry) followed by V_1 and V_3. In case of fresh weight of root, V_1, V_2 and V_3 were significantly differed from each other but in case of dry weight of root, V_3 (BARI wheat-26) exhibited the lower than V_1 and V_2 varieties and was significantly differed from other varieties. There were no significant differences between V_1 and V_2 varieties in case of dry weight of root. The results indicated that V_2 (Prodip) variety had better ability to increase fresh and dry weight of root against Pb toxicity. Bhatti *et al*. (2013) reported that Chakwal-97 (wheat variety) has produced only slightly more root fresh weight as compared to Sehar-2006, wheat variety.

4.1.6.4: Shoot and root length (cm)

The mean shoot and root length diversed among the wheat varieties (Table-15 and Figure-41). The highest shoot and root length (78.33 and 15.66 cm) was found in V_1 (Shotabdi) and V_2 (Prodip) varieties and the lowest (74.33 and 9.5 cm) in V_3 (BARI wheat-26) variety. There were no significant differences among the varieties in case of shoot length. However, in root length V_3 (BARI wheat-26) differed significantly from V_1 and V_2 but there were no significant differences between them. Bhatti *et al*. (2013) reported that Chakwal-97 (wheat variety) exhibited higher shoot length values than of Sehar-2006 under the Pb treatments and in case of root length. There was no significant variation in both varieties of wheat. These differences in the results of shoot and root length among the varieties might be due to varietal interferences. Chamon *et al*.(2006a) reported that wheat variety: Kanchan did not show significantly different shoot length on Tejgaon and Bajitpur soil.

4.1.6.5: No. of tiller/3 plant and 1000 grain weight (g)

The No. of tiller/3 plant and 1000 grain weight g/pot of wheat as affected by 200 ppm of Pb presented in Table-15 and Figure-41. The highest number of tiller (7.67) and 1000 grain weight (49.17 g) was found in V_1 (Shotabdi) and was significantly differed from other varieties. The lowest was (5.33 and 39.06 g) in V_2 and V_3 varieties, respectively. There was no significant difference between V_2 and V_3 varieties in both no. of tiller and 1000 grain weight. From the results it was concluded that V_1 (Shotabdi) variety had the highest ability to increase number of tiller/3 plant and 1000 grain weight (g) against Pb toxicity as compared with V_2 and V_3 varieties. Bhatti *et al.* (2013) reported that Chakwal-97 (wheat variety) has only slightly more number of tillers as compared to Sehar-2006 under the Pb treatments and there was least significant variation in both wheat varieties. Chamon *et al*. (2006a) observed the number of tillers was significantly lower on Bajitpur soil, which reflects once again the poor nitrogen status of that soil and also reported that no significant difference in 1000 grain weight occurred among the varieties.

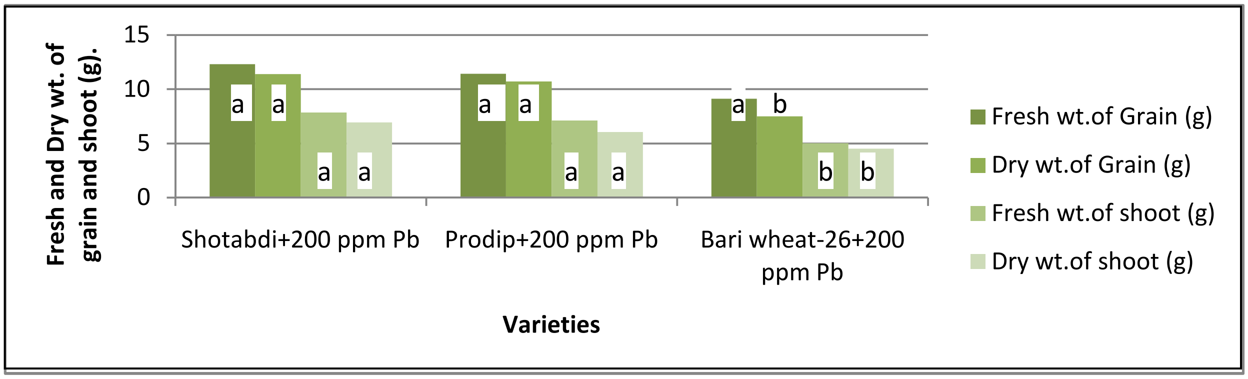


Fig-39: Effects of different varieties of wheat on fresh and dry wt. of grain and shoot (g/pot).

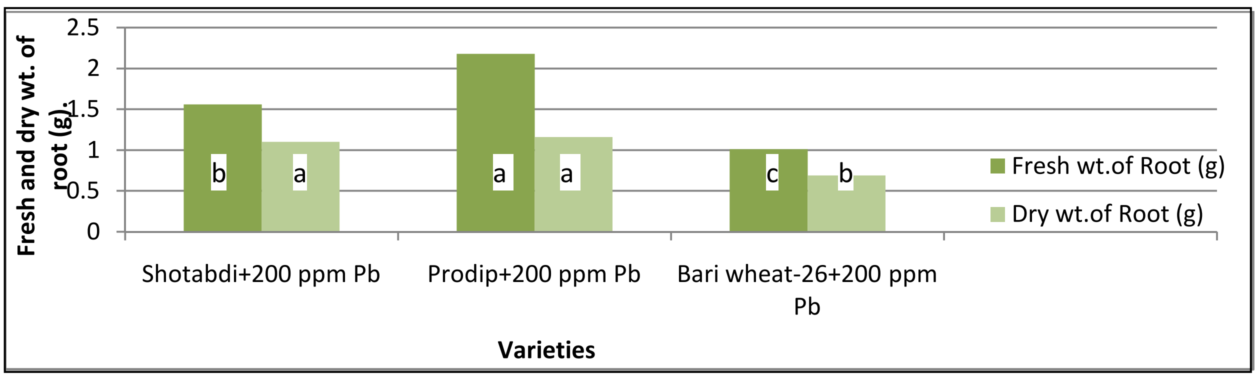


Fig-40: Effects of different varieties of wheat on fresh and dry wt. of root (g/pot).

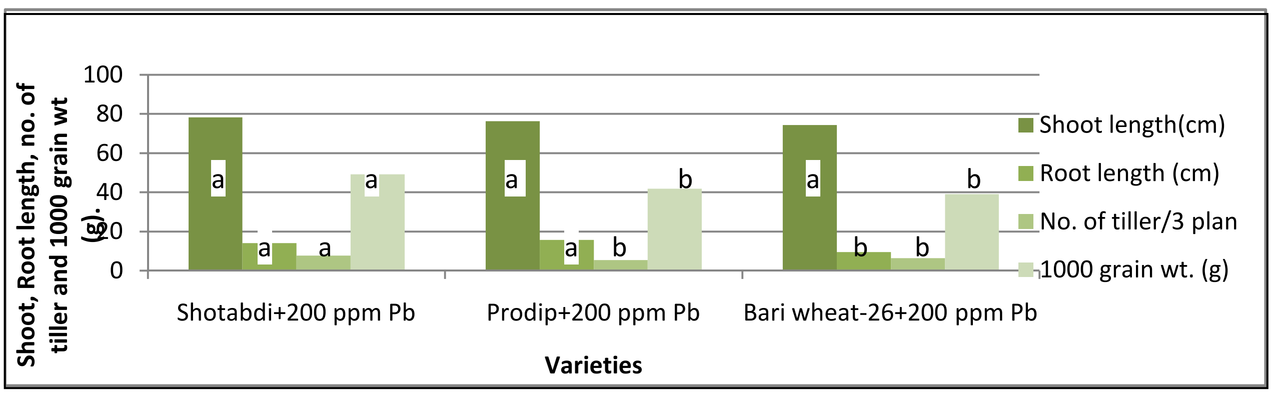


Fig- 41: Effects of different varieties of wheat on shoot, root length (cm), no. of tiller and 1000 grain weight (g/pot).

4.1.6.6: Nitrogen Concentration

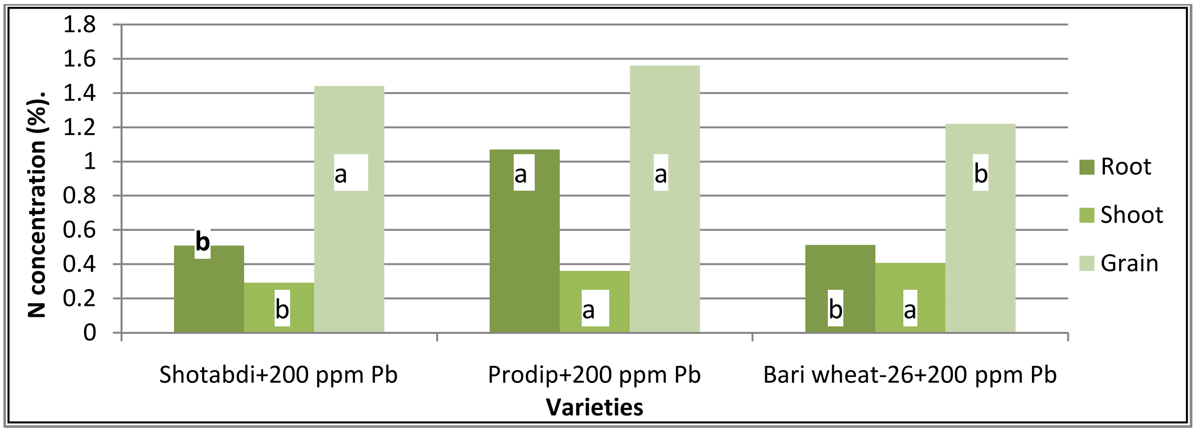
Root, shoot and grain of different wheat varieties showed appreciable differences in nitrogen concentration (Table-16 and Figure-42), the highest being observed in V_2 (Prodip) followed by $V_{3,}$ V_1 and was significantly differed from other varieties in case of root and in grain, V_2 (Prodip) followed by $V_{1,}$ V_3 and in case of shoot V_3 (BARI wheat-26) followed by $V_{2,}$ $V_{1..}$ There was no significant difference between $V_{1,}$ V_3 in root and $V_{2,}$ V_3 in shoot as well as V_1 and V_2 in grain. From the results it was evident that V_2 (Prodip) had greater ability to absorb nitrogen in root and grain and V_3 (BARI wheat-26) in shoot against Pb toxicity than all other varieties.

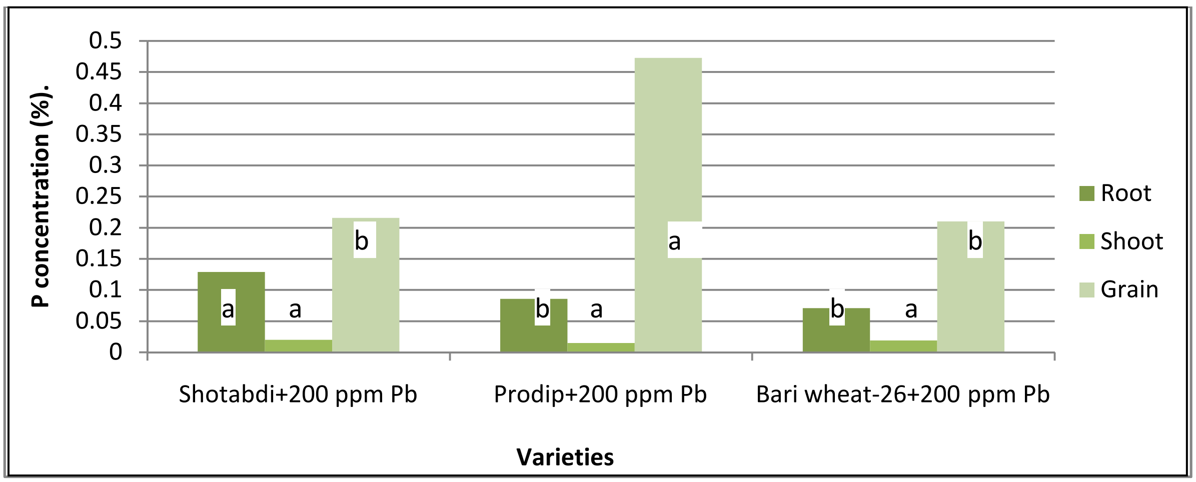
4.1.6.7: Phosphorus Concentration

Root and grains of different wheat varieties showed noteworthy differences in phosphorus concentration (Table-16 and Figure-42). The maximum concentration of phosphorus (0.129, 0.020 and 0.473% in root, shoot and grain, respectively) were obtained in V_1, V_1 and V_2 and the minimum amount (0.071, 0.015 and 0.210% in root, shoot and grain, respectively) at $V_{3,}$ V_2 and $V_{3,}$ respectively. Phosphorus concentration in shoots did not differ significantly among the varieties. In case of root, V_1 was significantly different from other varieties but no significant difference was observed between V_2 and V_3 varieties. In case of grain, V_2 was significantly different from other varieties however; there were no significant difference between V_1 and V_2 varieties. From the results it was observed that variety V_1 (Shotabdi) had greater ability to absorb phosphorus in root and V_2 (Prodip) in grain against Pb toxicity than other varieties.

4.1.6.8: Potassium Concentration

Potassium concentration in shoot and grain of wheat varieties were assorted significantly (Table -16 and Figure-42). Roots of potassium concentration did not differ significantly among the varieties. Variety V_1 (Shotabdi) had the highest potassium concentration in root and shoot followed by $V_{2,}$ $V_{3.}$ In case of grain potassium concentration, the highest being observed in V_3 variety followed by $V_{1,}$ V_2 and V_2 were significantly different from other varieties but there were no significant difference between V_1 and V_3 varieties. From the results it was evident that V_1 (Shotabdi) had greater ability to absorb potassium in root and shoot, while in grain V_3 (BARI wheat-26) had the greatest ability of all the varieties to accumulate K under Pb-stressed condition.





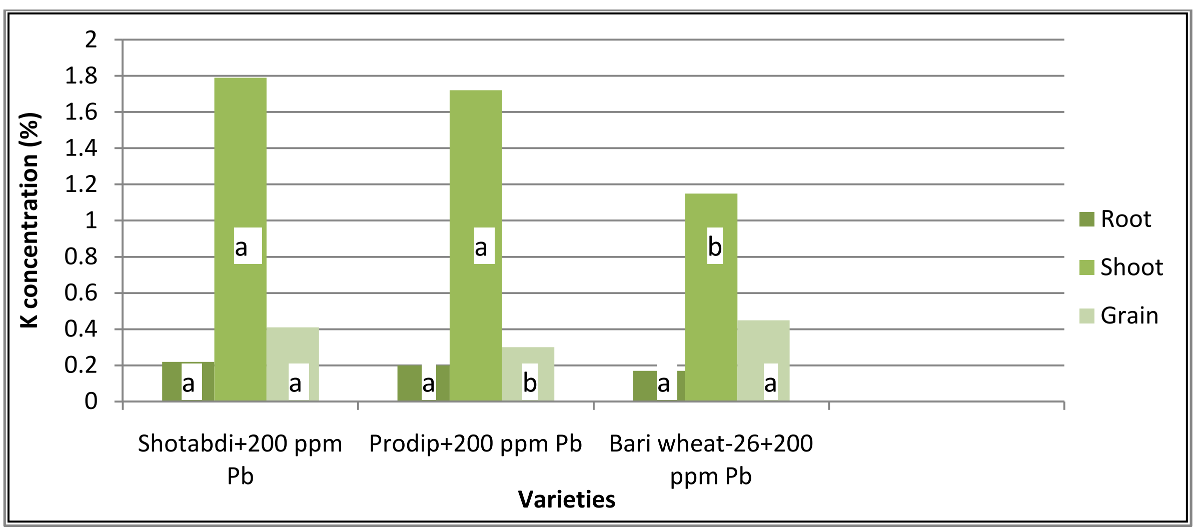


Fig-42: Effects of different varieties of wheat on N, P and K concentration (%) grown on soil contaminated with 200 ppm of Pb.

4.1.6.9: Calcium Concentration

Root, shoot and grain of different wheat varieties with 200 ppm of Pb treatments showed significant variation in Ca concentration (Table-16 and Figure-43). The maximum concentration of calcium (1.12, 0.48 and 0.034% in root, shoot and grain respectively) were found in V_1 (Shotabdi) and were significantly differed from other varieties. The minimum concentration was found (0.50, 0.35 and 0.017% in root, shoot and grain, respectively) in V_2 (Prodip). There was no significant difference between V_2 and V_3 varieties in all cases. From the results it was evident that V_1 (Shotabdi) had greater ability to absorb calcium in root, shoot and grain under Pb-stressed condition.

4.1.6.10: Magnesium Concentration

The wheat varieties have different abilities to take up magnesium under Pb stressed soil (Table-16 and Figure-43). Variety V_1 (Shotabdi) contained the maximum concentration of magnesium (0.190, 0.130 and 0.084% in root, shoot and grain) while the minimum (0.122, 0.070% in root, grain) was observed in V_3 (BARI wheat-26) and 0.11% in shoot was in V_2 variety. There was no significant difference among the varieties in case of shoot. Variety V_3 was significantly different from other varieties in case of root but there were no significant difference between V_1 and V_2 varieties. In case of grain, there was no significant difference between $V_{1,}$ V_2 as well as $V_{2,}$ V_3 varieties respectively. From the results it was evident that V_1 (Shotabdi) exhibited greater ability to absorb magnesium in root, shoot and grain against Pb toxicity than other varieties.

4.1.6.11: Lead Concentration

The Pb concentration in wheat plant differed among varieties (Table-16 and Figure-43). Variety V_3 (BARI wheat-26) contained the maximum amount of Pb (647.00, 54.00 and 35.67 ppm in root, shoot and grain), while the minimum (316.00, 24.00 and 16.00 ppm in root, shoot and grain) was observed in V_1 (Shotabdi). All varieties were significantly differed from each other in case of root, shoot and grain. From the results it was evident that V_1 (Shotabdi) had the ability to withstand Pb stressed soil and concentrate less amount of Pb in root, shoot and grain and hence a better capability to produce root, shoot and grain production and V_3 (BARI wheat-26) variety had a greater ability to absorb Pb in root, shoot and grain under Pb-stressed condition. Because of less Pb mobility in soil, its concentration decreases in the following order: root > shoot > grain. This distribution is due to the mobilization of the protective mechanisms of plants, which inhibits the transport to further tissues and organs. This difference in Pb uptake among wheat varieties could be related to a higher capacity of V_1 (Shotabdi) to resist oxidative stress generated by Pb, as also observed in previous work of Lamhamdi *et al.* (2010). Begonia *et al.* (1998) indicated Indian mustard (*Brassica juncea*) as an effective species in lead remediation because of its great biomass production, but it accumulated 95% of lead in its roots. Chamon *et al*. (2006 b) reported that Pb concentrations were the lowest in Agrani and the highest in Kanchan (wheat variety). Cheng *et al.* (2015) showed that the wheat varieties of Zhengdan 958 and Longping 206 have the maximum Pb tolerance, whereas Lianchuang 5's tolerance of Pb was the minimum. Tolerance of Zhengdan 958 to Pb stress was related to its strong ability to convert toxic Pb into non-toxic Pb.

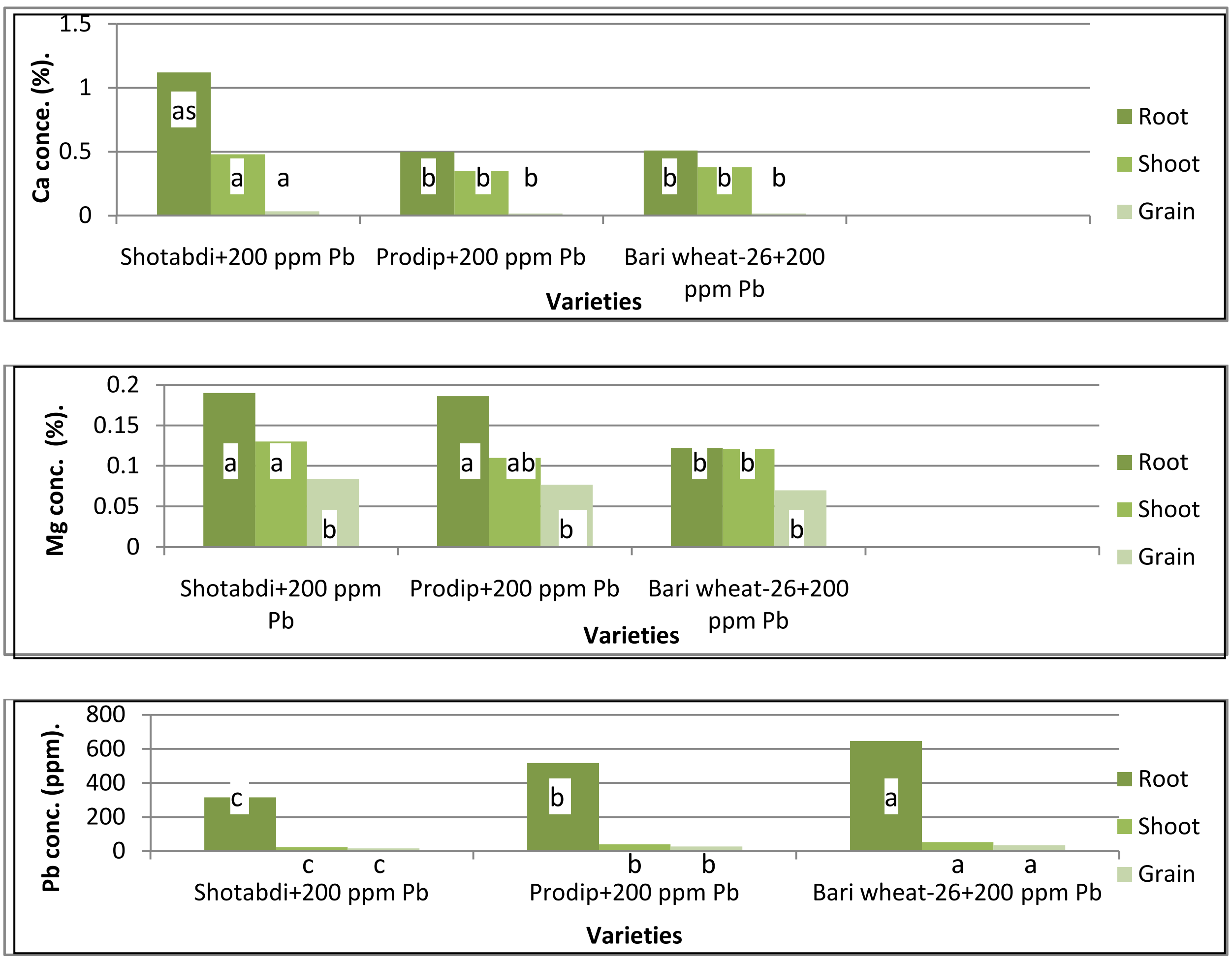


Fig-43: Effects of different varieties of wheat on Ca, Mg (%) and Pb concentration (ppm) grown on soil contaminated with 200 ppm of Pb.

4.1.7. Experiment-7: Maize: Effects of different doses of lead (Pb) on growth, yield and mineral nutrition of Maize (variety: BARI Maize-9)

4.1.7.1. Fresh and dry weight of grain

Different levels of lead applied in soil significantly affect the fresh and dry weight of grain (g/pot) of maize (variety: BARI maize-9) (Table-17 and Figure-44). The highest fresh and dry weight of grains/pot (96.89 and 69.33 g) was obtained in the T_0 treatment where no lead was applied. The lowest value (28.49 and 17.73 g) was in the T_4 treatment (at 200 ppm Pb). A gradual decrease in fresh and dry weight of maize grain was recorded with increasing Pb concentration. However, T_0 treatment differed significantly from $T_{1,}$ $T_{2,}$ T_3 and T_4 treatments but there were no differences among $T_{2,}$ T_3 and T_4 treatments in both fresh and dry weight (g/pot) of grain. At the highest dose of Pb application (200 ppm Pb), fresh and dry weight of grain decreased by 70.6 and 74.4% respectively, compared with that of the control treatment. At high Pb contents in soils, photosynthesis can also decrease due to both a lower carboxylase activity and the effects on metabolites of the carbon reduction cycle. As a result, the effect of Pb is to decrease plant growth and development (Stiborova *et al.,* 1987). Such growth retardation was due to metals toxicity that resulted in damages to various physiological and biochemical processes (Hussain, 2013).

4.1.7.2. Fresh and dry weight (g) of shoot

Exposure of maize variety to Pb stress resulted in a significant fresh weight of shoot inhibition though dry weight of shoot was not differed significantly (Table-17 and figure-44). The maximum fresh and dry weight of shoot pot^{-1} was 75.35 and 36.44 g obtained in the control treatment where no lead was applied. The lowest value was 45.0 and 26.0 g in the treatment T_4 (at 200 ppm Pb). The fresh and dry weight of shoot pot^{-1} was decreased with increasing Pb concentration and followed the sequence of $T_0>T_1>T_2>T_3>T_{4.}$ At the highest dose of Pb (200 ppm), fresh weight of shoot decreased by 40.3% compared with control and $T_{0,}$ $T_{1,}$ T_2 treatments were differed significantly from T_3 and T_4 treatments but there were no significant differences among $T_{0,}$ $T_{1,}$ T_2 as well as T_3 and T_4 treatments, respectively. However, in dry weight of shoot, treatments were not differed significantly though dry weight of shoot pot^{-1} was decreased with increasing Pb concentration. The higher the concentration of Pb the lower was the fresh and dry weight of maize shoot. The reduction of biomass by Pb toxicity could be the direct consequences of the inhibition of chlorophyll synthesis and photosynthesis (Chitterjee *et al.,* 2004). Similar phenomena were also described by Huang and Cunningham (1996) in corn and ragweed. Kopittke *et al*. (2007a) reported that relative fresh mass of cowpea (*Vigna unguiculata*) decreased by 10% for the shoots. In tomato seedlings, fresh and dry biomass of shoots was negatively affected by increasing Pb concentrations (Akinci *et al*., 2010). Shoot fresh and dry weight of *Zea Mays* was decreased by the increased concentrations of Pb (Hussain *et al.,* 2013).

Such growth retardation was due to metals toxicity that resulted in damages to various physiological and biochemical processes.

4.1.7.3. Fresh and dry weight (g) of root

The fresh and dry weight of root pot^{-1} (g) of maize (variety: BARI maize-9) was significantly affected by Pb application (Table-17 and figure-45). The highest fresh and dry weight of root pot^{-1} was 31.32 and 8.12 g in the T_0 treatments where no lead was applied. The lowest 14.40 and 3.33g was obtained in the T_4 treatment, at 200 ppm Pb. Fresh and dry weight of root was decreased significantly with increasing Pb concentration but there were no significant difference between T_0, T_1 as well as T_2, T_3, T_4 treatments in both cases. At the highest dose of Pb application (200 ppm Pb), fresh and dry weight of root decreased by 54.0 and 59.0% respectively, compared with that of the control. In agreement with the present study, Huang and Cunningham (1996) reported that increasing Pb concentration significantly decreased root weight of corn and ragweed. Similarly, in tomato seedlings, fresh and dry biomass of root was negatively affected by increasing Pb concentrations (Akinci *et al*., 2010) and in *Zea mays* by (Hussain *et al.,* 2013).

4.1.7.4. Shoot and root length (cm) and 1000 grain weight

The length of shoot, 1000 grain weight of maize (variety: BARI maize-9) were significantly affected by Pb application whereas the effect of Pb on root length was not significant (Table-17 and figure-46). The maximum and the minimum length of shoot, root and 1000 grain weight were obtained in T_0 (control) and T_4 (200 ppm of Pb) treatments. In case of length of shoot T_0 significantly different from other treatments but there were no significant differences between T_1, T_2 treatments as well as T_3, T_4 treatments respectively. In case of root length, there was no significant difference among the treatments though application of Pb decreased the root length. However, in case of 1000 grains weight, treatments T_0, T_1 and T_4 significantly differed from each other but there were no differences between T_2 and T_3 treatments. The above results indicated that the length of shoot, root and 1000 grain weight of maize declined with increasing level of Pb. This reduction of height might be attributed to the toxic effect of heavy metal present in them (McCalla *et al.,* 1977). Similar results also observed by Ghani (2010) and Hussain *et al.* (2013). Dmitrij *et al.* (2005) reported that low heavy metal concentrations had a tendency to increase root length though high amount resulted in root growth inhibition as compared to control plants.

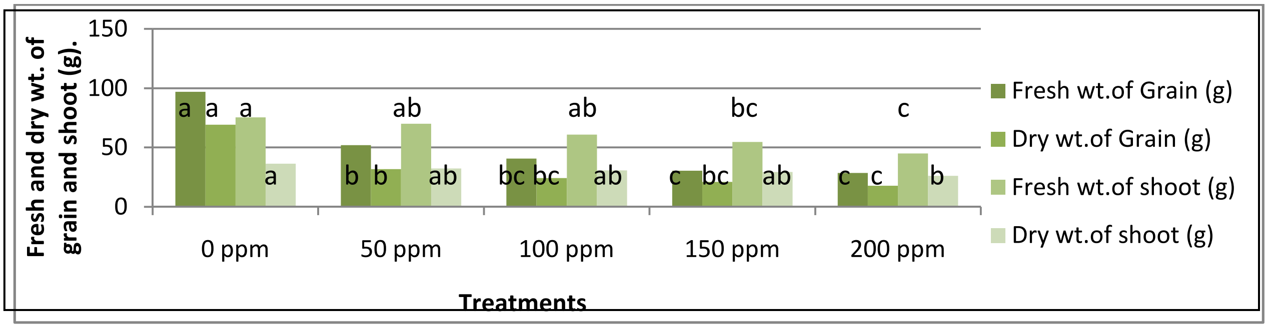


Fig- 44: Effects of different doses of Pb on fresh and dry weight of grain and shoot (g/pot) of maize (variety: BARI maize-9).

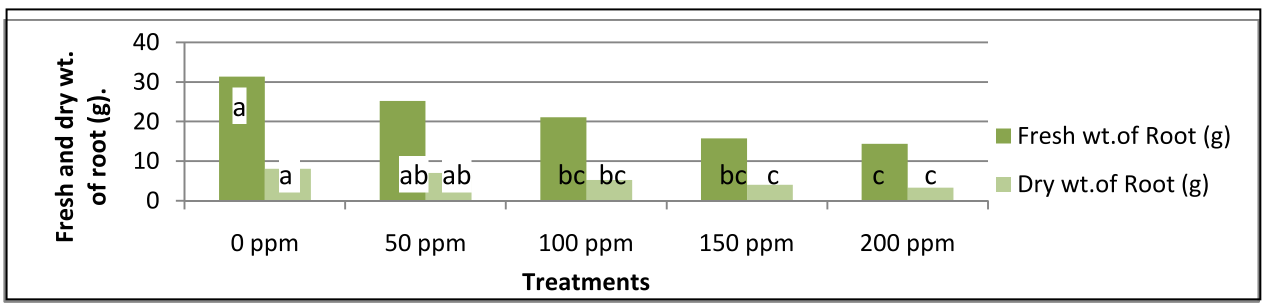


Fig- 45: Effects of different doses of Pb on fresh and dry weight of root (g/pot) of maize (variety: BARI maize-9).

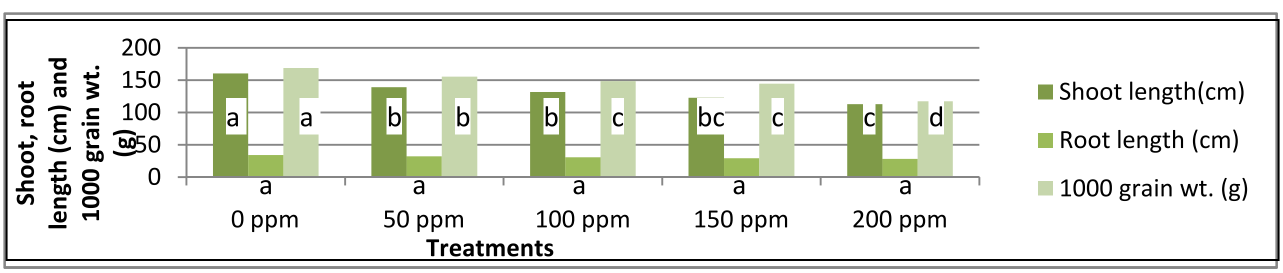


Fig-46: Effects of different doses of Pb on shoot, root length (cm), no. of tiller and 1000 grain wt.(g/pot) of maize (variety: Bari maize).

4.1.7.5. Nitrogen Concentration

Lead (Pb) application in soil significantly increased nitrogen concentration in root of maize (variety: BARI maize-9), being the highest with Pb @ 200 ppm was 115.2% higher compared to that of control plant (Table-18 and Figure-47) and all treatments differed significantly from each other. This is in agreement with Kibria *et al.* (2009) who reported that Pb application in soil significantly increased nitrogen concentration @ 26% with Pb @ 100 mg kg^{-1} of soil in shoot of *Amaranthus oleracea*. But in case of shoot and grain, nitrogen concentration increased up to 150 ppm of Pb application then decreased significantly with increasing Pb application. Similar phenomena were also described by Orhue and Inneh (2010) in *Celosia argentea*. The decline in nitrogen concentration due to Pb may be as a result of moisture stress created by Pb (Burzynisky and Grabowski, 1984). Binding of Heavy metals to sulphydryl (-SH) group of proteins also disturb the nitrogen uptake (Tomer et *al*., 2000).

4.1.7.6. Phosphorus Concentration

Phosphorus concentrations in root, shoot and grain of maize (variety: BARI maize-9) decreased significantly with increasing Pb concentration in soil (Table-18 and Figure-48). The maximum concentration of P was found in control (T_0) treatment and the minimum in the T_4 treatment in case of root, shoot and grain. Pb application up to 150 ppm decreased phosphorus significantly then decreased but differences were not statistically significant in all cases. From the result it may be concluded that application of lead reduced the concentration of phosphorus in root, shoot and grain of maize. Kibria *et al*. (2009) reported that phosphorus concentrations in shoots of *A. gangeticus* and *A. oleracea* decreased with increasing rates of Pb application. On the contrary, they found that phosphorus concentrations in root of *A. gangeticus* increased with higher rate of Pb (100 mg $kg\text{-}^{1}$) application in soil. Orhue and Inneh (2010) also reported that Pb decreased the uptake of phosphorus in *C. argentea*. These differences seem probably due to differences in plant species. It is known that lead physically blocks the access of many ions to their absorption sites on the roots (Godbold and Kettner, 1991), thus inhibiting their uptake. Walker *et al.* (1997) reported that Pb decreased the uptake of phosphorus in *Zea mays*.

4.1.7.7. Potassium Concentration

Lead application significantly decreased potassium concentration in root, shoot and grain of maize (variety: BARI maize-9) i.e. an inverse relationship between Pb and K was present (Table-18 and Figure-48). The concentration of potassium ranged from 0.18 to 1.30% in root, 0.65 to 1.46% in shoot and 0.40 to 0.53% in grain. The maximum concentration of potassium (1.30, 1.46 and 0.53% in root, shoot and grain respectively) were obtained in the control treatment and the minimum concentration (0.18, 0.65 and 0.40 % in root, shoot and grain respectively) in T_4 treatment. Potassium in root, shoot and grain were decreased by 86.2, 55.5 and 24.5%, respectively with the highest rate of Pb (200 ppm) application compared to that with the control. The effects of Pb on K concentration were more pronounced in roots than in shoot and grain which was also observed in case of rice and wheat. From the data it was evident that application of lead reduced the potassium concentration in root, shoot and grain of maize. The results of the present study are contrary to the findings of Kibria *et al.* (2009) with *A. oleracea* that might be due to difference in plant species. However, the results are in conformity to those of Walker *et al.* (1997). Orhue and Inneh (2010) also reported that Pb application significantly decreased potassium concentration in *C. argentea.* Akinci *et al.* (2010) found in the same inverse relationship between lead and K concentration in tomato.

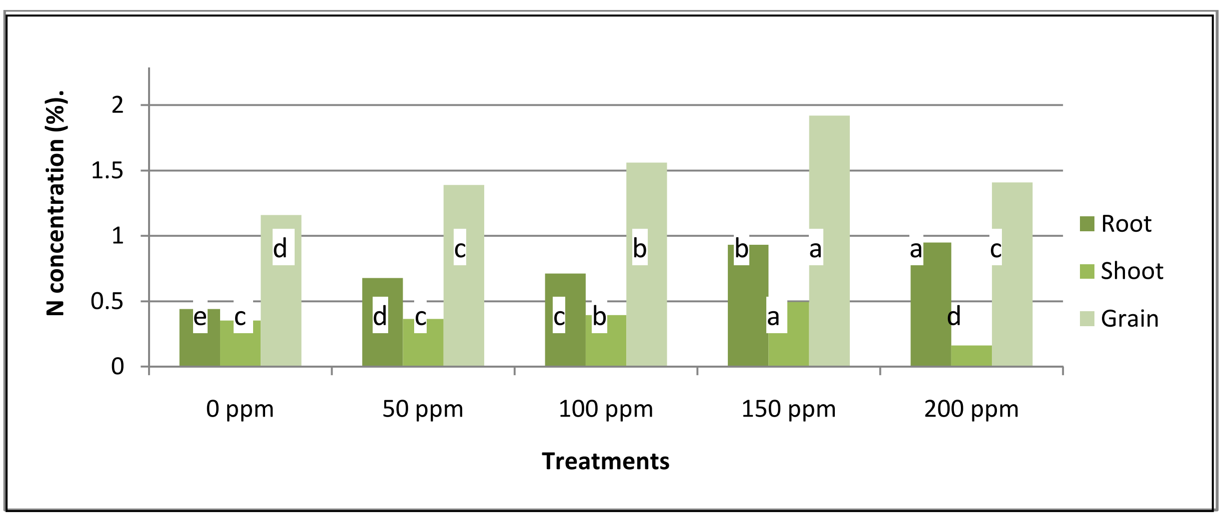


Fig-47: Effects of different doses of Pb on N conc. (%) of root, shoot and grain of maize (variety: BARI maize-9).

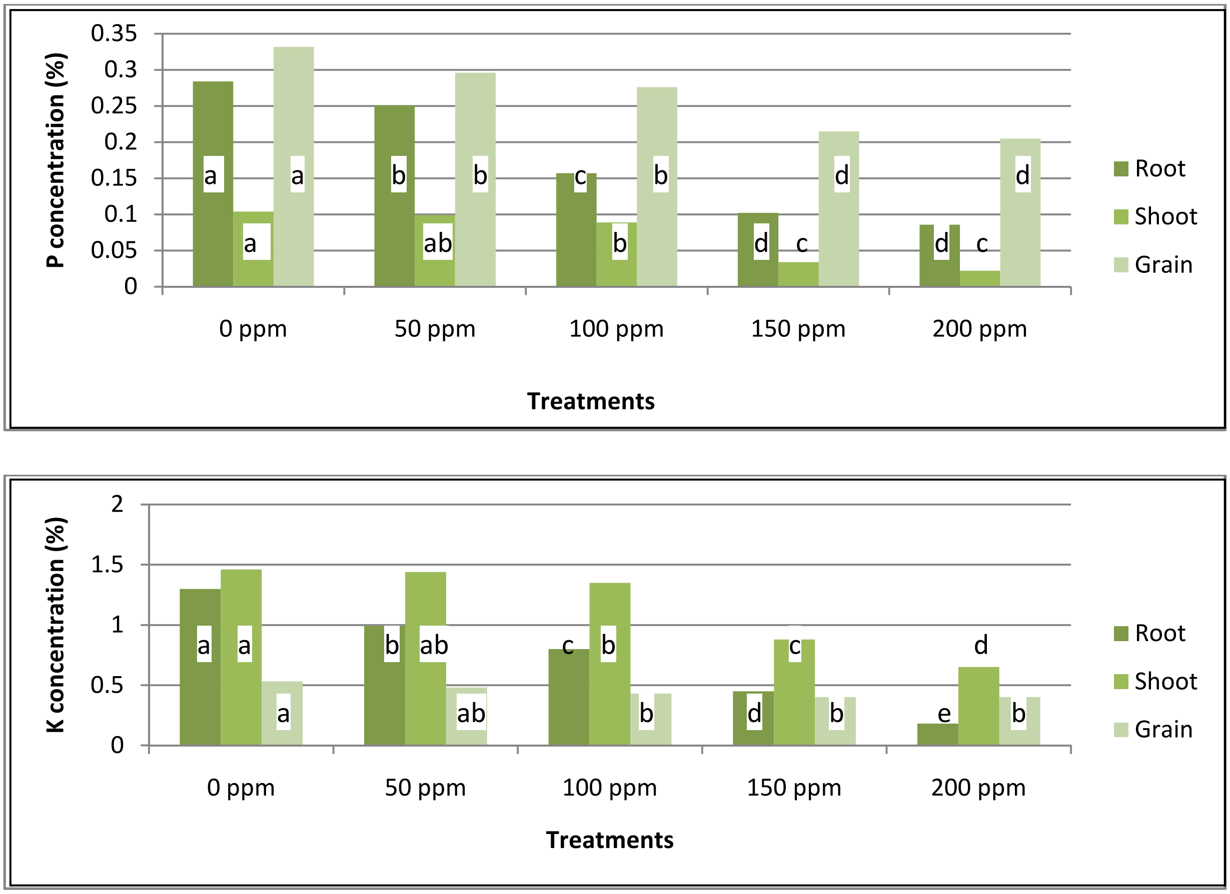


Fig-48: Effects of different doses of Pb on N, P and K conc. (%) of root, shoot and grain of maize (variety: BARI maize-9).

4.1.7.8. Calcium Concentration:

Calcium concentration in root and shoot of maize significantly decreased by Pb application whereas its effect on grain yield was not significant (Table-18 and Figure-49). The maximum calcium concentration in maize (0.713, 0.1.43 and 0.0053% in root, shoot and grain, respectively) was noted in the control treatment and the minimum concentration (0.353, 0.553 and 0.0040% in root, shoot and grain of maize) in T_4 treatment. Treatment T_4 was significantly differed from all other treatments but there was no significant difference between T_0, T_1 as well as T_2 and T_3 treatments, respectively in case of root. Treatments T_0, T_1 and T_4 were significantly different from T_2 and T_3 treatments but there were no difference between them in case of shoot Ca concentration. In grain, there was no significant difference among all treatments though calcium concentration decreased with increasing Pb concentration. At the highest rate of Pb application (200 ppm), Ca concentration in root, shoot and grain decreased by 50.5, 61.3 and 24.5% compared with that of control. Similar results were found by Hung and Cuningham (1996) with corn. Kibria *et al.* (2009) also reported that calcium concentration in shoot and roots of *A. gangeticus* and roots of *A. oleracea* were significantly decreased by Pb application. The decrease in Ca concentration in the roots in response to higher concentration of Pb was probably a result of osmotic adjustment (Azmat and Haider, 2007).

4.1.7.9. Magnesium Concentration

Magnesium concentration in root, shoot and grain of maize (variety: BARI maize-9) significantly decreased by Pb application (Table-18 and Figure-49). The maximum concentration of magnesium (0.140, 0.253 and 0.083% in root, shoot and grain of maize, respectively) was noted by the T_0 treatment. The minimum concentration (0.056, 0.163 and 0.066% in root, shoot and grain of maize, respectively) in T_4 treatment. A gradual decrease in Mg concentration in the root, shoot and grain parts of maize was observed with increasing rates of Pb application. At the highest rate of Pb application (200 ppm), Mg concentration in root, shoot and grain decreased by 60.0, 35.5 and 20.5% respectively compared with that of the control. This might be due to the antagonistic effect of Pb with that nutrient. Similar results were also found by Cuningham (1996) with corn and ragweed and Walker *et al*. (1997) with *Cucumis sativus* seedlings and Zea mays. On the contrary, they also reported that Pb application at 80 and 100 mg kg^{-1} significantly increased Mg concentration in shoots of *A. gangeticus* and *A.oleracea*, respectively.

4.1.7.10. Lead Concentration

The lead concentration of root, shoot and grain of maize increased significantly under Pb stress when compared to control (Table-18 and Figure-49). The highest concentration of lead was noted at 200 ppm of Pb-treated plants and the lowest was in the control treatment. In case of root Pb concentration, all treatments differed significantly from each other but in case of shoot, there were no significant difference among $T_{0,}$ T_1 and T_{3S} treatments. In case of grain, there was no difference between $T_{0,}$ T_1 as well as $T_{2,}$ T_3 treatments. However, Pb concentration in grain with Pb application up to 100 ppm was statistically similar to that with control and then increased significantly. Increasing Pb concentration in soil caused an increase in Pb concentration in root, shoot and grain of maize crops. Similar results were observed by Ghani *et al.* (2010) in maize.

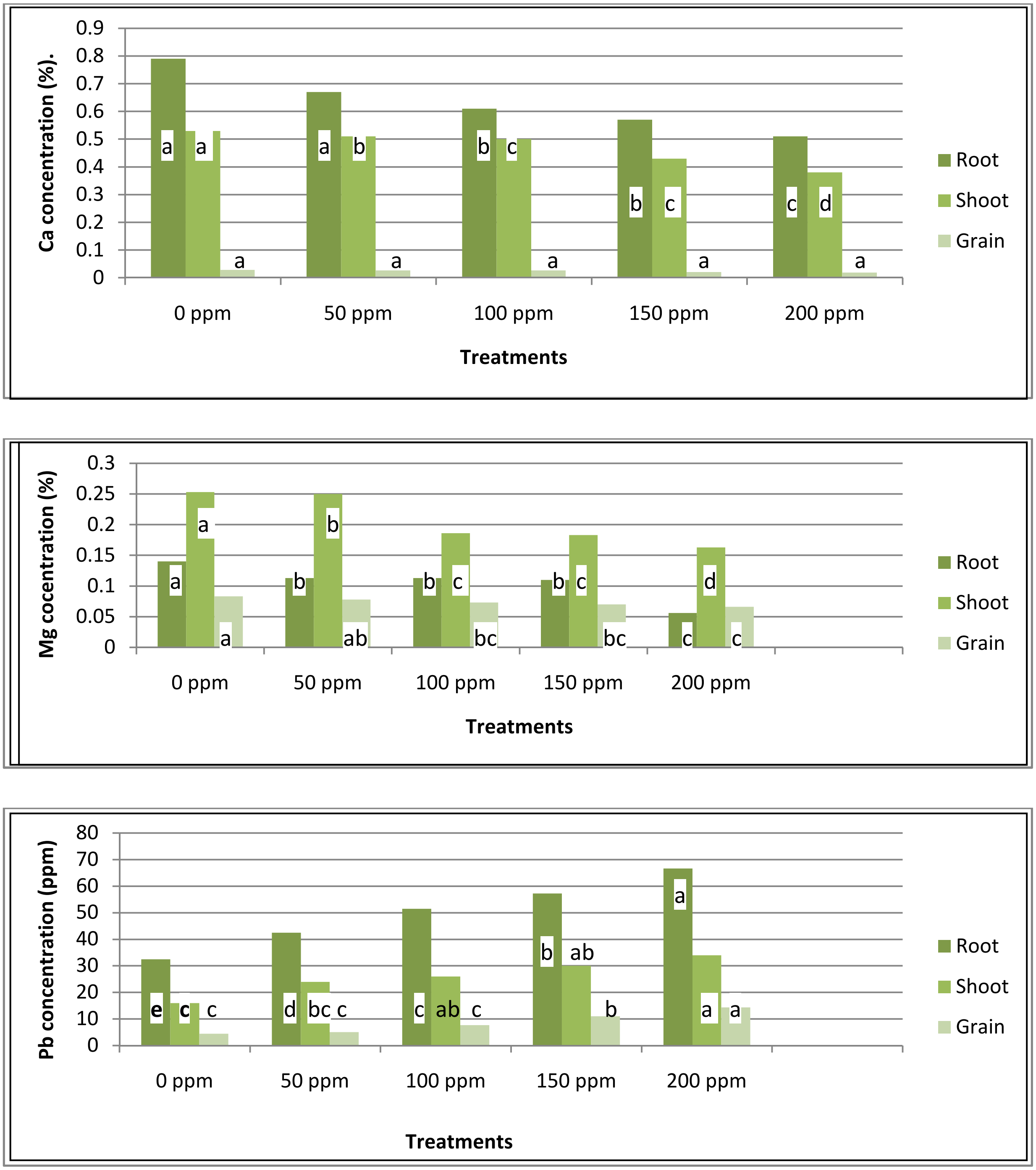


Fig-49: Effects of different doses of Pb on Ca, Mg (%) and Pb conc. (ppm) of root, shoot and grain of maize (variety: BARI maize-9).

4.1.8. Experiment-8: Growth, yield and mineral nutrition of maize (Variety: Bari maize-9), influenced by different amendments

4.1.8.1: Fresh and dry weight of grain

The amendments of leaded soils influence the yield of maize (variety: BARI maize-9) grains (Table-19 and Figure-50). The fresh and dry wt. of grains was highest in the pots receiving control followed by cow-dung, poultry litter, lime, and 100 ppm Pb treated pots, respectively. Application of 100 ppm of Pb in soil decreased significantly the fresh and dry weight of grain as compared with the control. Soil amendments with cowdung, poultry litter and lime were able to reduced Pb toxicity and increased 114.4, 60.0 and 48.8% fresh weight of grain and 130.8, 87.4 and 56.3% dry weight of grain as compared with 100 ppm of Pb applied pots through luxuriant vegetative growth. 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) (Schnitzer and Khan, 1978; Vaughan and Malcolm, 1985). Chamon *et al.* (2006b) reported that the dry matter yield of tomato fruit was increased by 13.4% due to the application of cowdung. Cattle manure gave the highest dry matter yield of maize, while sewage sludge resulted in the lowest (Ismail *et al.*, 1996).

4.1.8.2: Fresh and dry weight (g) of shoot

Shoot growth was hardly influenced by the amendments (Table-19 and figure-50). Application of 100 ppm of Pb decreased both fresh and dry weight of shoot. Cowdung, poultry litter and lime with 100 ppm of Pb increased 61.3, 29.3 and 23.2% fresh weight and 37.9, 24.9 and 28.7% dry weight of shoot compared with only 100 ppm of Pb treated pots, respectively. Amongst amendments cowdung application was found to be the most efficient ameliorators of Pb-toxicity with respect to fresh and dry weight of shoot (g pot^{-1}) of maize. The reduction of dry matter production of onion, potatoes, cabbage and lettuce plants by Pb and Ni toxicity was also reported by Patrick *et al.* (1981). Saini *et al.* (2001) reported that application of FYM @ 1.0 % enhanced straw yield by 15.2 and 5.7% in sandy and clay loam soil respectively, as compared with no manure.

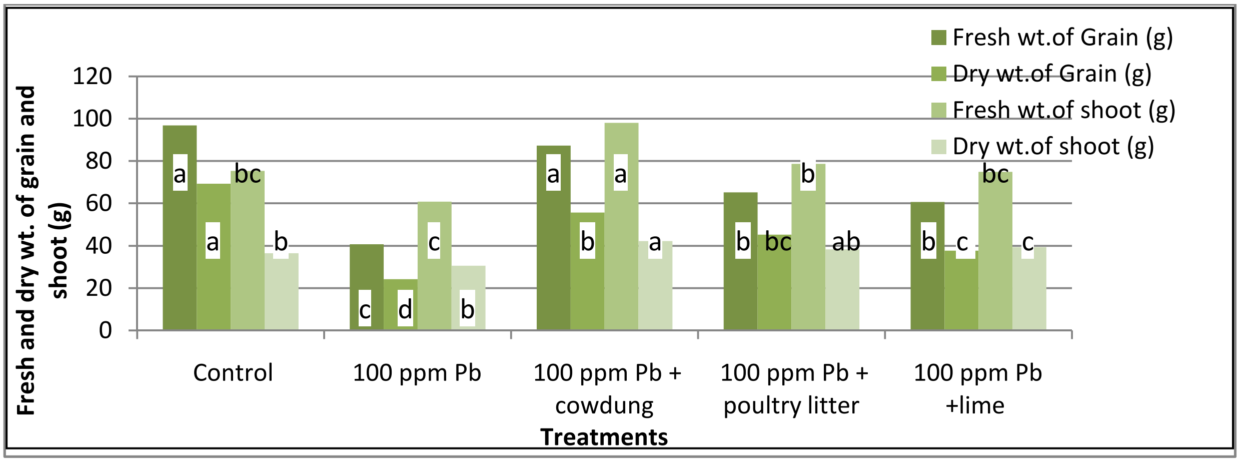


Fig-50: Effects of different amendments on fresh and dry wt. of grain and shoot (g/pot) of maize (variety: BARI maize-9).

4.1.8.3: Fresh and dry weight (g) of root

Dry weight of root of maize (variety: BARI maize-9) varied significantly with application of Pb and Pb with amendments while fresh weight of root was less affected (Table-19 and figure-51). The highest dry weight of root was observed in control (8.12 g/pot), followed by cowdung, poutry litter, 100 ppm of Pb and lime treatments and it was significantly different from the other treatments and the lowest in lime (5.24 g/pot) treatment. However, no difference was observed among 100 ppm of Pb, cowdung, lime and poultry litter treatment, respectively. There was no significant difference among all the treatments in case of fresh weight of root though cowdung, poultry litter and lime treatments increased the root biomass production.

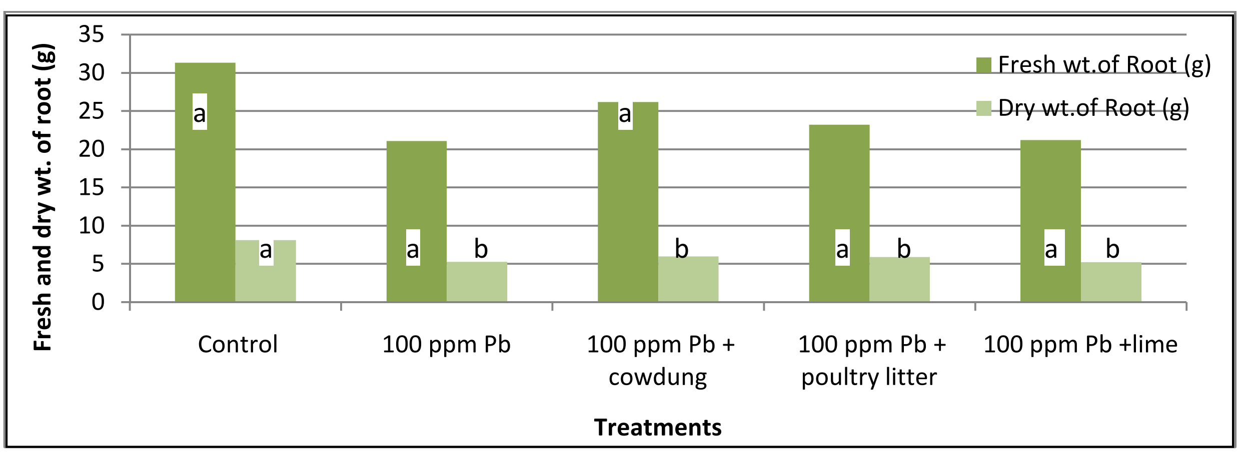


Fig-51: Effects of different amendments on fresh and dry wt. of root (g/pot) of maize (variety: BARI maize-9).

4.1.8.4: Shoot, root length (cm) and 1000 grain wt. (g)

The shoot length and 1000 grain wt. of maize (variety: BARI maize-9) was affected significantly by different amendments (Table-19 and figure-52) but in root length, the differences were not significant though Pb application decreased and amendments increased root length. The highest shoot length (161.1 cm) was observed in cowdung treatment followed by control, lime, poultry litter and 100 ppm of Pb treatments and 1000 grain weight (184.67 g) were observed in cowdung treatment followed by poultry litter, control, lime, and 100 ppm of Pb. Shoot length in cowdung treatment was 0.4% higher than control and 22.3% higher than 100 ppm Pb treated pots. 1000 grain wt. of maize in cowdung treatment was 9.5% higher than control and 24.2% higher than 100 ppm Pb treated pots and was significantly differed from other treatments. This reduction of height might be attributed to the toxic effect of heavy metal present in soil (McCalla *et al.,* 1977).

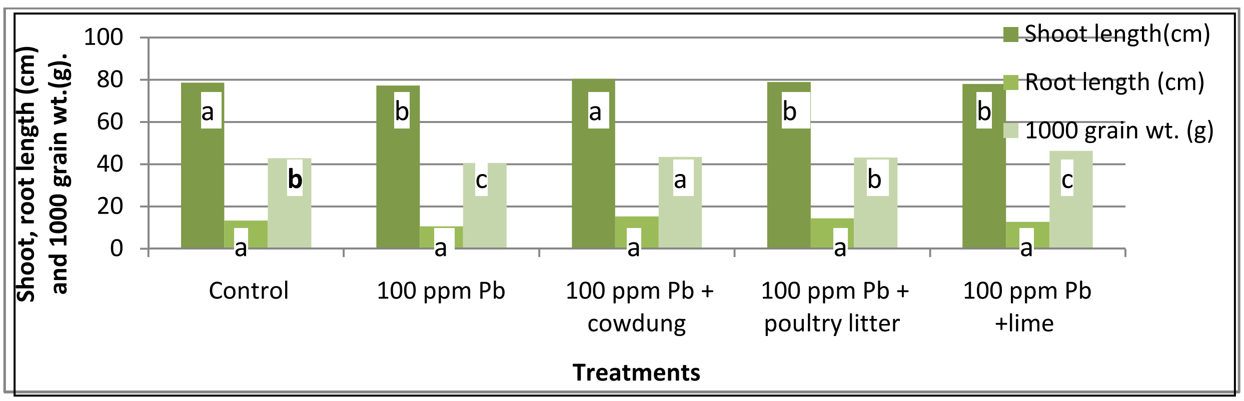


Fig-52: Effects of different amendments on shoot, root length (cm) and 1000 grain wt. (g/pot) of maize (variety: BARI maize-9).

4.1.8.5: Nitrogen Concentration

Lead (Pb) application significantly increased the concentration of nitrogen in maize root, shoot and grain compared with control treatment (Table-20 and Figure-53), probably Pb influence the concentration of N in both root, shoot and grains. Soil amendments with cowdung and poultry litter decreased N concentration in root by 30.9 and 27.0% and lime increased by 13.2% as compared with 100 ppm of Pb treated pots but there was no difference between cowdung and poultry litter treated pots and these treatments differed significantly from the other treatments in case of root. The highest amount of N was observed in the shoot and grain of cowdung treated pots followed by poultry litter and lime and all treatments differed significantly in case of shoot but in case of grain N concentration, there were no difference between 100 ppm of Pb, poultry litter and lime treated pots, respectively. This might be due to the effects of organic manure to reduce Pb toxicity hence increased N concentration. A slight increase in the contents of essential nutrients in crops through farmyard manure application was also reported by many investigators (Pierzynski, 1997; Emmerling *et al*., 2000).

4.1.8.6: Phosphorus Concentration

Phosphorus concentrations in root, shoot and grain of maize (variety: BARI maize-9) were considerably influenced by the amendments (Table-20 and Figure-53). Application of 100 ppm of Pb significantly reduced the concentration of phosphorus in root, shoot and grain of maize. All amendments increased root P concentration, the highest being observed in cowdung (0.275%) followed by lime (0.213%) and poultry litter (0.175%) and in case of shoot, and the highest being observed in cowdung (0.0.191%) followed by poultry litter (0.158%) lime (0.131%). In case of grain, cowdung and poultry litter increased by 25.4 and 15.6% and lime decreased by 23.2% of P concentration, compared with 100 ppm of Pb treatments. There was significant difference observed among all the treatments in case of root, shoot and grain phosphorus concentrations. Due to adverse or antagonistic effect of Pb, the uptake of P by maize plants decreased significantly and organic manure reduced Pb toxicity hence increased P concentrations. Nurruzzaman (1995) reported that application of cowdung in the polluted soil increased phosphorus concentration of (rice, wheat) crop but the effect was not significant.

4.1.8.7: Potassium Concentration

The concentration of K in maize root was notably influenced by the amendments in Pb stressed plant while shoot and grains were not significantly influenced (Table-20 and Figure-53). Application of Pb decreased potassium concentration in root, shoot and grain. Among amendments applied, the highest potassium concentration being observed in lime treatment (1.20%) followed by cowdung (0.840%) and poultry litter (0.780%) and was significantly differed from other treatments but there was no difference among 100 ppm of Pb, cowdung and poultry litter treatments in case of root. Shoot accumulated more potassium than root and grain which was also observed in case of rice and wheat. Shoot and grains K concentration in all treatments was not varied significantly though cowdung and lime treatments increased and poultry litter treatment decreased K concentration. Nuruzzuman (1995) observed that application of cow-dung in the polluted soil increased slightly the potassium concentration in (rice, wheat) crop but the effect was not significantly different. Chamon *et al.* (2005a) reported that application of cowdung and waterhyacinth in polluted soil enhanced the K contents in rice.

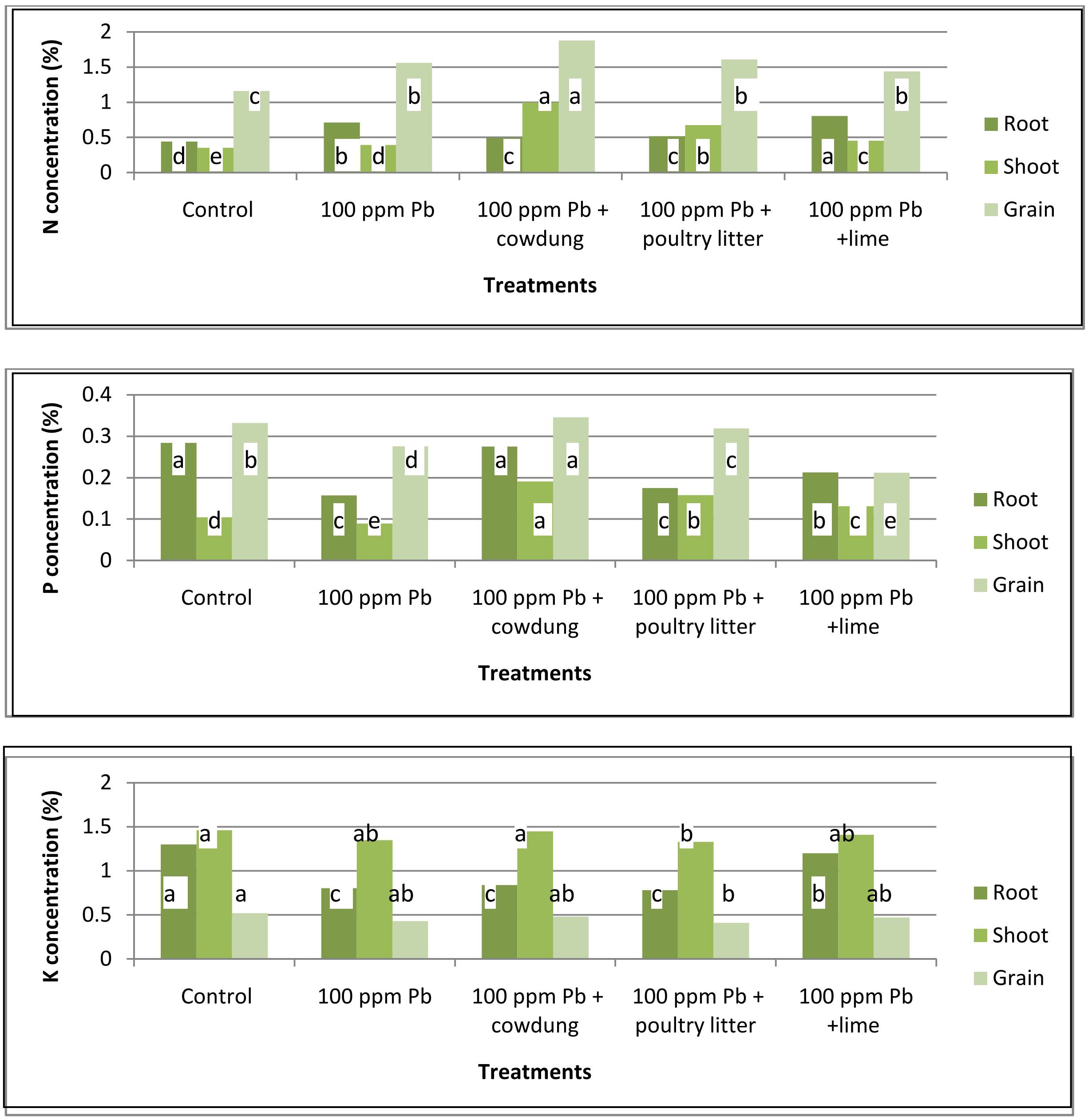


Fig-53: Effects of different amendments on N, P and K conc. (%) of root, shoot and grain of maize (variety: BARI maize-9).

4.1.8.8: Calcium Concentration

The concentration of Ca in maize root and shoot was considerably influenced by the amendments in Pb stressed plant while grains Ca concentration was not significantly influenced (Table-20 and Figure-54). Application of only 100 ppm of Pb treatment reduced the calcium concentration in root, shoot and grain as compared with control. Among amendments applied, the highest calcium concentration in root and shoot of maize being observed in lime treatment (0.720%) and (2.20%) followed by cowdung (0.713, 0.933%) and poultry litter (0.360, 0.876%). Grains Ca concentration was not varied significantly though cowdung and lime treatments increased and poultry litter treatment decreased Ca concentration. Among amendments, liming enhanced Ca concentration in root, shoot by 30.91 and 260.9% and cowdung by 29.6% and 53.0% and poultry litter decreased by 34.5% in root and increased by 43.6% in shoot compared with 100 ppm of Pb treatments.

4.1.8.9: Magnesium Concentration

Magnesium concentrations in maize root and shoot varied significantly with amendments but grain magnesium concentrations did not assorted significantly (Table-20 and Figure-54). Application of 100 ppm of Pb decreased significantly magnesium concentration of maize root and shoot compared with control treatment. The highest concentration of Mg in maize root was observed in poultry litter treatment (0.156%) followed by cowdung and lime amendments. In case of shoot, the highest was observed in cowdung (0.337%) followed by poultry litter and lime treatments. Application of 100 ppm of Pb decreased by 21.4% Mg concentration compared with control treatment and application of poultry litter, cowdung and lime amendments with 100 ppm of Pb increased by 41.8, 33.6 and 15.5% in maize root and in case of shoot, application of 100 ppm of Pb decreased by 29.3% Mg concentration compared with control treatment and application of cowdung, poultry litter, and lime amendments with 100 ppm of Pb increased by 81.2, 25.3% and decreased by 1.6% compared with 100 ppm Pb treatment. There were no significant differences among the treatments in case of Mg concentration in grain of maize.

4.1.8.10: Lead Concentration

Lead application and amendments influenced the Pb absorption and accumulation of maize plants (Table-20 and Figure-54). Application of 100 ppm of Pb notably increased by 58.5, 62.5 and 69.8% Pb concentration of maize root, shoot and grain compared with the control treatment. Among amendments with 100 ppm of Pb, cowdung, lime treatments decreased by 37.7, 2.7% and poultry litter increased by 26.2% Pb concentration in root, while in shoot, cowdung, poultry litter decreased by 34.6, 6.4% and lime increased by 11.5% and in grain, cowdung, poultry litter and lime treatment decreased by 84.7, 17.3 and 8.2% compared with 100 ppm of Pb treatment. Pb concentrations in all treatments differed significantly from each other in case of root and grain but in case of shoot Pb concentrations, there was no significant difference among the 100 ppm of Pb, poultry litter and lime treatments, respectively. From the results it may be concluded that application of lead significantly increased the concentration of Pb in root, shoot and grain of maize. Amongst amendments cowdung had the greater ability to reduce Pb toxicity in grain then poultry litter and lime probably due to binding up of lead rendering it less available to plants by organic manure. Similar results were also observed by Madrid *et al.* (1999) who reported 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. Lagerwerff (1972) observed that soil organic matter strongly adsorbed the heavy metals and helped in formation of insoluble organo-metal complexes, suggested a possibility. Soil organic matter adsorbs available Pb ions, producing and preserving forms of Pb that are less available for plant uptake or leaching (Berti *et al*., 1994). Organic matter i.e. plants and animal tissues contain a large number of acids, which may be released into the soil during decomposition. These can range from simple aliphatic acids to complex aromatic and heterocyclic acids (Huang and Schnitzer., 1986). These biochemical compounds have chelating characteristics and have the ability to mobilize heavy metal in soil. Simple aliphatic acids are of special interest as natural chelators because they are ubiquitous and because many of their hydroxyl derivatives are effective solubilizers of metals (Wasay *et al.,* 1998). Liming increases soil pH, resulting in the precipitation of heavy metals and a reduction in toxic concentrations in the soil solution (Kreutzer, 1995).

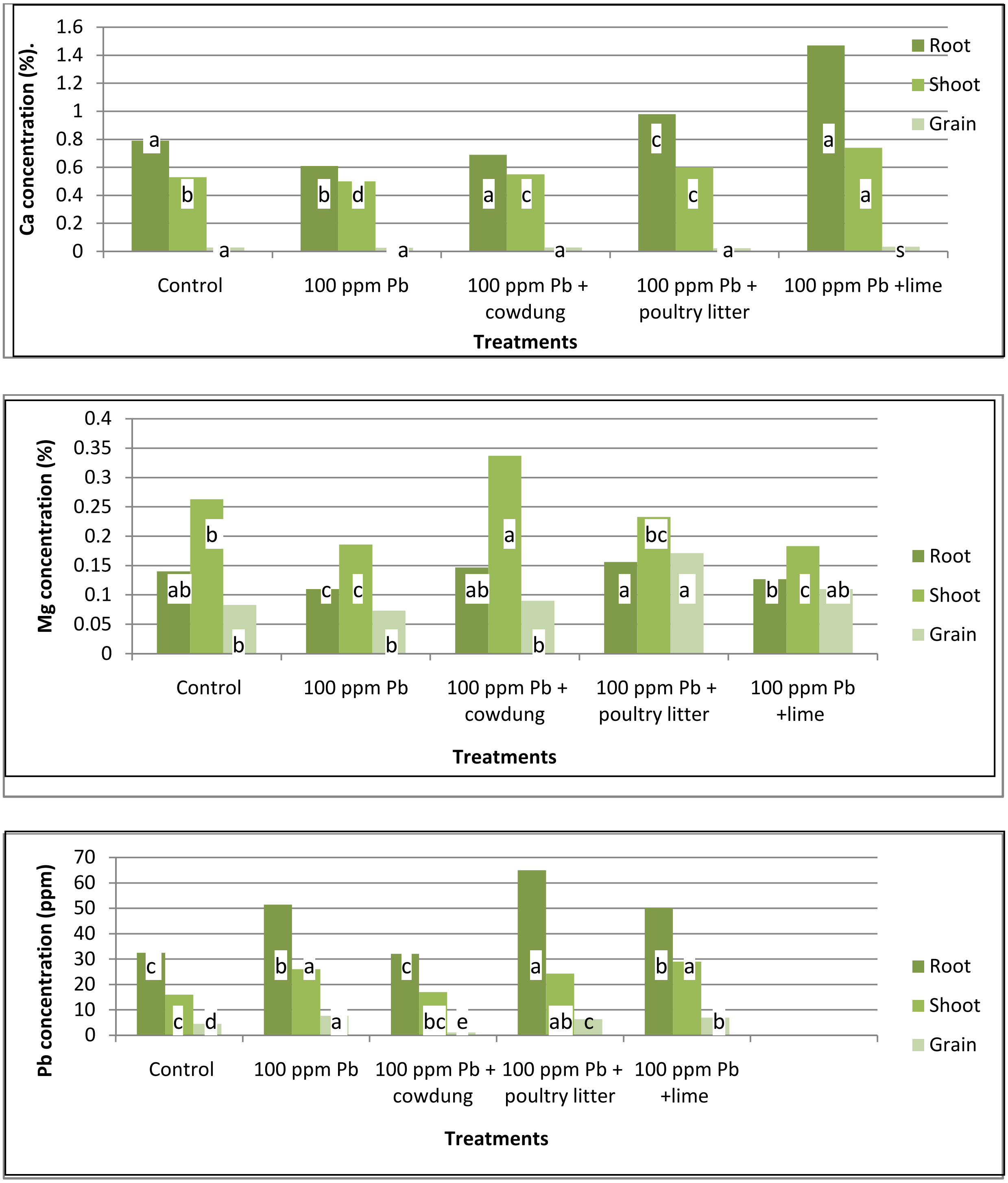


Fig-54: Effects of different amendments on Ca, Mg (%) and Pb conc. (ppm) of root, shoot and grain of maize (variety: BARI maize-9).

4.2. Field Experiment: Wheat

4.2.1. Experiment-1: Effects of different doses of lead (Pb) on growth, yield and mineral nutrition of wheat (variety: Shotabdi, Prodip and BARI wheat-26)

4.2.1.1. Fresh and dry weight of grain

The fresh and dry weight (g/plot) of shotabdi, prodip and BARI wheat-26 (wheat variety) grain affected considerably with different Pb treatments (0, 50 and 100 ppm) (Table-23 and Figure-55). The highest fresh and dry weight of grains/plot (272.6 and 258.1 g) was obtained in the V^0_3 (BARI wheat-26 control) and the lowest value (173.3 and 158.2 g) were obtained in the V^2_3 treatment (BARI wheat-26 with 100 ppm of Pb). In general, application of Pb caused a decrease in the fresh and dry weight of grain in all varieties of wheat however, no difference was observed among $V^2_{1,}$ $V_2{}^1{}_,$ V^2_2 and V^1_3 as well as $V^0_{1,}$ V^0_3 treatments in case of fresh weight of grain whereas in dry weight grain, there was no difference between $V^0_{1,}$ V^0_3 and $V^2_{1,}$ V^1_2 as well as $V^2_{2,}$ V^1_3 $V^2_{3,}$ respectively. The results indicated that application of Pb in all varieties of wheat decreased the fresh and dry weight of wheat grains remarkably as compared with their control. At the highest dose of Pb application (100 ppm), fresh and dry weight of shotabdi grain decreased by 26.3 and 28.0% respectively, compared with the control. The corresponding reductions for prodip and BARI wheat-26 were 26.2, 31.9 and 36.4, 38.7%, respectively. Such reduction in grain yields might have been caused probably by physiological disorders, impaired biochemical, physiological and enzymatic processes. In agreement with the present study, Kosobrukhov *et al.* (2004) reported a considerable decrease in dry weights of different plant parts under Pb treatments.

4.2.1.2. Fresh and dry weight (g) of shoot

Data showed that Pb treatment had significantly reduced the shoot fresh and dry weight (g) in all varieties of wheat at all Pb treatments in the field (Table-23 and figure-56). The maximum fresh and dry weight of shoot was (206.3 and 167.5 g) obtained in the V^0_1 (Shotabdi, control) treatment. The lowest value was (99.44 and 89.2 g) in the V^2_2 (Prodip) at 100 ppm Pb treatment respectively. Due to application of 100 ppm of Pb the fresh matter production in shoot decreased by 30.2, 43.3 and 22.3% in shotabdi, prodip and BARI wheat-26 and 28.8, 41.2 and 23.3% in dry weight of shoot, respectively. The reduction of biomass by Pb toxicity could be the direct consequences of the inhibition of chlorophyll synthesis and photosynthesis (Chitterjee *et al.*, 2004). Similar phenomena were also described by Kosobrukhov *et al.* (2004) and Bhatti *et al.* (2013) in wheat.

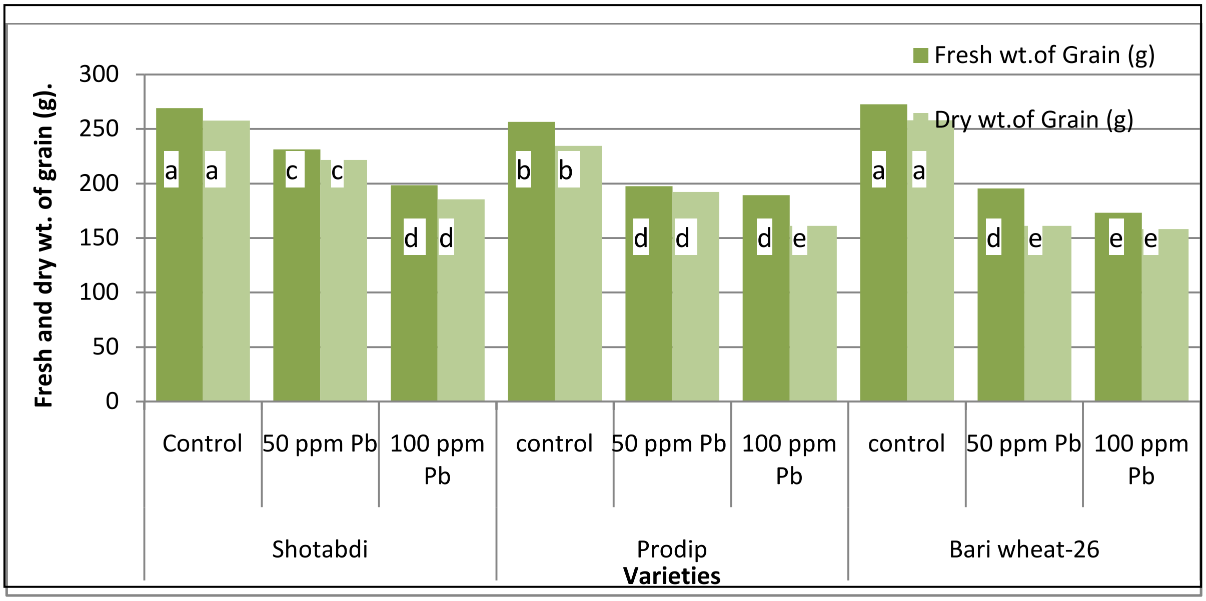


Fig-55: Effects of different doses of Pb on fresh and dry wt. of grain (g/plot) of different wheat varieties in the field.

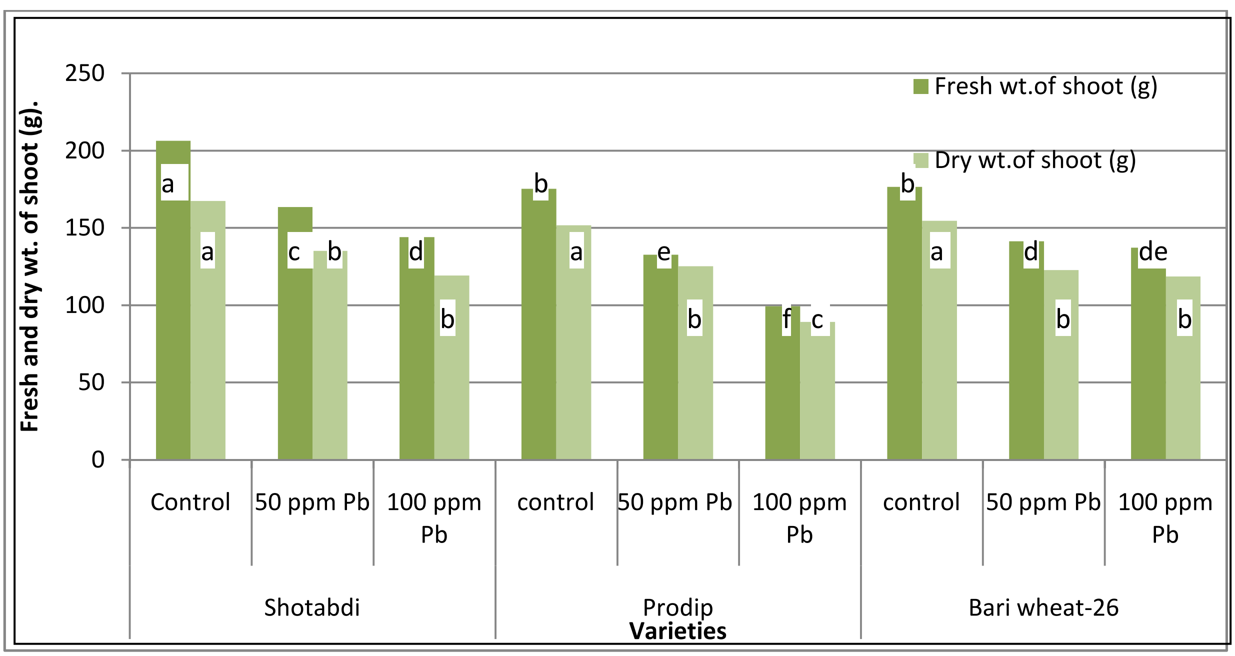


Fig-56: Effects of different doses of Pb on fresh and dry wt. (g/plot) of shoot of different wheat varieties in the field.

4.2.1.3. Fresh and dry weight (g) of root

Increasing Pb concentration significantly decreased both fresh and dry weight of root of all varieties of wheat of Pb exposure at 0, 50 and 100 ppm in the field (Table-23 and figure-57). At the highest dose of Pb application (100 ppm), fresh weight of root decreased by 54.8, 53.3, 60.2% and dry weight by 41.6, 49.8, 51.7% in shotabdi, prodip and BARI wheat-26, respectively, compared with that of their control. Similar results were also obtained by Bhatti *et al.* (2013) and Saini *et al*. (2001) in wheat.

4.2.1.4. Shoot and root length (cm)

The length of shoot and root of different wheat variety were influenced by the application of Pb (Table-23 and figure-58). The maximum shoot length (77 cm) was obtained in V^0_1 (Shotabdi, control) and the minimum (64.67 cm) in V^2_3 (BARI wheat-26, 100 ppm Pb). In case of root length the maximum (13.67 cm) and the minimum (8 cm) was observed in V^0_2 (Prodip, control) and V^2_1 (Shotabdi, 100 ppm Pb) respectively. The results indicated that the shoot and root length of all wheat varieties in the field decreased due to application of Pb. Similar results were also observed by Aur *et al.* (2012) and Bhatti *et al.* (2013) in wheat. This reduction of height might be attributed to the toxic effect of heavy metal present in them (McCalla *et al.,* 1977). Chen *et al.* (1998) also reported that the height of vertiver was reduced by heavy metal pollution.

4.4.1.5. Number of tiller and no. of panicle/plot:

The number of tiller and panicle $plot^{-1}$ of all wheat varieties was significantly affected by increasing Pb concentration (Table-23 and figure-59). The highest no. of tiller (145) was obtained in V^0_1 (Shotabdi, control) and lowest (95) in V^2_2 (Prodip, 100 ppm of Pb) and V^2_3 (BARI wheat-26, 100 ppm Pb), respectively. All treatments differed significantly except $V^0_{1,}$ V^0_3 as well as $V^1_{2,}$ V^1_3 and $V^2_{2,}$ V^2_3 treatments. In case of no. of panicle/plot, the highest being observed in V^0_1 (Shotabdi, control) and the lowest in V^2_3 (BARI wheat-26, 100 ppm Pb). At the highest dose of Pb application (100 ppm), the number of tiller and panicle $plot^{-1}$ decreased by 24.1, 17.4, 32.1 and 24.1, 33.3, 25.9% in Shotabdi, Prodip and BARI wheat-26, respectively, compared with their control. The results of the present investigation are analogous to the earlier findings of Bhatti *et al.* (2013) in wheat varieties at both treatments (40 and 60 ppm) as compared to the control.

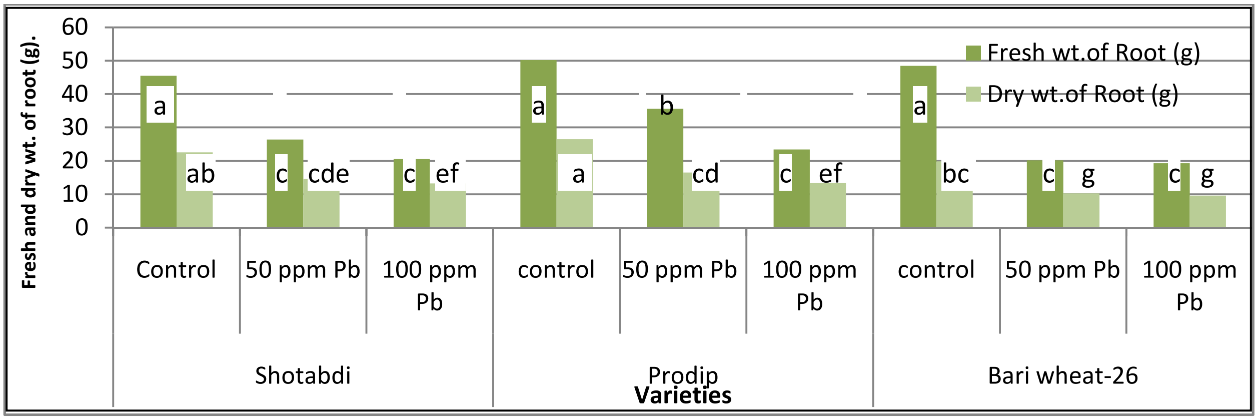


Fig-57: Effects of different doses of Pb on fresh and dry weight (g/plot) of root of different wheat varieties in the field.

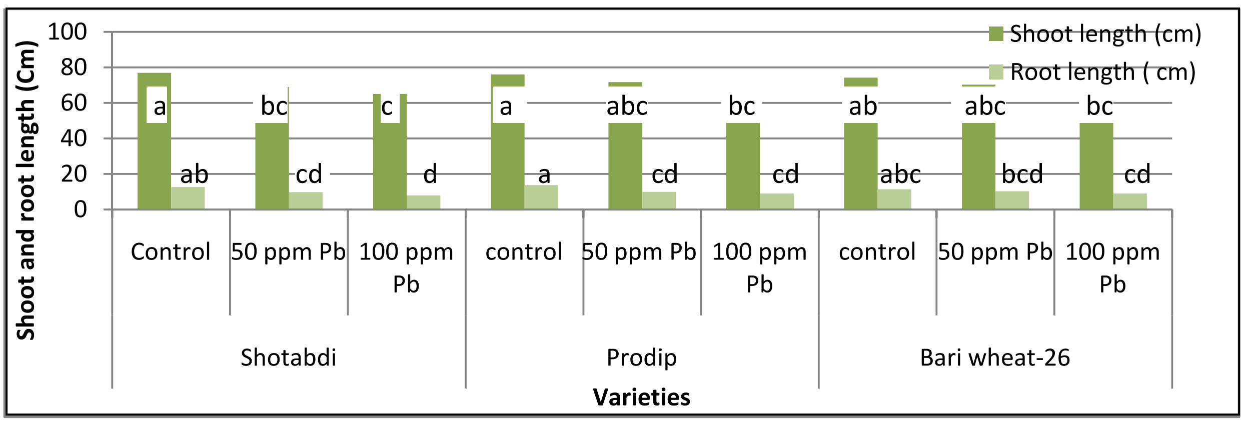


Fig-58: Effects of different doses of Pb on shoot and root length (cm) of different wheat varieties in the field.

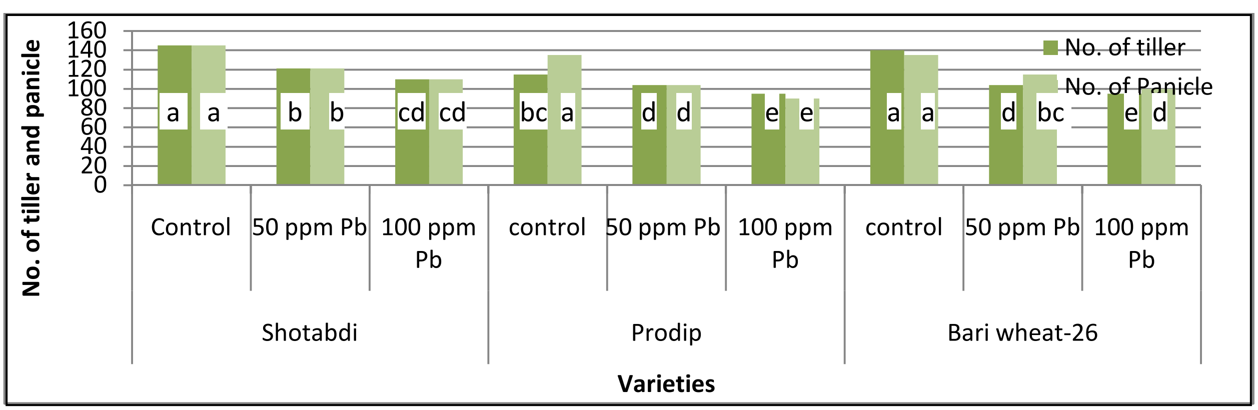


Fig-59: Effects of different doses of Pb on no. of tiller and panicle $plot^{-1}$ of different wheat varieties in the field.

4.2.1.6. 1000 grain weight (g) and yield t/ha

Due to application of Pb, 1000 grain weight (g/plot) and total yield (t/ha) of all varieties of wheat was significantly suppressed (Table-23 and figure-60). Among three varieties of wheat, 1000 grain weight (g) and total yield (t/ha) was highest in V^0_1 (Shotabdi, control) and lowest V^2_3 (BARI wheat-26,100 ppm Pb), respectively. Due to application of 100 ppm of Pb, 1000 grain weight (g) and total yield (t/ha) decreased by 8.3, 6.4, 7.6 and 34.6, 36.6, 44.6% in Shotabdi, Prodip and BARI wheat-26, respectively, compared with their control.

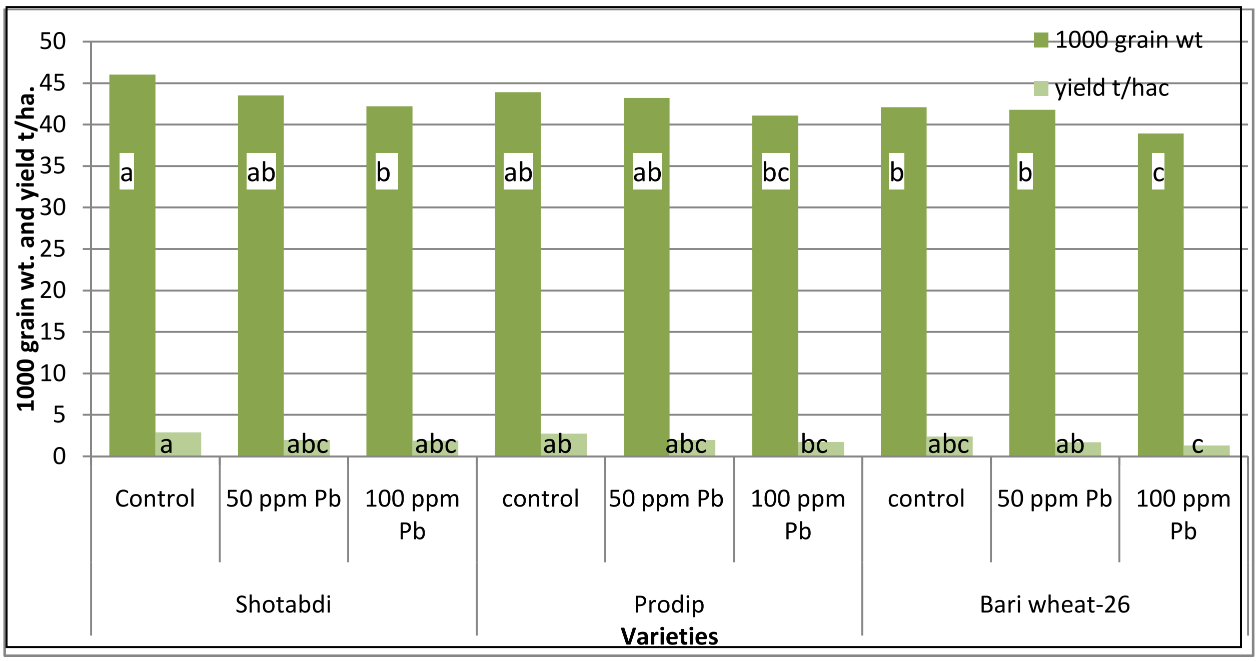


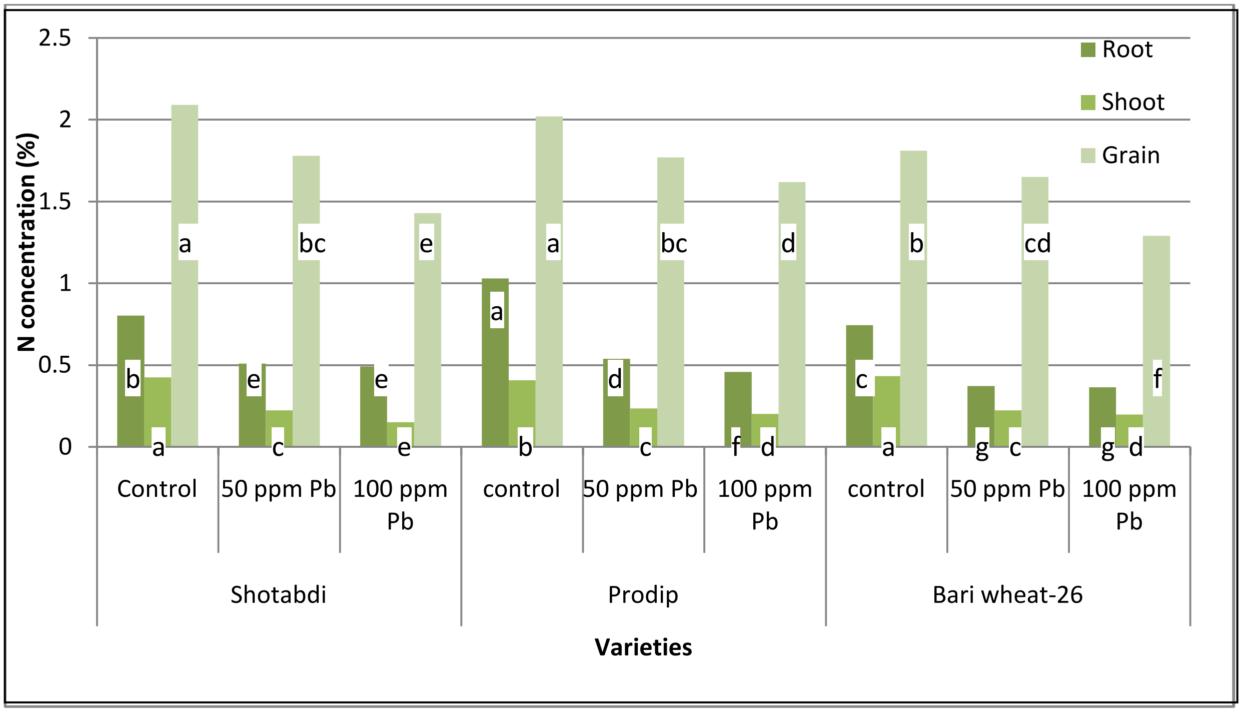
Fig-60: Effects of different doses of Pb on 1000 grain wt. (g/plot) and yield t/ha of different wheat varieties in the field.

4.2.1.7: Nitrogen Concentration

The wheat varieties behaved differently in absorbing and accumulating nitrogen in root, shoot and grain (Table-24 and Figure-61), among three varieties of wheat in the field, the highest being observed in V^0_2 (Prodip, control) in root, V^0_3 (BARI wheat-26, control) in shoot and V^0_1 (Shotabdi, control) in grain and the lowest in V^2_3 (BARI wheat-26, 100 ppm of Pb) root and grain, V^2_1 (Shotabdi, 100 ppm of Pb) in shoot. Nitrogen concentration in root, shoot and grain of wheat varieties were declined by increasing amounts of Pb application in soil. The reduction in nitrogen concentration in Prodip, Shotabdi and BARI wheat-26 root, shoot and grain were 38.9, 55.5, 50.9 (root), 64.5, 50.4, 54.3 (shoot) and 31.6, 19.8, 28.7% (grain), respectively with 100 ppm Pb application compared with their control. Such reduction might have been caused by physiological disorders, impaired biochemical, physiological and enzymatic processes. Strand and Lisovski (1990), Lee *et al*. (1991) also reported that nitrogen concentration decreased gradually at higher concentration of Pb.

4.2.1.8. Phosphorus Concentration

Phosphorus concentration of root, shoot and grain of Shotabdi, Prodip and BARI wheat-26 (wheat varieties) decreased significantly with increasing rate of Pb application showing a negative relation between Pb and P (Table-24 and Figure-61). This observation also found in case of wheat in pot experiment. Among three varieties of wheat in the field the maximum concentration of phosphorus (0.102, 0.075 and 0.491% in root, shoot and grain, respectively) were obtained in $V^0_{1,}$ V^0_1 and V^0_3 and the minimum concentration (0.056, 0.026 and 0.215% in root, shoot and grain, respectively) at V^2_2 variety. The decreased in nitrogen concentration in prodip, shotabdi and BARI wheat-26 root were 24.5, 32.5, 22.9%, shoot: 22.7, 21.2, 19.1% and grain: 11.2, 31.7, 16.7% with 100 ppm Pb application compared with their control. Similar findings were also observed by many scientists (Muchrimsyah and Mercado, 1990; Lamhamdi *et al. (*2013). Due to adverse or antagonistic effect of Pb, the uptake of P by rice and other plants decreased significantly (Frostegard *et al*., 1993; Gigliotte *et al.,* 1990).



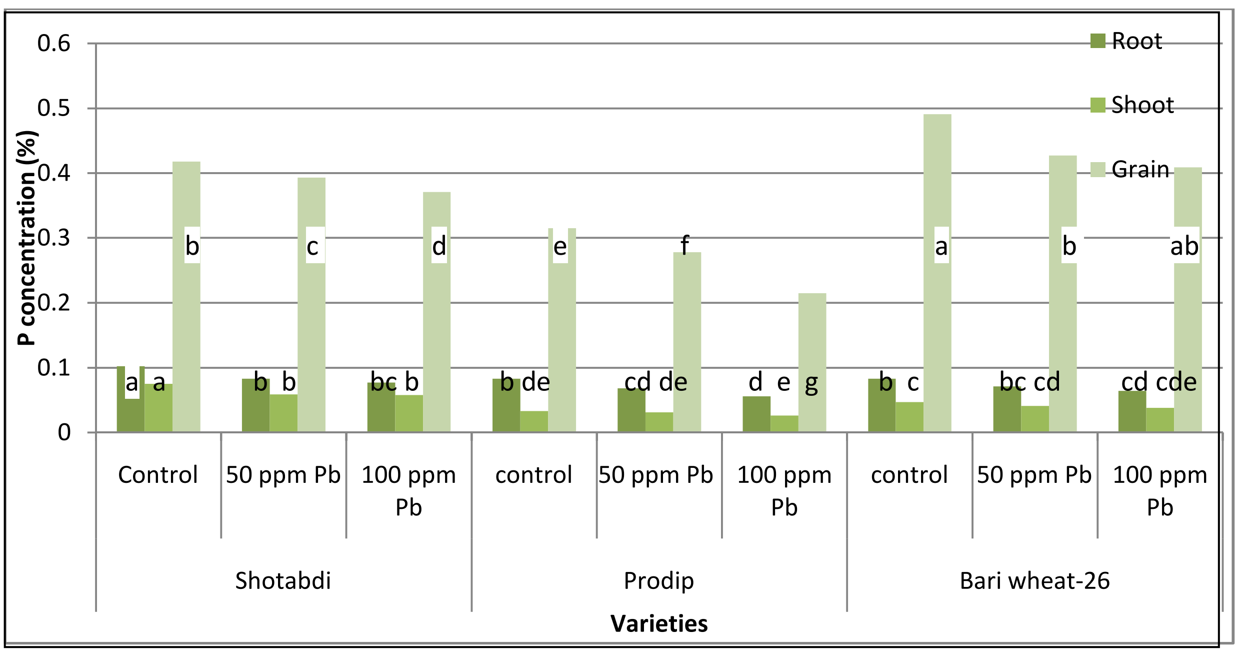


Fig-61: Effects of different doses of Pb on N and P concentration (%) of different wheat varieties in the field.

4.2.1.9. Potassium Concentration

The potassium concentration in root, shoot and grain of different wheat varieties varied significantly by Pb application in the field (Table-24 and Figure-62). Among three varieties of wheat the maximum concentration of potassium (0.72, 1.66 and 0.59 % in root, shoot and grain respectively) were obtained in the V^0_3 (BARI wheat-26, control), V^0_2 (Prodip, control) and V^0_2 (Prodip, control) and the minimum concentration (0.183, 1.12 and 0.48% in root, shoot and grain respectively) in V^2_2 (Prodip 100 ppm Pb) and V^2_3 (BARI wheat-26 with 100 ppm of Pb) treatments. Potassium concentration in root, shoot and grain were decreased by16.7, 44.6 and 68.1% in Shotabdi, 14.4, 29.5 and 25.3% in Prodip and 16.9, 13.6, 15.8% in BARI wheat-26 variety respectively with the highest rate of Pb (100 ppm) application compared to that with the control. From the data it was evident that application of lead significantly reduced the potassium concentration in root, shoot and grain of all wheat varieties in field. Shoot accumulated more potassium than root and grain which was also observed in case of pot experiments, probably maintained the mobility and ion balance in shoot. Similar results were also found by Lamhamdi *et al. (*2013) and Batti *et al*. (2013) in wheat.

4.2.1.10. Calcium Concentration

The mean values of calcium concentration in the root and shoot of shotabdi, prodip and BARI wheat-26 as affected significantly by different Pb treatments (0, 50 and 100 ppm) in the field, where as calcium concentration in grain of all wheat varieties were not differed significantly (Table-24 and Figure-62). Calcium concentration in root and shoot was decreased by 62.1, 50.6% in Shotabdi, 83.7, 34.5% in Prodip and 93.5, and 22.0% in Bari wheat -26 variety, respectively with the highest rate of Pb (100 ppm) application compared to the control. This might be due to the interaction of Pb with Ca in soil and Ca became less available to wheat. Similar results were also found by Lamhamdi *et al. (*2013) in wheat, Hung and Cuningham (1996) with corn, Kibria *et al.* (2008) in rice, radish and Indian spinach. However, the same Pb treatments did not significantly affect Ca concentration in grains of all wheat varieties in the present study.

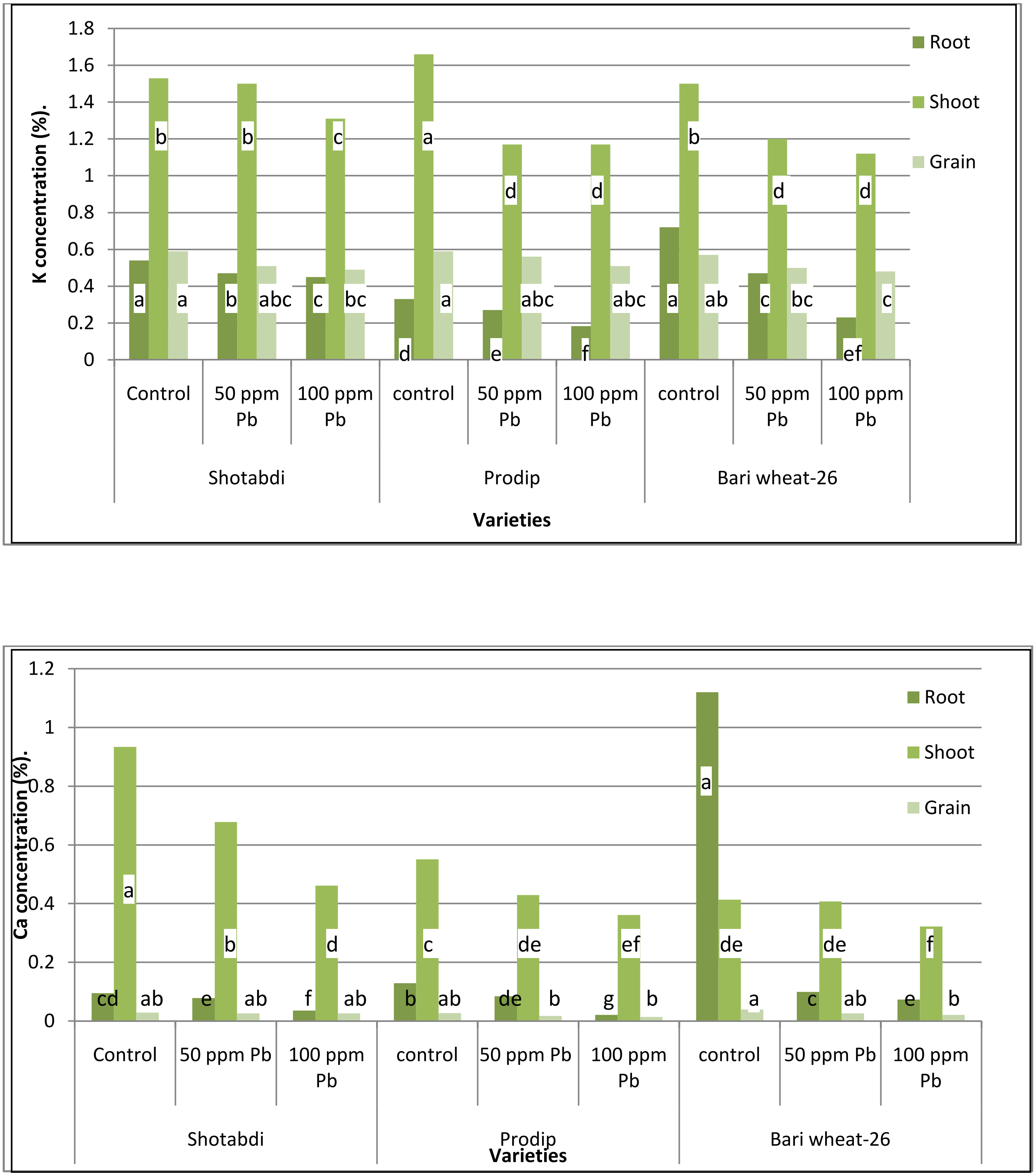


Fig-62: Effects of different doses of Pb on K and Ca concentration (%) of different wheat varieties in the field.

4.2.1.11. Magnesium Concentration

Magnesium concentration in shoot and grain of three wheat varieties showed gradual decrease over control with all rates of Pb and the lowest values were obtained with the highest rate of Pb application in all cases (Table-24 and Figure-63) whereas root magnesium concentration of all wheat varieties were not differed significantly. There were no differences observed in all treatments in case of shoot of BARI wheat-26 variety. From the results, it was evident that the higher the concentration of Pb the lower was the concentration of magnesium in root, shoot and grain of all wheat varieties in the field and this might be due to antagonistic effects of Pb with those nutrient. Similar results were also found by Lamhamdi *et al. (*2013) in wheat, Hung and Cuningham (1996) with corn and ragweed, Kopittke *et al.* (2007a) with cowpea.

4.1.1.12. Lead Concentration

Addition of lead (Pb) in soil increased the concentration of Pb in root, shoot and grain of all varieties of wheat remarkably as compared with their control in the field (Table-24 and Figure-63). Among three varieties of wheat the maximum concentration of lead (515.0, 45.0 and 23.50 ppm in root, shoot and grain respectively) was obtained in the V^2_3 (BARI wheat-26, 100 ppm of Pb) and the minimum concentration (35.01, 14.0 and 5.15 ppm in root, shoot and grain respectively) in V^0_2 (Prodip, control) and V^0_1 (Shotabdi, control) treatments. From results it was evident among three varieties of wheat that at 100 ppm of Pb application (Shotabdi) had the ability to withstand Pb-stressed soil and concentrate less amount of Pb in root, shoot and grain and hence a better capability to produce root, shoot and grain production and BARI wheat-26 variety had a greater ability to absorb Pb in root, shoot and grain under Pb stressed condition and produces less root, shoot and grain biomass as well as less yield which was also observed our present study in case of pot experiment. Tolerance of Shotabdi to Pb stress was related to its strong ability to convert toxic Pb into non-toxic Pb. Cheng *et al.* (2015) showed that the wheat varieties of Zhengdan 958 and longping 206 have the maximum Pb tolerance, whereas Lianchuang 5's tolerance of Pb was the minimum. Chamon *et al*. (2006a) reported that Pb concentrations were lowest in Agrani and highest in Kanchan (wheat variety). Varieties differed significantly in Pb uptake and translocation (Huang and Cunningham., 1996). Tolerance of Zhengdan 958 to Pb stress was related to its strong ability to convert toxic Pb into non-toxic Pb.

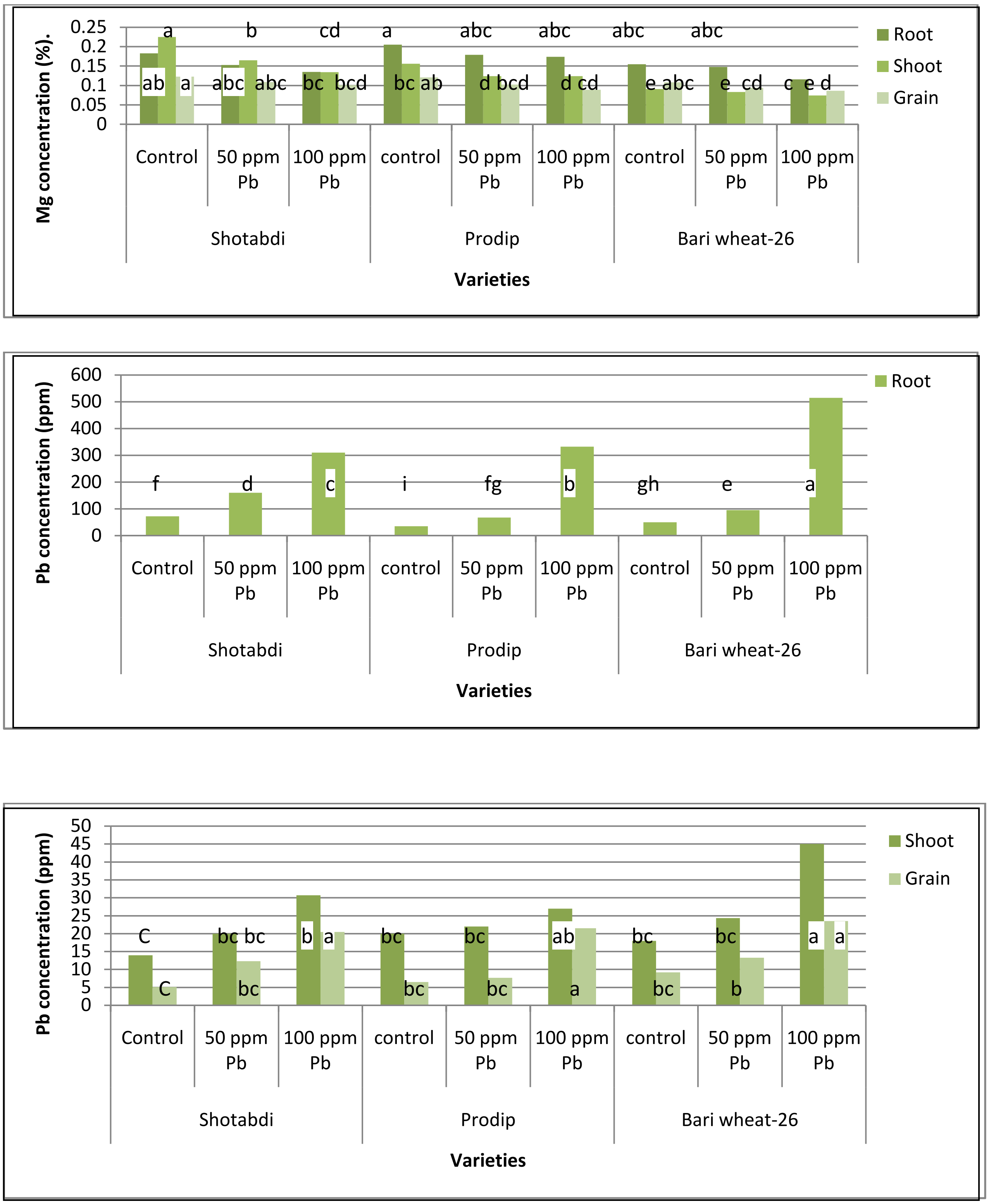


Fig-63: Effects of different doses of Pb on Mg (%) and Pb (ppm) concentration of different wheat varieties in the field.

4.2.2. Experiment-2: Field experiment: Maize: Effects of different doses of lead (Pb) on growth, yield and mineral nutrition of Maize (variety: Bari Maize-9) in the field

4.2.2.1. Fresh and dry weight of grain

The fresh and dry weight of maize (variety: BARI maize-9) grain differed considerably among different levels of Pb treatment (0, 50 and 100 ppm) in the field (Table-25 and Figure-64). The highest fresh and dry weight of grains/plot (682.2 and 435.7g) was obtained in the $v^0{}_1$ treatment where no lead was applied. The lowest value (599.3 and 373.6 g) was in the $v^2{}_1$ treatment (at 100 ppm Pb). All treatments differed significantly in both cases. At the highest dose of Pb application (100 ppm Pb), fresh and dry weight of grain in the field decreased by 12.2 and 14.3%, respectively compared with the control treatment. Similar results were also reported by Lubis. (1988), Kim *et al*. (1986), Santos-Diaz and Cirugenda-Delgado, (1992).

4.2.2.2. Fresh and dry weight (g) of shoot

Lead (Pb) application in soil significantly affected the fresh and dry weight of shoot in the field (Table-25 and figure-64). The maximum fresh and dry weight of shoot $plot^{-1}$ was 832.2 and 751.6 g obtained in the control ($v^0{}_1$) treatment where no lead was applied. The lowest value was 476.2 and 389.2 g in the treatment $v^2{}_1$ (at 100 ppm Pb). The fresh and dry weight of shoot of maize, being the highest with Pb @ 100 ppm which was 42.8 and 48.2% lower compared to that of the control plant. All treatment differed significantly in case of dry weight of shoot whereas no difference being observed between $v^1{}_1$ and $v^2{}_1$ treatments in case of fresh weight of shoot. The higher the concentration of Pb the lower was the fresh and dry weight of maize shoot. The reduction of shoot biomass by Pb toxicity could be the direct consequences of the inhibition of chlorophyll synthesis and photosynthesis (Chitterjee *et al.,* 2004). Similar phenomena were also described by Huang and Cunningham (1996) in corn and ragweed, Kopittke *et al*. (2007a) in cowpea (*Vigna unguiculata*) and Akinci *et al*. (2010) in tomato.

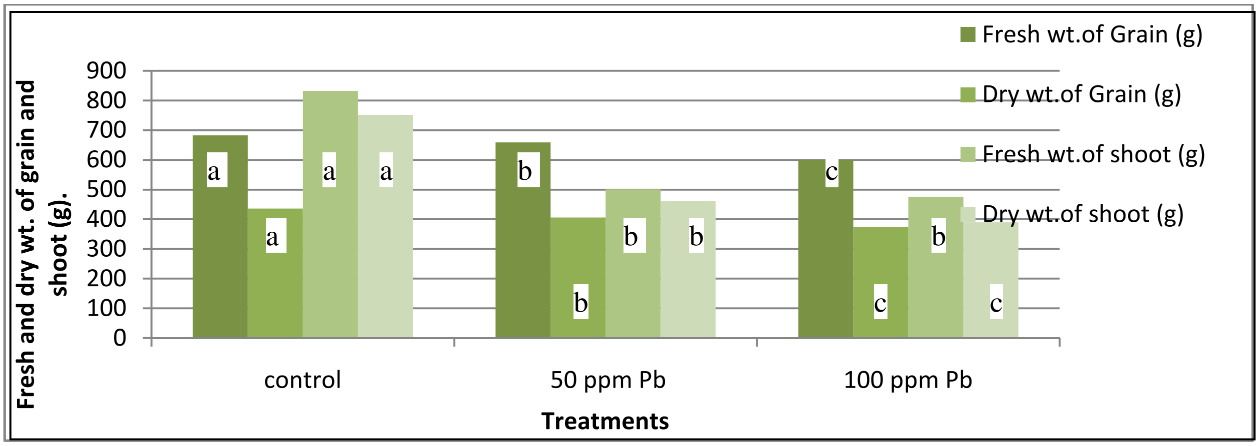


Fig-64: Effects of different doses of Pb on fresh and dry wt.(g/plot) of grain and shoot in maize in the field.

4.2.2.3. Fresh and dry weight (g) of root

The fresh and dry weight of root per plot (g) of maize (variety: BARI maize-9) was notably affected by Pb application (Table-25 and figure-65). The highest fresh and dry weight of root plot^{-1} was 188.31 and 108.13g in the v^0_1 treatments where no lead was applied. The lowest 88.53 and 34.30 g was obtained in the v^2_1 treatment, at 100 ppm Pb. Fresh and dry weight of root was decreased significantly with increasing Pb concentration. At the highest dose of Pb application (100 ppm Pb), fresh and dry weight of root decreased by 53.0 and 68.3% respectively, compared with the control. Similar phenomenon was reported by Huang and Cunningham (1996) in corn and ragweed, Akinci *et al*. (2010) in tomato.

4.2.2.4. Shoot and root length (cm), 1000 grain weight and yield t/ha

The root length, 1000 grain weight of maize (variety: BARI maize-9) were significantly affected by Pb application in the field whereas the effect of Pb on shoot length and yield (t/ha) was not varied significantly (Table-25 and figure-65). The maximum and the minimum length of root and 1000 grain weight were obtained in v^0_1 (control) and v^2_1 (100 ppm of Pb) treatments. In case of root length v^0_1 significantly deferred from other treatments but there were no differences between v^1_1 and v^2_1 treatments, respectively. In case of shoot length and yield (t/ha), there was no significant difference among the treatments though application of Pb decreased shoot length and yield (t/ha). 1000 grain weight was decreased by 21.38% with the highest rate of Pb (100 ppm) application compared with the control and all treatments differed significantly. Shoot and root length decreased due to reduction of meristematic cells in the shoot and root region by the accumulation of Pb. Ghani (2010) also reported the reduction of height in maize due to application of Pb. Hussain *et al.* (2013) reported that the growth retardation of maize was due to metals toxicity that resulted in damages to various physiological and biochemical processes.

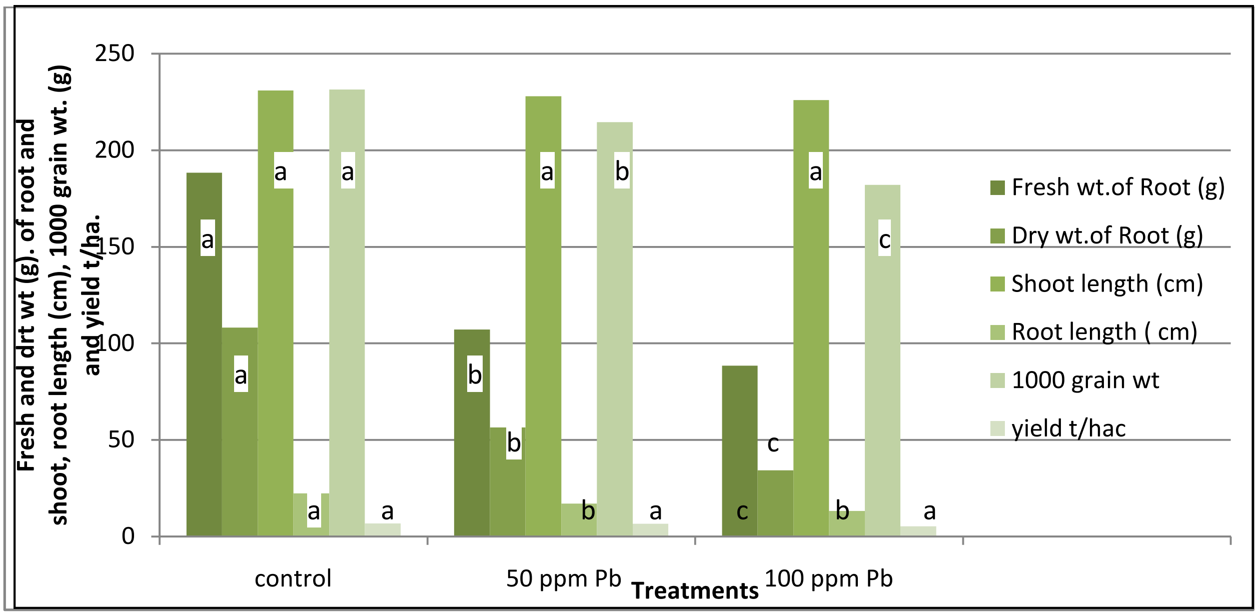


Fig- 65: Effects of different doses of Pb on fresh and dry wt. (g/plot) of root and shoot, root length (cm), 1000 grain wt. (g/plot) and yield (t/ha) in maize in the field.

4.2.2.5. Nitrogen Concentration

Nitrogen concentration in root and grain of maize (variety: BARI maize-9) increased significantly with increasing Pb concentration (Table-25 and Figure-66) but in case of shoot N concentration decreased significantly with increasing Pb concentration and all treatments differed significantly from each other. The decline in nitrogen concentration due to Pb may be as a result of moisture stress created by Pb (Burzynisky and Grabowski, 1984). Pb blocks the entry of N in the root system (Sharma and Dubey, 2005).

4.2.2.6. Phosphorus Concentration

Phosphorus concentrations in root, shoot and grain of maize (variety: BARI maize-9) decreased considerably with increasing Pb concentration in the field (Table-25 and Figure-66) which was also observed in case of pot experiment. The maximum concentration of P was found in control (V^0_1) treatment and the minimum in the v^2_1 treatment in case of root, shoot and grain. All treatments differed significantly both in shoot and grain phosphorus concentration but in case of root P cocentration, no difference being observed among the v^0_1 and v^1_1 treatments. From the result it may be concluded that application of lead reduced the concentration of phosphorus in root, shoot and grain of maize. This might be due to block the entry of P in the root system by Pb. Similar phenomena were also reported by Paivoke (2002), Orhue and Inneh (2010) and Walker *et al.* (1997).

4.2.2.7. Potassium Concentration

Potassium concentration in grain of maize was not affected by Pb application (Table-25 and Figure-66). However Pb application significantly decreased potassium concentration in root and shoot of maize in the field. The maximum concentration of potassium (0.96, 1.36 and 0.43% in root, shoot and grain, respectively) were obtained in the control treatment (v^0_1) and the minimum concentration (0.47, 1.17 and 0.38% in root, shoot and grain respectively) in v^2_1 treatment. Potassium concentration in root, shoot and grain were decreased by 51.0, 14.0 and 11.6%, respectively with the highest rate of Pb (100 ppm) application compared to that with the control. From the data it was evident that application of lead reduced the potassium concentration in root, shoot and grain of maize. This might be due to the antagonistic effect of Pb on K uptake in maize plant. The results are in conformity to those of Walker *et al.* (1997), Orhue and Inneh (2010) and Akinci *et al.* (2010).

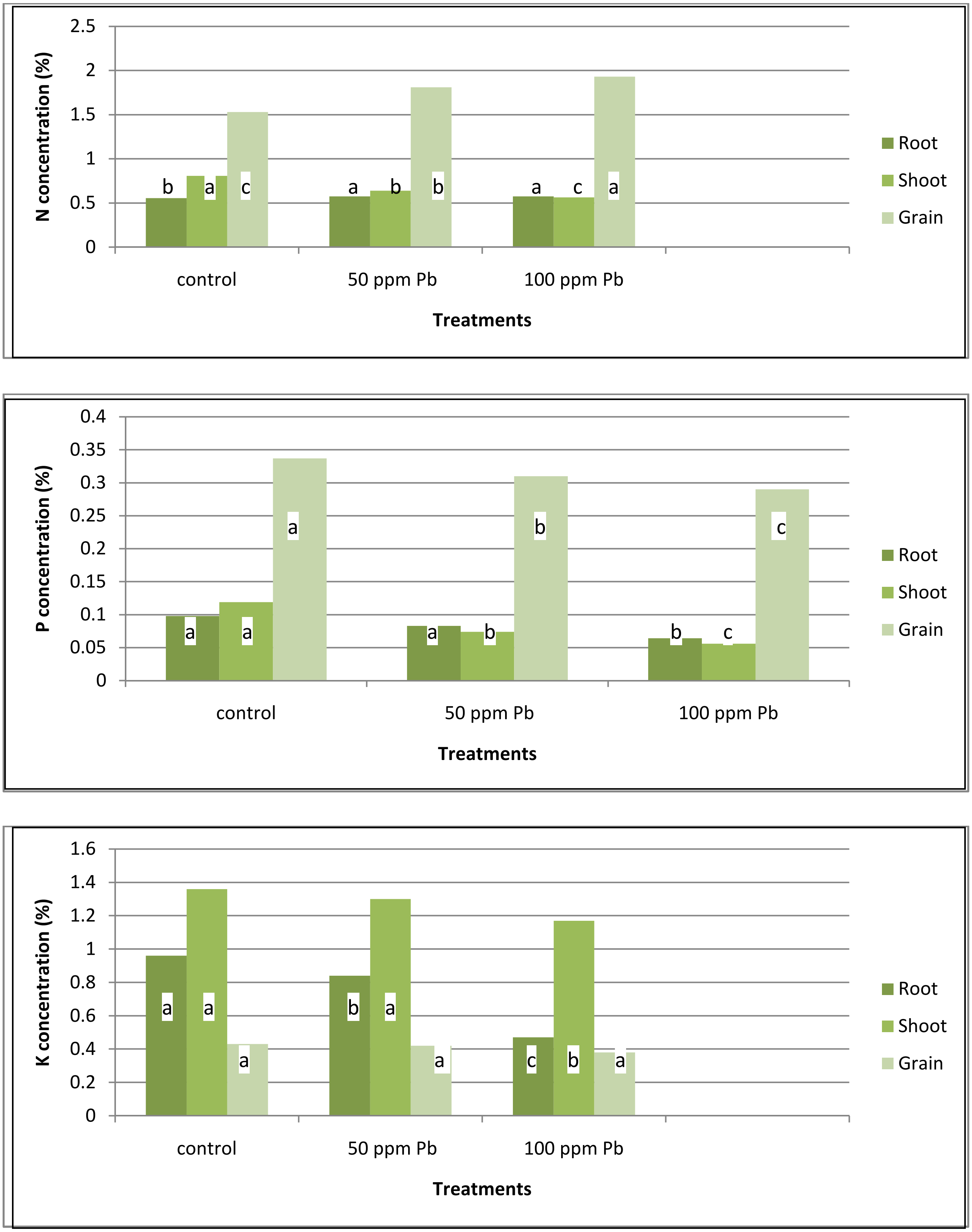


Fig-66: Effects of different doses of Pb on N, P and K concentration (%) of maize in the field.

4.2.2.8. Calcium Concentration

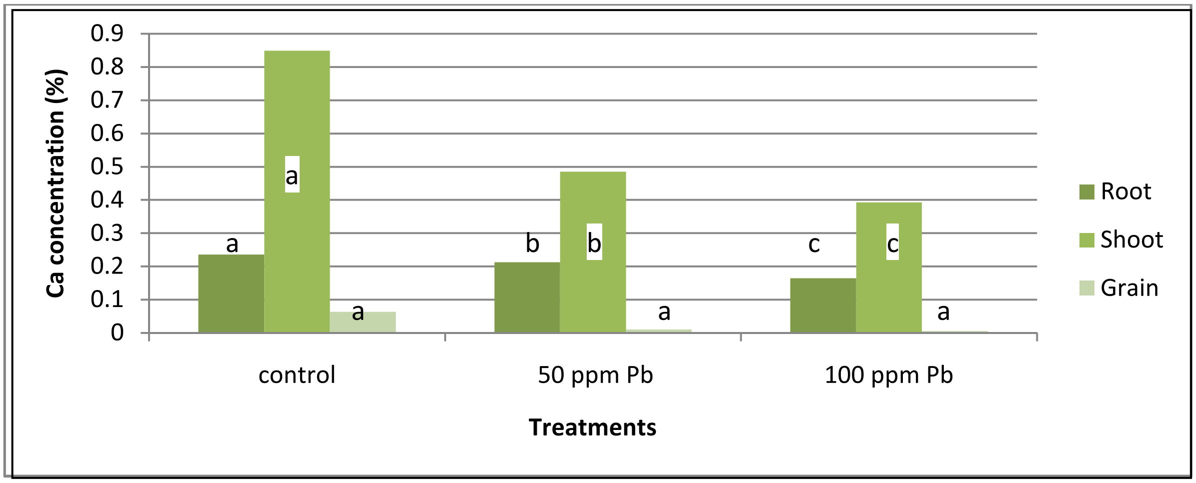
Calcium concentration in root and shoot of maize significantly decreased by Pb application whereas its effect on grain was not significant in the field (Table-25 and Figure-67) which also observed in case of pot experiment. The maximum calcium concentration in maize was noted in the control (v^0_1) and the minimum concentration in v^2_1 (100 ppm of Pb) treatment and all treatment differed significantly in both case of root and shoot Ca concentration. The decrease in Ca concentration in the roots in response to higher concentration of Pb was probably a result of osmotic adjustment (Azmat and Haider, 2007). Similar results were also reported by Hung and Cuningham (1996) with corn.

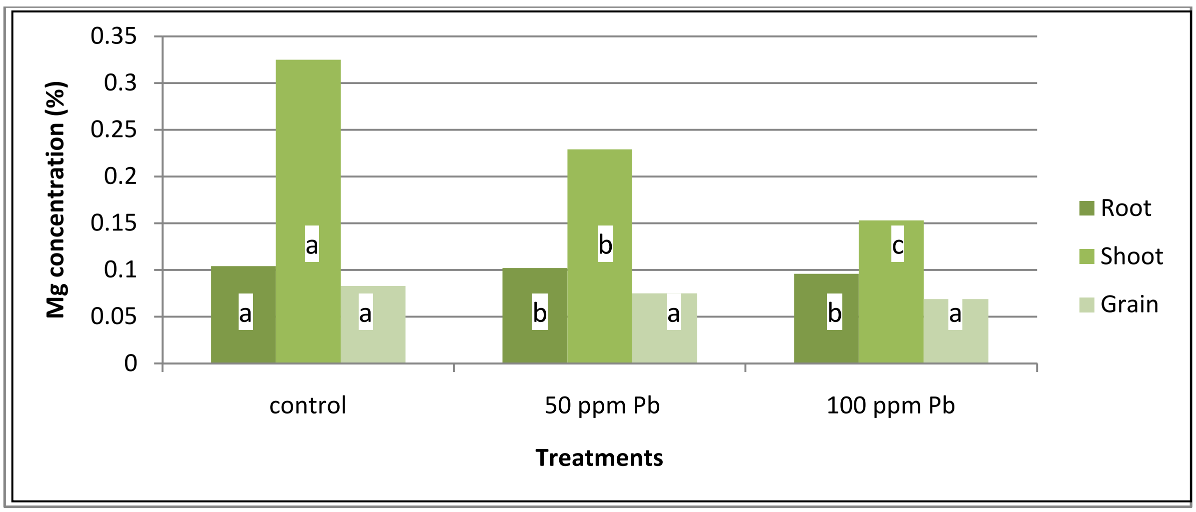
4.2.2.9. Magnesium Concentration

Magnesium concentration in root and shoot of maize (variety: BARI maize-9) significantly decreased by Pb application (Table-25 and Figure-67) but its concentration in grain was not differed significantly. The maximum concentration of magnesium in root, shoot and grain of maize was noted in control (v^0_1) and the minimum concentration in v^2_1 (100 ppm of Pb) treatment respectively in all cases. A gradual decrease in Mg concentration in the root, shoot and grain parts of maize was observed with increasing rates of Pb application. This might be due to antagonistic effects of Pb with that nutrient. Similar results were also found by Cuningham (1996) with corn and ragweed and Walker *et al*. (1997) with *Cucumis sativus* seedlings and *Zea mays.*

4.2.2.10. Lead Concentration

The lead concentration of root, shoot and grain of maize increased significantly with Pb treatment (Table-25 and Figure-67). The highest concentration of lead was noted at 100 ppm of Pb-treated plants and the lowest was in the control treatment. All treatments differed significantly from each other in all cases. Increasing Pb concentration in soil caused an increase in Pb concentration in root, shoot and grain of maize crops in the field which was also observed in case of pot experiment. Similar results were observed by Ghani *et al.* (2010) in maize and Irfan (2010) in tomato.





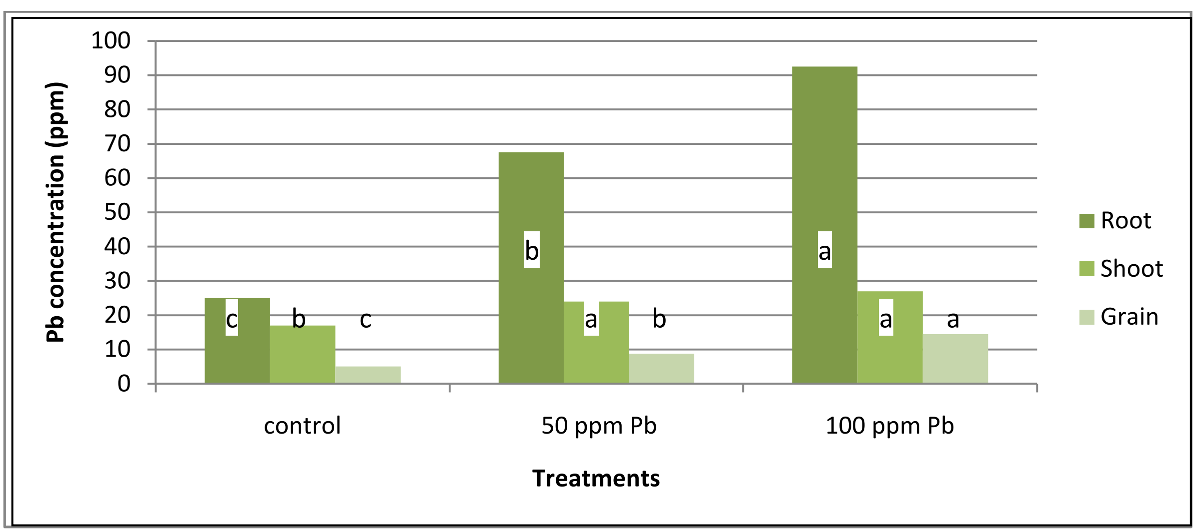


Fig-67: Effects of different doses of Pb on Ca, Mg (%) and Pb (ppm) concentration of maize in the field.

Summary and conclusion

Pot experiments were conducted in the Research field of Soil Science Department under Govt. Bangla College, Dhaka, at different doses of Pb (0, 50, 100, 150 and 200 ppm) and different amendments (cowdung, poultry litter and lime) and rice (variety: BRRIdhan-49), wheat (variety: BARI wheat-26) and maize (variety: BARI maize-9) were grown as test cereal crops.For varietal remediation of soils with 200 ppm Pb using four rice varieties (BRRIdhan- 33, 49, 53 and 54) and three wheat varieties (Shotabdi, Prodip and BARI wheat-26). A field experiment was also conducted to investigate the effect of different Pb doses (0, 50 and 100 ppm) on above mentioned wheat varieties and one maize variety (BARI maize-9). Lead concentrations were below the tolerable limit in all soil and amendments (Tolerable limit of Pb: 100 ppm).During experimental period growth and yield parameters of root, shoot, grain and total concentrations of N, P, K, Ca, Mg and Pbin rice, wheat and maize root, shoot and grain were determined and results are summarized below:

Pot experiments

Comparison among treatments (different doses of Pb)

Rice (variety: BRRIdhan-49) was grown on soil with application of 0, 50, 100, 150 and 200 ppm of Pb in the pot and results showed that a gradual decrease in the growth and yield parameters of rice with increasing Pb concentration except fresh wt. of grain increased upto 50 ppm of Pb treatment then decreased with increasing level of Pb as compared with the control treatments. Besides, application of Pb declined the N concentration in root and shoot, P, K, Ca, Mg concentration in root, shoot and grain however, grain N concentration increased significantly up to 100 ppm of Pb applied treatment then decreased and also increased Pb concentration in root, shoot and grain of rice with increasing Pb concentration compared with that of control treatment.

Comparison among amendments (different amendments with 100 ppm of Pb)

The amelioration of Pb toxicity in rice (variety: BRRIdhan-49) was examined by adding various amendments: cowdung, poultry litter and lime with application of 100 ppm of Pb. The results showed that application of Pb reduced the growth and yield parameters, N concentration in root, shoot, P, K, Ca and Mg concentration in root, shoot and grain and increased N concentration in grain and Pb concentration in root, shoot and grain as compared with control treatments. All amendments significantly declined Pb concentration and increased growth and yield parameters. Amongst soil amendments cowdung had greater ability to enhanced N, P and Mg and reduced Pb concentration of root, shoot and grain of rice against Pb toxicity. Besides poultry litter enhanced the K concentration in shoot, grain and lime increased the Ca concentration in root and shoot.

Comparison among Rice varieties with addition of 200 ppm of Pb

Rice varieties (BRRIdhan-33, 49, 53 and 54) with 200 ppm of Pb results also showed differences in their growth and yield production and mineral nutrition.V_4 (BRRIdhan-54) variety had the highest ability to increase fresh and dry weight (g) of grain, shoot, root, number of grains/panicle, root and panicle length and 1000 grain weight (g) and N, Ca concentration in root, shoot and grain, P in grain, K in root and grain, Mg in root, shoot significantly against Pb toxicity and accumulate less Pb concentration as compared with other varieties and V_2 (BRRIdhan-49) accumulated highest Pb and its agronomic parameter and nutrient concentration is less. Besides these V_1 (BRRIdhan-33) had highest ability to absorb P in root, shoot, K in shoot, and Mg in grain.

Comparison among treatments (different doses of Pb)

Wheat (variety: BARIWheat-26) Application of different doses (0, 50, 100, 150 and 200 ppm) of Pb in wheat (variety: BARI wheat-26) in the pot experiment, result showed that except fresh and dry weight of grain and K concentration in root increased upto 50 ppm of Pb application other growth and yield parameters and N, P, Ca and Mg concentration in root, shoot and grain, K concentration in shoot and grain were decreased and Pb concentration increased with increasing Pb concentration as compared with their control.

Comparison among treatments (different amendments with 100 ppm of Pb)

Wheat (variety: BARI wheat-26) Application of 100 ppm of Pb significantly decreased the growth and yield parameters, N, P, K, Ca, Mg concentration and increased the Pb concentration in root, shoot and grain of wheat as compared with their control. All amendments with 100 ppm of Pb increased the growth and yield parameters and the highest being observed in cowdung followed by poultry litter and lime except 1000 grain weight, the highest (46.43 g/pot) being observed in lime followed by cowdung and poultry litter treatments. Amongst amendments cowdung had greater ability to reduced Pb concentration and increased N, P, K concentration in root, shoot and grain and Mg concentration in root and grain. Besides liming enhanced the Ca concentration in root, shoot, grain and Mg concentration in shoot.

Comparison among varieties with addition of 200 ppm of Pb (Wheat) Comparison among wheat varieties (Shotabdi, Prodip and BARI wheat-26) with 200 ppm of Pb result showed that variety V_3 (BARI wheat-26) accumulated the highest Pb concentration in root, shoot and grain which exhibited lesser growth, yield and mineral nutrient content and V_1 (Shotabdi) had the ability to withstand Pb stressed soil and concentrate less amount of Pb in root, shoot and grain.

Comparison among treatments (different doses of Pb)

Maize (variety: BARI Maize-9) Application of different doses (0, 50, 100, 150 and 200 ppm) of Pb in Maize (Variety: BARI maize-9) in the pot experiment, result showed that growth and yield parameters, P, K, Ca and Mg concentrations were decreased and increased N concentration significantly in root (all treatment), shoot and grain (upto 150 ppm of Pb treatment) and Pb concentration in root, shoot and grain as compared with their control.

Comparison among amendments (different amendments with 100 ppm of Pb)

Maize (Variety: BARI Maize-9) Application of 100 ppm of Pb significantly decreased the growth and yield parameters, P, K, Ca, Mg and increased the N, Pb concentration in root, shoot and grain of maize as compared with their control. Amongst amendments cowdung had greater ability to reduced Pb concentration in root, shoot and grain followed by poultry litter and lime and also increased N, P in root, shoot and grain, K in shoot and grain and Ca in grain, Mg concentration in shoot as compared with 100 ppm of Pb treated treatments.

Field experiment

Comparison among wheat varieties (different doses of Pb)

Application of different doses (0, 50 and 100 ppm) of Pb in wheat varieties (Shotabdi, Prodip and BARI wheat-26) in the field, results showed that growth, yield parameters and N, P, K, Ca, Mg concentration decreased and Pb concentration increased significantly with increasing Pb concentration in all varieties of wheat.

Comparison among treatments (different doses of Pb) on Maize Application of different doses (0, 50 and 100 ppm) of Pb in Maize (Variety: BARI maize-9) in the field, result showed that growth, yield parameters and P, K, Ca, Mg concentration in root, shoot and grain decreased significantly and N concentration in root and grain and Pb concentration in root, shoot and grain increased significantly with increasing Pb concentration.

Comparison among crops (different doses of Pb) Comparison among rice, wheat and maize with different Pb treatments results showed that rice root accumulated highest amount of Pb where as wheat shoot and grain accumulate highest Pb and maize root, shoot and grain accumulated lesser amount of Pb in pot experiment. Among three wheat varieties and one maize variety grown on field with different doses of Pb showed that maize root, shoot and grain accumulated less Pb compared to the wheat varieties.

Comparison among crops (different amendment) All amendment reduced Pb concentration and cowdung was the best to ameliorate Pb toxicity in rice, wheat and maize but in rice and wheat followed the sequence cowdung>lime>poultry litter and in maize cowdung>poultry litter>lime.

The result of the present investigation showed some specific indications:

Lead (Pb) causes adverse/negative effects on growth, yield and yield attributes of cereal crops.

In absence of Pb rice, wheat and maize crops showed better performance in respect to growth, yield and mineral nutrient concentration.

Application of Pb significantly increased Pb concentration in all crops and total N concentration in maize and reduced the P, K, Ca and Mg concentration in root, shoot and grain of all crops.

All amendments (cowdung, poultry litter and lime) reduced Pb concentration and increased growth, yield and mineral nutrient concentration of all crops but amongst them cowdung had greatest ability to ameliorate Pb toxicity.

Rice and wheat varieties exhibited different susceptibilities to Pb treatments.

Among Pb stressed four rice varieties, V_4 variety (BRRIdhan-54) showed better performance and had the ability to withstand Pb toxicity and V_2 variety (BRRIdhan-49) had least ability to withstand Pb toxicity.

In comparison among Pb stressed three wheat varieties, V_3 variety (BARI wheat-26) was found to be sensitive to Pb toxicity and V_1 (Shotabdi) had the ability to withstand Pb toxicity.

BRRIdhan-54and BARI wheat-26 can be taken as Pb tolerant variety and can be used for developing low Pb accumulating new varieties through breeding/genetic engineering.

As BRRIdhan-49 and BARI wheat-26 varieties Pb sensitive can be used for developing new varieties through breeding/genetic engineering for cleaning soils of Pb contaminating areas of Bangladesh.

Maize accumulated less Pb in root, shoot and grain than rice and wheat.

The result of the present investigation clearly demonstrates the effects of Pb and possible remediation of Pb toxicity particularly for cereal crops of Bangladesh (Rice, Wheat and Maize). However, further trials are suggested to be conducted at different Agro Ecological Zones (AEZ) of Bangladesh. Similar experiments also are undertaken with other nutrients (Macro and Micro nutrient). Further research is needed to fully understand the effects of cowdung on crop Pb accumulation. The most important action, which should be taken into consideration in order to control the Pb contaminated sites in Bangladesh is sharply decreased further emission and should to be use lead free gasoline, compressed natural gas in vehicles and catalyser plants, which are resistant to the Pb toxicity should be found out.

References

Adriano, D. C.; Albright, J.; Whicker, F. W.; Iskander, I. K. and Sherony, C. 1997. "Remediation of metal-and radionuclide-contaminated soils," In. Advances in Environmental science- Remediation of soils contaminated with Metals. I.K. Iskander and D.C. Adriano (eds). Cambrian Printers, Aberystwyth, Wales, UK.pp. 27-46.

Ahmad, S. A.; Khan, M. H.; Khandker, S.; Sarwar, A. F. M. 2014. Blood Lead Levels and Health Problems of Lead Acid Battery Workers in Bangladesh. The Scientific World Journal Volume 2014 (2014), Article ID 974104, 7 pages. http://dx.doi.org/10.1155/2014/974104

Ahmed, H. R.; Ghafoor, A.; Corwin, D. L.; Aziz, M. A.; Sailfullah and Sabir, M. 2011. Organic and inorganic amendments affect soil concentration and accumulation of cadmium and lead in wheat in Calcareous Alkaline soils. Institute of soil and environmental science, University of Agriculture, Faisalabad, Pakistan communications in soil science and plant analysis, 42:111-122.

Akinci, I. E.; Akinci, S. 2010. Yilmaz K. Response of tomato (Solaman lycopersicum L.) to lead toxicity: growth, element uptake, chlorophyll and water content. Afr. J. Argic. Res. 2010;5:416-423.

Alamgir, M. M. G.; Kibria and Islam, M. 2011. Effects of farm yard manure on cadmium and lead accumulation in Amaranth (*Amaranthus oleracea L.*).Journal of Soil Sci. and Environmental Management Vol. 2(8). Pp. 237-240.

Aliyu, H. G. and Adamu, H. M. 2014. The potential of maize as Phytoremediation tool of heavy metals Chemistry Programme, Abubakar Tafawa Balewa University, Bauchi.European Scientific Journal February 2014 edition vol. 10, No. 61SSN: 1857-7881.

Allaway, W. H. 1968. Agronomic controls over the environmental cycling of trace elements. Adv. Agron. 20: 253-274. department of Soil Science, University of Agriculture, Faisalabad, Pakistan.

ATSDR, 2008. Agency for Toxic Substances and Disease Registry. 06 de fevereiro. Disponevel http://www.atsdr.cdc.gov/cercla/05list.html.

Azmat, R. and Haider, S. 2007. Pb stress on photochemistry of seedlings of phaseolus mungo and lens culinaris. Asian Journal of plant Sciences 6(2): 332-337.

Bai, X. Y.; Dong, Y. J.; Wang, Q. H.; Kong, J. 2015. Effects of lead and nitric oxide on photosynthesis, antioxidative ability, and mineral element content of perennial ryegrass. January 2015, Volume 59, Issue 1, pp 163-170.

Bangladesh Bureau of Statistics (BBS), 2004. Baseline Survey on Child Workers in Battery Recharging/Recycling Sector 2003-2004, Planning Division,

Bassuk, N. L. (1986) Reducing lead uptake in lettuce. Hort. Science. vol.21(4), pp. 993-995.

Batti, K. H.; Anwar, S.; Nawaz, K.; Hussain, K. 2013. Effect of heavy metal lead (Pb) stress of different concentration on wheat (*Triticum aestivum* L.). Middle east journal of scientific research 14 (2): 148-154, 2013. ISSN 1990-9233.

Begonia, G. B.; Davis, C. D.; Begonia, F. T.; Gray, C. N. 1998. Growth responses of Indian mustered (Brassica juncea L. Czern.) and its phytoextraction of lead from a contamination soil. Bull. Environ. Contam. 61, 38, 1998.

Berti, W. R. and Cunningham, S. D. 1994. Remediating soil lead with green plants. In. Trace substances, Environment and Health. A successor to the series " Trace substances in Environmental Health. C. Richard Cothern (ed). Science Reviews. Northwood, pp. 43-51.

Bhatti, K. H. S.; Anwar, K.; Nawaz, K.; Hussain, E. H.; Siddiqi, 2013. Effect of Heavy Metal Lead (Pb) Stress of Different Concentration on Wheat (*Triticum aestivum* L.). Middle-East Journal of Scientific Research 14 (2): 148-154, ISSN 1990-9233.

Black, C. A. (1965) Methods of soil analysis, part 1, and part 2 . Soc. Of Agron. Inc. publisher, Wisconsin, USA.

Blaylock, M. J. 2000. Field demonstration of phytoremediation of lead contaminated soils. In Terry, N. and Banuelos, G. eds. Phytoremediation of contaminated soil and water. Lewis publishers, Boca Raton London, 1-12.

Blum, W. E. H.; Spiegel, and Wenzel, W. W. 1996. Bodenzutstandsinventur.Konception, Durchführung und Bewertung, EmpfehlungenZurVereinheitlichung der Vorgangsweise in Österreich.Bundesministeriumfür Land und Forstwirtschaft, Wien.2nd edition. Pp. 102-103.

Bodak, I.; Lyman, W. J.; Reehl, W. F. and Rosenblatt, D. H. 1988. Environmental inorganic chemistry properties, processes and estimation methods. Pergamon press, Oxford., England.

Bolan, N. S.; Adriano, D. C.; Mani, P. A. and Duraisamy, 2003. Immobilization and phytoavailability of cadmium in variable charge soils, II: Effect of lime addition. *Plant and Soil* 251:187–198.

Boman, J.' Gatari, M. J.; Wagner, A.; Hossain, M. I. 2005. Elemental characterization of aerosols in urban and rural locations in Bangladesh. X-ray Spectrometry. 2005;34:460–467.

Bowen, H. J. M. 1966. Trace elements in Bio chemistry. Academic Press, London. Pp.113-120.

Breckle, S.W. 1991. Growth under Stress**:** Heavy Metal. In: Plant Roots: The Hidden Half. (Eds.):Y. Waisel, A. Eshel and U. kafkafi. Marcel Dekker, New York, pp. 351-373.

Brook, R. R. 1998. Plants that Hyperaccumulate Heavy Metals. CAB international, Wallingford, 379.

Burzynski, M. and Grabowski, A. 1984. Influence of lead on nitrate uptake and reduction in cucumber seedlings, yield and metabolism of rice. Communications in Soil Science and Plant Analysis 35:255-265.

Cao, R. X.; Ma, L. Q. ; Chen, M.; Singh, S. P. and Harris, W. G. 2003. Phosphate-induced metal immobilization in a contaminated site. *Environmental Pollution* 122:19–28.

Castadi P, Melis, P.; Silvetti, M., Deiana, P. and Garau, G. 2009. Inflence of pea and wheat growth on Pb, Cd and Zn mobility and soil biological status in a polluted amended soil. Volume 151, pages 241-248

.

Chamon, A. S.; Gerzabek, M. H.; Mondol, M. N.; Ullah, S. M.; Rahman, M. and Blum, W. H. 2011. Influence of cereal varieties and site conditions on heavy metalaccumulation in cereal crops on polluted soils of Bangladesh. Communications in Soil Science and Plant Analysis 36(7): 889-906.

Chamon, A. S.; Gerzabek, M. H.; Mondol, M. N.; Ullah, S. M.; Rahman, M. and Blum, W. H. 2005 (a). Influence of soil amendments on heavy metal accumulation in crops on polluted soils of Bangladesh. Comm. Soil Sci. and plant Analysis 36: 907-924.

Chamon, A. S.; Gerzabek, M. H.; Mondol, M. N.; Ullah, S. M.; Rahman, M. and Blum, W. H. 2005. (b) .Heavy metal uptake into crops on polluted soils of Bangladesh. I. Influence of crop and crop varieties. J. Comm. Soil Sci. Plant analysis. Pp. 36-39.

Chamon, A. S., Mondol, M. N. and Ullah, S. M. 2006 (a). Influence of lime application on heavy metal accumulation in wheat grown on contaminated soils. Bangladesh J. Agric. And Environ. 2(1) : 93-97.

Chamon, A. S.; Mondol, M. N. and Ullah, S. M. 2006 (b). Effects of different organic amendments on growth and elemental composition of tomato grown on polluted soil. J. Asiat. Soc. Bangladesh, Sci., 32(1):127-139.

Chatterjee, C.; Dube, B. K. 2004. Detrimental effects of lead phyto-toxicity on growth, yield and metabolism of rice. Communications in soil science and plant analysis, volum-35, Issue 1 and 2, page 255-265.

Chen, H. M., Zheng, C. R. and Sun, X. H. 1991. Effects of different Pb compounds on growth and heavy metal uptake of wetland rice. Pedosphere (China). 1 (3): 253-264.

Chen, H. M., Zheng, C. R. and Sun, X. H. 1991. Effects of different Pb compounds on growth and heavy metal uptake of wetland rice, Pedosphere (China), Vol. 1(3):253-264

Chen, Z. S. and Lee, D. Y. 1997. Evaluation of remediation techniques on two cadmium polluted soils in Taiwan. In *Remediation of soils contaminated with metals*, ed. A Iskandar and D. C. Adriano, 209–223. London: Science Review.

Chen, Z. S., and Lee, D. Y. 1997. Evaluation of remediation techniques on two cadmium polluted soils in Taiwan. In *Remediation of soils contaminated with metals*, ed. A Iskandar and D. C. Adriano, 209–223. London: Science Review

Chen, Z. S., Lee, G. J. and Li, J. C.U. 2000. The effects of chemical remediation treatments on the extractability and speciation of cadmium and lead contaminated soils. *Chemosphere* 41:235–242

.

Chen, Z. S.; Lee, G. J. and Liu, J. C. 1998. Chemical remediation treatments affect the change of extractability and metal sequential fractionation of Cd and Pb in contaminated soil. International Conference on Environmental Contamination Toxicity and Health. Pp.44.

Cheng, H. K.; Zhang, B.; Jing, X.X.; Yang, S. O.; Zhao, P.; Sun, X. X.; Zhou, 2015. Response of wheat to Lead stress and relevant chemical forms of lead. Huan jing ke Xue. 2015 Apr;36 (4):1468-73.

Chino, M.; Kawashima, I.; Takahashi, K. 1997 Accumulation of heavy metals in higher plants. In Advances in environmental science – Remediation of Soils contaminated with metals; Iskandar. I. K. and Adriano. D. C. eds; Lewis publishers; Chelsa. MI. 99-110

.

Conner, J. K. 1994. Chemical Stabilization of contaminated Soils. In Hazardous waste site soil remediation (Wilson, J.D. Clarke, A. N. eds), Marcel Dekker, Inc., New York, USA, 81-70.

Cordavil, CM.; Coutinho, J. F. and Neto, M. M. 1999. Effect of lime on Cd and Pb uptake by Sudangrass. 5 th international conf. on the Biogeochem. Of trace elements Vienna. P. 549.

Dahmani-Muller, H.; Van, F.; Balabane, M. 2001. Metal extraction by Arabidosis halleri grown on an unpolluted soil amended with various metal- bearing solids. 318-319.

Davis, B. E. 1980. Critical levels of twenty potentially toxic elements in yong spring bearly. J. Agric, Sci. Camb. Pp.290.

De, A. K. 1994. Environmental Chemistry. 3rd Ed. New Age International (p) Limited, Department of Biochemistry, Faculty of Chemical Science, University of Port Harcourt, Rivers State, Nigeria. J. Appl. Sci. Environ. Man -age. March, 2015. Vol. 19(1) 103-107). Jasem ISSN 1119-83962.

Deuny, P.; Hart, B. T.; Lasheen, M. R. and Wong, M. H. 1987. Lead, mercury, cadmium and arsenic in the environment, Histchinsen, T. C. and Meema, K. M. (Eds). Scientific Committee on problems in the Environment (SCOPE). 31: 3-16.

Dinev, N. 1988. Effects of heavy metals (Cu, Zn, Cd) on the growth of oat plants. Soil Sci. Agrochem. Ecol., 33: 5-9

Dmitrij, I. B; Lukatkin, A. S.; Revin, V. V.; Duchovskis, P. A. Brazaityte and Baranauskis, K. 2005. Growth of maize seedlings affected by different concentrations of heavy metals. EKOLOGIJA. Nr. 3. P. 22-27.

Du, Y.; Chang, J. and Xue, F. H. 2010. Influence of adding Pb to soil on the growth of wheat seedlings. 19 th World Congress of Soil Science, Soil Solutions for a changing world. 1-6 August 2010, Brisbane, Australia. Published on DVD.

Ebbs, S. D. and Kochian, L. V. 1997. Toxicity of Zinc and copper to Brassica species: Implication for Phytoremediation. J. Envir. Qual. 26:776-784.

Emmerling, C. C.; Liebner, M.; Haubold-Roser, J.; Katzur and Schroder, D. 2000. Impact of application of organic waste materials on microbial and enzyme activities of mine soils in the Lusatian coal mining region. Plant and Soil. 220: 129-138.

Enayetullah, S.; Ahmm, A.; Atmn, K. H.; Khan and S. K. Roy, 2006. "Lead acid battery recycling in Bangladesh," Study report prepared for the Ministry of Environment and Forest and Supported by UNDP, Waste Concern, 2006.

Essien, E.B.; Ifeanacho, M.; Nwachukwu, G. 2015. The impact of Cow Dung Augmentation for Remediation of Crude Oil Polluted Soil by *Eleusine indica.*

Eun, S. O.; Youn, H.S. and Lee, Y. 2000. Lead disturbs microtubule organization in the root meristem of Zea mays. Physiologia Plantarum 110:Windows, Microsift Corporation, USA.

Fang, M. and Wong, J. W. C. 1999. Effects of lime amendment on availability of heavy metals and maturation in sewage sludge composting. Environment pollution 106: 83-89.

Fargasova, A. 1994. Effect of Pb, Cd, Hg, As and Cr on germination and root growth of Sinapsis alba seeds. Bull. Environ. Contam. Toxicol., 52: 452-456.

Farooqi, Z. R.; Iqbal, M. Z.; Kabir, M. and Shafiq, M. 2009. Toxic effects of Lead and Cadmium on germination and seedling growth of *Albizia Lebbeck* (L.) Benth. Pak. J. Bot., 41(1): 27-33.

Farrah, H. and Pickering, W. F. 1977. The sorption of lead and cadmium species by clay minerals. Aust. J. Chem. 30: 14-17.

Fleming, G. A.; Walsh, T. and Ryan, P. 1968. Some factors influencing the content and profile distribution of trace elements in Irish soils, Proc. 9th int. Congr. Soil Sci. 2: 341 Adelaide, Autralia.

Forstner, U. and Wittmann, G. T. W. 1983. .Metal pollution in the aquatic environment.Springer, Berlin.Pp.220.

Gambus, F. 1991. Comparison of the up take of heavy metals by vegetables with a differentiated soil content of the former. Biul. Reg. ZUP AR Krakow 295, 41, 1991, (In Polish).

Garau, G. Castaldi.; Santona, P. L. Deiana, P. 2007. Influence of red mud, Zeolite and lime on heavy metal immobilization, culturable heterotrophic microbial populations and enzyme activities in a contaminated soil, original research Article, Geodenia, volume 142. Page 47-57.

Geebelen, W.; Vangronsveld, J.; Adriano, D. C.; Carleer, R. and Clijsters. H. 2002. Amendmentinduced immobilization of lead in a lead-spiked soil: Evidence from phytotoxicity studies.*Water, Air, and Soil Pollution* 140:261–277.

Gerzabek, M. H. and Ullah, S. M. 1990. Influnce of fulvic and humic acids on Cd-and Ni-toxicity to Zea mays (L.), Bodenkultur. 41: 115-124.

Ghani, A. 2010. Effect of Lead Toxicity on Growth, Chlorophyll and Lead (Pb) Contents of Two Varieties of Maize (Zea mays L.). Pakistan Journal of nutrition 9 (9):887-891. ISSN 1680-5194.

Gleason, K.; James, P.; Shobnam, N.; Rokoff, B. L. 2014. Contaminated Turmeric is a Potential Source of Lead Exposure for Children in Rural Bangladesh. Journal of Environmental and Public HealthVolume 2014 Article ID 730636, 5 pages.

Gleason, K.; Shine, J. P.; Shobnam. 2014. Contaminated Turmeric is a Potential Source of Lead Exposure for Children in Rural Bangladesh. Journal of Environmental and Public Health.

Godzik, B. 1993. Heavy metals content in plants from zinc dumps and reference area. Pol. Bot. Stud.*, 5:* 113-132.

Goldschmidt, V. M. 1959. Geochemistry, Oxford University Press, London.Pp.35-60.

Gomez, A. K. and Gomez, A. A. 1984. Statistical procedures for Agricultural Research. Second edition, John Wiley and Sons. Newyork, U.S.A.

Gray, C. W.; Dunham, S. J.; Dennis, P. G.; Zhao, F. J.; McGrath, S. P. 2006. Field evaluation of in situ remediation of a heavy metal contaminated soil using lime and red-mud, Original research Article. Environmental pollution, Volume-142, page 530-539.

Gupta, D. K.; Srivastava, A.; Singh, V. P. 2010. Phytoremediation of induced lead toxicity in Vigna Mungo (L) heooer by Vertiver grass. Department of Plant Science,Faculty of Applied Sciences, M.J.P. Rohilkhand University, Bareilly-243 006, India.

Hasnian, S.; Yasmin, S. and Yasmin, A. 1993. The effect of lead resistant *Pesudomonads* on the growth of *Tricticum aestivum* seedlings under lead stress. Environ. Pollut., 81: 179-184.

Heimhardt, H. J. 1990. Waschem. In: Altlasten erkennen, sanieren (weber, H.H. ed) springer verlay, Berlin, Germamy. 239-270.

Hildbrand, E. E. and Blume, W. E. 1974. Lead fixation by clay minerals. Naturwissenschafilen. 61: 169.

Hirayama, C. and Kabayashi, N. 1989. Soil pollution by heavy metals. Improvement inter mountain paddy field polluted heavy metals and absorption of rice plant. Bulletin of Ibaraki Ken Agricultural Experimental Station (Japan). 28: 103-117.

Hossain, M. T.; Soga, K. and Wakabayashi, K. 2015. Effects of Lead toxicity on growth and cell wall extensibility in rice seedlings. Bangladesh J. Bot. 44(2): 333-336, 2015.

Huang, J. W. and Cunningham, S. D. 1996. Lead phytoextraction: species variation in lead uptake and translocation. New Phytology, 134 (1): 75-84.

Huang, P. M. and Schnitzer, M. 1986. Interactions of soil minerals with natural organics and microbes. SSSA special publication. No. 17, Madison, Wisconsin, USA.im Gefässversuch. Oefzs-Bericht 4414, LA-187.

Hughes, K. K.; Leep, N. W. and Phipps, D. A. 1980. A real heavy metal pollution and terrestrial ecosystems. Adv. Ecol. Res. 11: 217.

Hung, J. W.; Chen, J. J., Berti, W. R. and Cunningham, S. D. 1997 (b). Phytoremediation of lead- contaminated soils: Role of synthetic chelates in lead phytoextraction. Environ. Sci. Technol. 31:800-805.

Hussain, A.; Abbas, N.; Arshad, F.; Akram, M. 2013. Effects of diverse doses of Lead (Pb) on different growth attributes of Zea Mays L. Agricultural Sciences. Vol. 4. 262-265.

Hussain, S. I. 2000. Irrigation of crops with sewage effluent: Implication and movement of Pb and Cr as affected by soil texture, lime, gypsum, and organic matter. PhD thesis, Department of Soil Science, University of Agriculture, Faisalabad, Pakistan.

Hutton, M. and Symoan, C. 1987. The quantities of Cd, Pb and Hg chattering the UK environment from human activities. Sci. Total Environ. 57: 129-150. in Agriculture, Soiul Science Society of America.Inc. Madison. USA. Pp. 79-114.

Iqbal, S. B and Halinderdeep, K. 1992. Heavy metal inhibition of nitrate uptake and in vivo nitrate reductase in roots of wheat .Indian.J.plantphysiol.XXXV, 3:281-284

Ismail, A. S.; Abdel, Sabour, M. F. and Abou Naga, H. 1996. Accumulation of heavy metals by plants as affected by application of organic wastes. Fourth National Congress on Pollution Control of Agricultural Environment. Egyptian J. of Soil Sci. Vol. 36, No. 1-4, pp. 99-107, 7ref.

Isoyama, M. and Wada, S. I. 2007. Remediation of Pb-contaminated soils by washing with hydrochloric acid and subsequent immobilization with calcite and allophonic soil. *Journal of Hazardous Materials* 143:636–642.

Jamali, M. K.; Kazi, T. G.; Arain, M. B.; Afridi, H. I.; Memon, A. R.; Jalbani, N.; Shah, A. 2008. Use of sewage sludge after liming as fertilizer for maize growth, pedosphere 18: 203-2013.

Jarvis, S. C. and Jones, L. H. P. 1978. Uptake and transport of CD by perennial ryegrass from following solution culture with a constant concentration of cadmium. Plan on soil; 333-342

Jarvis, S. C. and Jones, L. H. P. 1978. Uptake and transport of Cd by perennial ryegrass from flowing solution culture with a constant concentration of cadmium. Plant and Soil, vol. 49, pp. 333-42.

Javed, I. and Sahar, M.1987. Effects of lead germination, early seedling growth and soluble protein and acid phosphatase content in Z*ea mays* L. *Pakistan Journal of Scientific and Industrial Research*, 30: 853-856

Jianguo, L. K.; Li[a], Xu[b], J.; Zhang[a], Z.; Ma[c], T.; Lu[a], X.; Yang, J. and Zhu[a], Q. 2003. Lead Toxicity, uptake, and translocation in different rice cultivars. Plant Science 165 (2003) 793 802.

John, M. K. 1973. Cadmium uptake by eight food crops as influenced by various soil levels of cadmium. Environment pollution, 4: 7-15.

Jones, L. H. P.; Clement, C. R. and Hopper, M. J. 1973. Lead uptake from solution by perennial ryegrass and its transport from roots to shoots. Plant and Soil, 38: 403-414.

Jones, L. H. P.; Clement, C. R. and Hopper, M. J. 1973. Lead uptake from solution by perennial ryegrass and its transport from roots to shoots. Pl. Soil, vol. 38, pp. 403-14.

Juma, N. G. and Tabatabai, M. A. 1988. Phosphate activity in com and soyabean roots. Conditions for assay and effects of metals. Plant and Soil. 107: 39-47.

Kabata-Pendias, A. 2004. Soil plant transfer of trace elements an environmental issue. *Geoderma* 122:143–149.

Kabir, M.; Iqball, M. Z.; Shafiq, M. and Farooqi, Z. R. 2008. Reduction in germination and seedling growth of *Thespesia Populnea L.*, caused by lead and Cadmium treatments. *Pak. J. Bot*., 40(6): 2419-2426.

Kang, L.; ChengAi, Z.; Na, L. 2000. Pollution effect and the accumulation of lead in the loam soil/rice system. Journal of Jilin Agricultural university. Vol. 22 No. 2 pp.68-70.

Kannan, K. 1997. Fundamentals of environmental pollution. S. Chand and Company Ltd. Ramnagar, New Delhi..

Kansal, B. D.; Saini, S. P. and Thakur, N. P. 1992. Indian J. agric. Sci. 62, 77.

Kaplan, M., S. Orman, I. Kadar, and Koncz, J. 2005. Heavy-metal accumulation in calcareous soil and sorghum plants after the addition of sulfur-containing waste as soils amendment in Turkey. *Agriculture, Ecosystems and Environment* 111:41–46.

Kaur, G.; Singh, H. P.; Batish, D. R.; Kohli R. K. 2012. Growth, photosynthetic activity and oxidative stress in wheat (*Triticum aestivum*) after exposure of lead to soil. J. Environ. Biol. 33, 265-269 (2012) ISSN: 0254-8704.

Keawsringam, T.; Wongchawallit, J.; Panich-pat, T. 2015. Lead accumulation and isolation of Rhizobacteria from Maize grown in contaminated soil. Pol. J. Environ. Stud. Vol. 24, No. 5 (2015). DOI: 10. 15244/pjoes/58872.

Khan, S. and Khan, N. 1983. Influence of Pb and Cd on the growth and nutrient concentration of tomato and eggplant. Plant and Soil. 74: 287-394.

Khan, A. G. 2001. Reletationships between chromium biogamnification ratio, accumulation factor, and mycorrhizae in plants growing on tannery effluent-polluted soil. Environ Int 26. 417-423.

Kibria, M. G. 2008. Dynamics of cadmium and lead in some soils of Chittagong and their influx in some edible crops. Ph. D. Thesis, University of Chittagong, Bangladesh.

Kibria, M. G. 2008. Dynamics of cadmium and lead in some soils of Chittagong and their influx in some edible crops. Ph.D. Thesis, University of Chittagong, Bangladesh.

Kibria, M. G.; Maniruzzaman, M.; Islam, M. 2010. Effects of soil applied lead on growth and partitioning of ion concentration in *spinacea oleracea L.* tissues. Soil and Environment 29 (1): 1-6, 2010. www. se. org. Pk online ISSN: 2075 – 1141 print ISSN : 2074-9546.

Kibria, M. G.; Osman, K. T. and. Ahmed, M. J 2006. Cadmium and lead uptake by rice (*Oryza sativa* L.) grown in three different textured soils. *Soil and Environment* 25 (2): 70-77.

Kibria, M. G.; Osman, K. T. and Ahmed, M. J. 2007. Cadmium and lead uptake by radish (*Raphanus sativus* L.) grown in three different textured soils. *Soil and Environment* 26 (2): 106-114.

Kibria, M. G.; Islam, M. and Osman, K. T. 2009. Effects of lead on growth and mineral nutrition of *Amaranthus gangeticus L.* and Amaranthus oleracea L. Soil and Environ. 28(1):1-6.

Kibria, M. G.; Moniruzzaman, M.; Islam M. and Osman, K. T. 2010. Effect of Soil-applied lead on growth and partitioning of ion concentration in *Spinacea oleracea* L. Tissues. Soil and environment 29 (1): 1-6.

Kim, K. S.; Kim, B. Y. and Han, K. H. 1986. Studies on uptake by crops of lead and reduction of its damage, Journal of Korean Society of Soil Science, Vol. 19(4):217-221.

Kim, S. J.; Ryu, T. K.; Lee, M. S.; Jeon, K. S.; Beak, S. H. and Yang, C. H. 1992. Variation of lead content in paddy rice and soil of Janghang smelter area, Korean Journal of Environmental Agriculture (Korea Replic), Vol., 11(3) : 185-193

Kitagishi, K. and Yamare, I. 1981. Heavy metals pollution in soils of Japan.Japan Science society press. Tokyo.

Kopoittka. P. M.; Aster, C. J.; Kopittke, R. A. and Menzies, N. W. 2007 (a). Toxic effects of Lead on growth of cowpea (Vigna unguiculata). Environmental pollution 150: 280-287.

Kosobrukhov, A.; Knyazeva, I.; Mudrik, V. 2004. Plantago major plants responses to increase content of lead in soil: growth and photosynthesis. Plant Growth Regul. 2004;42:145-151.

Kreutzer, K. 1995. Effects of forest liming on soil processes. Plant and Soil, vol. 168/169, pp. 447-470.

Lagerwerff, J. V. 1972. In Micronutrients in Agriculture (Mortvedi, j.j., Giordano, P. M. and Lindsay, W. L. eds) SSSA, Madison, WI, pp 593-628.

Lamhamdi, M.; Aarab; Lafont, R. 2013. Effect of lead stress on mineral content and growth of wheat (*Triticum aestivum*) and Spinach (*Spinacia oleracea*) seedlings. Saudi J Bio Sci. Jan 2013; 20(1): 29-36.

Lamhamdi, M.; Bakrim, A.; Aarab, A.; Lafont, R.; Sayah, F. 2011. Lead phytotoxicity on wheat (Triticum aestivum L.) seed germination and seedlings growth. C R Biol.2011 Feb; 334(2):118-26. Doi:10.1016/J. crvi.2010.12.006.Epub 2011 Jan 12.

Lamhamdi, M.; Bakrim, A.; Arab, A.; Lafont, R.; Sayah, F. 2010. A comparison of lead toxicity using physiological and enzymatic parameters on spinach (*Spinancia oleracea*) and wheat (*triticum aestivum*) growth. Moroccan J. Biol.6-7; 64-73.

Lee, H. S.; Kim, Y. E.; Yun, J.; Kim, G. 2011. In situ stabilization of arsenic and metal-contaminated agricultural soil using industrial by–products. Original Research Article Geoderma, volume 161, page 1-7.

Lee, S. J. and Kim, J. E. 1991. Pollution of Pb in paddy field, soil and rice plants at road side areas. Korean Environment Agriculture. 10: 138-148.

Leeper, G. W. 1978. Managing the heavy metals in land, New York, USA.

Lijuan; Kang, C.; Zhao, 2000. Pollution effect and the accumulation of lead in the loam soil/rice system. Journal of Jilin Agriculture university, vol 2.

Liu, J. C.; Looi, K. S.; Chen, Z. S. and Lee, D. Y. 1998. The effects of composts and calcium carbonate on the uptake of cadmium and lead by vegetables grown in polluted soils. *Journal of the Chinese Institute of Environmental Engineering* 8:53–60.

Lubben, S. and Sauerbeck, D. 1991. The uptake and distribution of heavt metals by spring wheat.Water, air, and awter pollution.57-58; pp239-247.

Lubis, A. M. 1988. Study of material distribution of four heavy metals (Zn, Cu, Pb and Co) in rice grain of plants grown along the sides of the main road between Medan and Pematang Siantar (North Sumatra, Indonesia), Bulletin-Pertanian, Vol. 7(2):5-11.

Ma, L. Q. 1996. Factors influencing the effectiveness and stability of Aqueous lead immobilization by hydroxapatite. Journal of environmental quality 25:1420-1429.

Madrid, L.; Diaz barrientos, E. and Cardol, 1999. Sequential extraction of metals from artificially contaminated soil in the presence of various compost.5th Intern.Conf. on Biogeochemistry of trace elements, Vienna. Pp.120

Mahmood, T. K;. Islam, R. and S. Muhammad, 2007. Toxic effects of heavy metals on early growth and tolerance of cereal crops. Pak.J.Bot., 39(2):451-462.

Mail online. 2015. Lead levels in rice imported from Taiwan and China are up to 60 TIMES higher than recommended 'safe' levels for children, Thursday, October 29 th, 2015

Malkowoski, E.; Kita, A.; Galas, W.; Kuperberg, J. M. 2002. Lead distribution in corn seedlings (*Zea mays L.*) and its effect on growth and the concentration of potassium and calcium. Plant Growth Regul.2002;37:69-76.

Malone, G.; Koeppe, D. E. and Miller, R. J. 1974. Localization of lead accumulation by corn plants. Plant Physiol. 53: 388.

Manninen, S. and Tanskanen, N. 1993. Transfer of lead from shotgun pellets to humus and three plant species in a finish shooting range. Archive of environmental contamination and Toxicology 24: 410 – 414.

Mapanda, F.; Mangwayana, E. N.; Nyamangara, J. and Giier, K. E. 2005. The effect of iong term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. Agriculture Ecosystem and environment 107:151-165. Doi:10.1016/j.agee.2004.11.005.

Markert, B. 1993. Plants as Biomonitors.Indicatrs for Heavy Metals in the Terrestrial Environment.VCH VerlagsGesellschaftmbh. D-6940 Weinheim(FRG). Pp 453.

Mason, C.F. and Moore, J. W. 1982. Hewavy metals in Naturals waters Springer Verlag, Newyork, USA.

Matos, A. T. D.; Fontes, M. P. E.; Costa, L. M. D. and Martinez, M. A. 2001. Mobility of heavy metals as related to soil chemical and Mineralogical characteristics of Brazilian soils. Environmental pollution 111: 429 – 435.

McCalla, T. M.; Peterson, J. R. and Luetting, C. 1977. Properties of agricultural and municipal waste.

McGrath, S. P.; Zhao, F. J.; Lombi, E. 2002. Phytoremediation of metals, metalloids, and radionuclides, Ads Agron 75, 1-56.

Mesmar, M. N.; Jaber, K. 1991. The toxic effect of lead on seed germination, growth, chlorophyll and protein contents of wheat and lens. Acta Biol. Hung. 42:331-344 [Pub Med] 5.

Mishra, A. and Chowdhury, M. A 1998. Amelioration of lead and mercury effects on germination and rice seedling growth by antioxidants. Plant physiology and Biochemistry laboratory, Department of Botany, University of Burdwon, Burdwon 713 104. W Bangal, India Biological Plantarium 41 (3); 469-473.

Misra, S. G. and Mani, D. 1991. .Soil Pollution. In Akther, R. (eds) , Environmental pollution and problem. Ashis pub. House New Delhi. Pp. 32-33.

Mitchell, R. L. 1964. Trace elements in soils, In F.E. Bear (ed), Chemistry of soils. Reinhold, New York, USa.pp.320-368.

Mondol, M. N. 1995. Effect of heavy metals from applied and industrial sources on nutrient and metal uptake, growth and yield of crops. M Sc. Thesis, Dept. Soil Science, University of Dhaka, Bangladesh, Bangladesh. Pp. 4-10.

Muchuweti, M., J. W.; Birkett, E.; Chinyanga, R.; Zvauya, M.D.; Scrishaw. and Lester, J. 2006.. Heavy metal content of vegetables irrigated with mixture of wastewater and sewage sludge in Zimbabwe: Implications for human heaith. Agriculture Ecosystems and environment 112, 41-48. Doi:10.1016/J.agee.2005.04.028.

Mumtaz, H.; Ahmad, M. S. A. and Kausar, A. 2006. Effect of lead and chromium on growth, Photosynthetic pigments and yield components in Mash Bean (Vigna Mungo (L.) Hepper.Pak. J. Bot., 38(5): 1389-1396.

Nardi, S.; Pizzeghello, D.; Muscolo, A. and Vianello, A. 2002. Physiological effects of humic substances on higher plants. *Soil Biology and Biochemistry* 34:1527–1536.

Nedjah. I.; Boudelaa, M.; Benkaddour, M.; Slimani, S. and Ladjama, A. 2013. Effect of Lead Toxicity on Germination and Enzymatic Activity of Durum Wheat *Triticum durum* Desf. Journal of Agricultural Science and Technology A 3 (2013) 436-442

Norrish, K. 1975. The geochemistry and mineralogy of trace elements. In: Trace elements in soil – plant – animal system. Nicholas, D. J. D. and Egan, A. R. (Eds). Academic press. New York. pp. 55.

Nuruzzaman, M.; Gerzabek, M. H. and Ullah, S. M. 1995. Studies on Heavy Metal and Microbiological Pollution of Soils, Sediments and Water Systems in and Around Dhaka City; Bericht an die O"sterr. Akademie der Wissenschaften, OFZS, 1995.

Oades, J. M. 1967. Carbohydrates in some Australian soils. Aust. J. Soil Res. Vol. 5, pp.103-115.

Obroucheva, N. V.; Bystrova, V. B.; Ivanov, O. V.; Antipova, M. S. and Seregin, I. V. 1998. Root growth responses to lead in young maize seedlings. *Plant Soil*, 200: 55-61.

Olsen, K. W. and Skogerbee, R. K. 1975. Environ. Sci. Tech. 9: 227.

Olsen, S. R. 1972. Micronutrient interaction. In J.j. Morvedt, p. M. Glordano and W. L. Lindsay (eds.), Micronutrients in Agriculture, soil science society of America. Inc. Madison, Wisconsin, Usa. Pp. 243-264.

Orhue, E. R. and Inneh, S. 2010. Uptake of lead by Celosia argetia in an ultisol. Research Journal of Agriculture and Biological Science 6(2): 103-107.

Pahlsson, A. B. 1989. Toxicity of heavy metals (Zn, Cu, Cd, Pb) to vascular Plants. Water Air Soil Pollut., 47: 287-319.

Pais, I.; Benton, J. and Jones, J. 1997. The hand book of trace elements. St. Lucie Press. Florida. USA.

Pallabi, S. and Dubey, R. S. 2005. Lead toxicity in plants. Braz. J. Plant Physiol. vol.17 no.1 Londrina Jan./Mar. 2005 *On-line version* ISSN 1677-9452

Palmar, J. P.; Williams, K. P; Prosser, H. J. 1995. Decontamination of metal containing soils. In contaminated soil 95 (WJ) von Den Brink, Bosman, R., Arent, F. (eds) Kluwer Academic Publ. Dordrecht, The Netherlands, 883-893.

Parvin, J.; Ullah, S. M.; Rahman, M. A.; Khatun, T. 2003. Effect of soil amendments on nutrient content and their transfer co-efficient into straw and grain of Bridhan-30.

Pierzynski, Gary, M. 1997.. Strategies for remediating trace element contaminated sites.In Advances in Environmental Science. Remediation of Soils Contaminated with Metals; Iskander, I. K. Adriano, D. C. (eds). Lewis Publishers: Chelsea, MI: pp. 67-84.

Pillai, K. C. 1991. Water pollution and management. Varshney, K. C. Willy Eastern Ltd. pp. 74-93.

Piper, 1950. Soil and Plant Analysis. Hassel Press. Adelaide, Australia. Publishers. New Delhi, India.

Qiao, X. L. and Luo, Y. M. 2001. Land application of sewage sludge. Sewage sludge with high copper content. Soils 33, 222-224.

Rahman, K. 1992. Industrial pollution and control for sustainable development. Training manual on environmental management in Bangladesh. Department of Environment.184-206.

Rameshkumar, J.; Baskaran, L.; Rajendran, R. and Thiyagarajan, G. 2013. Enhancement of groundnut yield by soil amendments. International Journal of Environmental Biology 2013; 3(4): 199-202.

Rashid, P. and Mukharjee, A. 1990. Effects of lead nitrate on some anatomical features of mung been. Bangladesh Journal of Botany, 19: 149-154.

Saini, S. P.; Gupta, V. K. 2001. Lead and FYM influence on yield and Pb concentration of wheat grown on sandy and clay loam soils. Journal of the Indian Sociaty of soil science. Vol. 49. no. 3. pp 508-510.

Rule, J. H. and Martin, S. 1999. Effects of Fe- Oxides on the bioavailability of metals in Biosolids. 5^{th} International Conferences on the biogeochemistry of trace elements Viena.

Sabnam, S. 2012. Atmospheric Aerosols: Their composition, concentration and effects on soils, plant and human. M.Sc. thesis Department of soil, water and Environment, University of Dhaka,Bangladesh.

Sajwan, K. S. and Linsay, W. L. 1986. Effects of redox on Zn deficiency in paddy rice soil Sci. Am. J. 50:pp.1264-1278.

Salt, D.E.; Blaylock, M.; Kumar, P. B. A. N.; Dushenkov, V.; Ensley, B.D.; Chet, I.. and Raskin, I. 1995. Phytoreme-diation: A novel strategy for the removal of toxic metals from the environment using plants, *Biotechnology*, **13**, 468-475.

Santos-Diaz, Maftoun, M. D. and Cirugeda-Delgado, C. 1992. Study of lead and cadmium contents in basic foods, 4 : Rice Alimentaria (Spain), no. 230:59-60.

Sarkunan, V.; Misra, A. K. and Nayer, P. K. 1991. Interaction of Zn, Cu and Ni in soil on yield and metal content in rice. J. Environ. Sci. Health 14: pp. 459-466.

Schnitzer, M. and Kerndorff, H. 1981. Reaction of fulvic acid with metal ions. Water, air and soil pollution. 15: 97.

Schnitzer, M. and Khan, S. U. 1978. Soil organic matter. Elsevier Scientific Publishing company, Amsterdam, Oxford, New York.

Seaman, J. C.; Hutchison, J. M.; Jackson, B. P and Vulava, V. M. 2003. In situ treatment of metals incontaminated soils with phytate. *Journal of Environmental Quality* 32:153–161.

Sekara, A.; Poniedziaek, M.; Ciura, J. 2005. Cadmium and Lead Accumulation and distribution in the Organs of Nine Crops: Implications for Phytoremediation. Polish Journal of Environmental Studies Vol. 14, No 4 (2005), 509-516.

Seregin, I.. V. and Ivaniov, V. B. 2001. Physiological as-pects of cadmium and lead toxic effects on higher plants, *Russian Journal of Plant Physiology*, **48**, 606-630.

Sharma, P. and Dubey, R. S. 2005. Lead toxicity in plants. Brazillian Journal of Plant Physiology 17:35-52.

Sharma, R. K.; Agrawal, M. and Marshall, F. 2007. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicology and environmental Safety 66. 258-266. Doi: 10.1016/J.ecoenv.2005. 11.007.

Sood, P. P. and Prakash, R. 1998. Metal pollution:Toxication and Chelation. M .D. Publication Pvt. Ltd. Pp. 277. Plant Physiol. 84: 94 – 100.

Stevenson, F. J. 1991. Organicmattermicronutrient reactions in soil. In *Micronutrients in agriculture*, ed. J. J.Mortvedt, F. R. Cox, L. M. Shuman, and R.M.Welch, 145–168. Madison,Wisc.: SSSA.

Stevenson, F. R. J. and Ardakni, M. S. 1972. Organic matter reacrion involving micronutrients

tiborova, M.; Ditrichova M. and Brezinova, A. 1987. Effect of heavy metal ions on growth and biochemical characteristics of photosynthesis of barley and maize seedlings. Biologia Plantarum 29:453467.

Strand, V.; Zolotareva, B. N. and Lisovskij, A. J. 1990. Effect of Pb, Cd and Cu content in the soil on their accumulation and yields of crops, Rostlinna-Vyroba, 36(4): 411-417; 3 ref.

Tadesse, B.; Donaldson, J. D. and Grims, S. M. 1994. Contaminated and polluted land: A general review of dcontamination management and control. J. Chem. Tech. Biotechnol. 60:227-240.

Tafvizi, M. and Motesarezadeh, B. 2014. Effects of lead on Iron, Manganese and Zinc concentrations in different varieties of maize (Zea Mays).Communications in Soil Science and Plant analysis. Volume 45, Issue 14, 2014. Pages 1853-1865.

Tariq, M.; Islam, K. R. and Muhammad, S. 2007. Toxic effects of heavy metals on early growth and tolerance of cereal crops. Pak. J. Bot., 39(2): 451-462.

Thakur, I.. S. 2006 a. Industrial Biotechnology:Problems and Remedies. I. K. International Pvt. Ltd. Pp. 266.

Thakur, I.. S. 2006 b. Industrial Biotechnology:BasicConcepta and Applications. International Pvt. Ltd. Pp. 154.

Tisdall, J. M. and Oades, J. M. 1980. The effect of crop rotation on aggregation in a red-brown earth. Aust. J. Soil Res., vol. 18, pp. 423-434.

Titov, A. F.; Talanova, V. V.; Boeva, N. P. 1996. Growth responses of barely and wheat seedlins to lead and cadmium. Institute of biology, Russian Academy of Science. Biological Plantarum 38 (3): 431-436.

Tlustos, P.; Balik, J.; Pavlikova, D.; Szakova, J. 1997. The uptake of cadmium, zinc, arsenic and lead by chosen crops. Rostlinna Vyroba 43 (10) 487.

Tomar, M.; Kaur, I,; Neelu; Bhatbagar, A. K. 2000. Effect of enhanced lead in soil on growth and development of Vigna radiate (L.) Wilezek. Indian J. Plant Physio. 5 (1); 13-18.

Trevedi, S. and Erdei, L. 1992. Effects of cadmium and lead on the accumulation of Ca+2 and K+ and on the influx and translocation of K+ status, Phtsiol., Plant, 84:94-100.

Trivedi, S. and Erdel, L. 1992. Effect of cadmium and lead of accumulation of Ca^+ and k^+

Tu, C.; Zheng, C. R. and Chen, H. M. 2000. Current status of the soil – plant system in a copper gangue area. Acta Pedol Sin 37, 284-287.

Turpeinen, R.; salminen, J. and Kairesalo, T. 2000. Mobility and Bioavailability of lead in contaminated boreal forest soil. Environmental science and technology 34: 5152 – 5156.

Ullah, S. M. and Gerzabek, M. H. 1991. Influence of fulvic and humic acids on Cu-and V-toxicity to Zea mays (L). Bodenk. 42: 123-134.

Ullah, S. M.; Kamal, A. T. M. M.; Al-Neyam, S. G.; Faizullah, A. M. M and Jahan, S. 2011. Effect of Lead on growth and mineral content of rice. (*Oryza sativa L.*) . Bangladesh J. Sci. Res. 24(1):67-74.

Ullah, S. M.; Gerzabek, M. H.; Mondol, N.; Rashid, M. M. and Islam, M. 1999. Heavy metal pollution of Soils and water and their transfer into plants in Bangladesh. In 5^{th} internation conference on the biogeochemistry of trace elements, July 11-15 (1999) Vienna, Austria. Vol. 1, page:260-261.

United States Salinity Laboratory Staff (USSL) 1954. Diagnosis and improvement of saline and alkali soils. Agric. Handbook No. 60, United States Dept. Agric.

US environmental protection Agency (USEPA), 2001. EPA – 902 – B01 – 001: Best Management practices for lead at outdoor shooting ranges EPA – 902 – B01 – 001. United States Environmental Protection Agency Region 2

USDA, (1951). Soil Survey Manual, Handbook, 18. p-503.

Vaughan, D. and Malcolm, R. E. 1985. Soil organic matter and biological activity. Martinus Nijhoff/Dr. W. Junk Publishers, Dordrecht, Boston, Lancaster.

Vdlufa, 1975. Kunigswasserauszug (Vorschlag des Agrikultur Chemischen Institutes der Universität Bonn) Beurteilung der Siedlungsabfallkomposte (SAK) als Produktionsmittel der Landwirtschaft Heft, vol. 4/1975, pp. 731.

Venkatesh, B. and Abhimanya. 1998. Lead (Pb) accumulation of roadside soils. In: 16^{th} World Congress of Soil Science in France (20-26^{th} Aug.1998) Symposium No. 25.

Verma, S.; Dubey, R. S. 2003. Lead toxicity induces lipid peroxidation and alters the activities of antioxidant enzymes in growing rice plants. Department of Biochemistry, Faculty of science, Banaras Hindu University. Varanasi 221 005, India.Volume 2014 (2014), Article ID 730636, 5 pages.

Wagastuma, T. I..; Krashi, H. and Ishii, K. 1985. Lead toxicity in crops, comprehensive studies on the environmental improvement for crop production. J. Yamagata Agri. And Forestry Soc. 42:65-74

Walker, W. M.; Miller, J. E. and Hasset, J. J. 1997. Effect of lead and cadmium upon the calcium, magnesium, potassium and phosphorus concentration in young corn plants. Soil Science 124: 145-151.

Wasay, S. A.; Barrington, S. F. and Tokunaga, S. 1998. Remediation of soils polluted by heavy metals using salts of organic acids and chelating agents. Environmental Technology, vol. 19, pp. 369-380.

Water, R. D. 1992. Competitive sorption of Co, Cu, and Ni ions by a calcium-saturated soil. Soil Sci.Ameri. J. (USA).56(2):444-449.

Web-1: https://www.google.com.bd/search?q=image+of+lead+pb+affected+leaf&espv=2&biw=1366&bih=705&tbm=isch&tbo=u&source=univ&sa=X&ved=0CDYQ7AlqFQoTCO-Xt8XNl8kCFdTEjgodaSQPvw#imgrc=KnlDQOHzhtMPGM%3A

Web-2: (http://dx.doi.org/10.4314/jasem.v19i1.14)

Web-3 http://dx.doi.org/10.1155/2014/730636

Web 4: http://www.buzzle.com/articles/uses-of-lead.html

Weiwei. S.; Tao, X.; Yan, J. H.; Yue, Z. 2009. Ecotoxicological effects of lead and copper on seed germination of wheat. Journal of shaughai jiaotong university-Agricultural science Vol. 27, no.3 pp 196-199 ISSN 1671-9964. Record number 20043214598.

Wending, X.; Guining, L.; Zhi, D.; Chngum, L. 2013. Uptake and distribution of Cd in sweet maize grown on contaminated soils: A field scale study. Bioinorg Chem Appl 2013.

WHO 2009. Global health Risks: Mortality and burden of disease attributable to selected major risks. Geneva,World Health Organization.

Xian, X. 1989. Effect of chemical forms of Cd, Zn, and Pb in polluted soils on their uptake by cabbage plants. Plant and Soil. 113:257-264.

Xie-Zhengmiao and Huang-Changyong. 1994. Relationship between lead, Zinc and arsenic contents and rice tillering in soil – rice system. J. Zhejiang – Agricultural University (china). 20 (1): 67-71.

Young, T. M.; Heeraman, D. A.; Sirin, G. and Ashbaugh, L. L. 2002. Resuspension of soil as a source of airborne Lead near industrial facilities and highways. Environ. Sci. Technol. 36:2484-2490

Zehetner, F. and Wenzel, W. W. 2000. Nikel and cooper sorption in acid forest soils. J. Soil Sci. 165(6): 463-472.

Zeng, L. S.; Liao, M.; Chen, C. L. 2006. Effects of lead contamination on soil microbial activity and rice physiological indices in soil-Pb- rice system. Department of Resources Science, Zhejian university, Kaixuan road 268, Zhejiang province 310029, China.

Zeng, L. S.; Liao, M.; Chen, C. L.; Huang, C. Y. 2007. Effects of lead contamination on soil enzymatic activities, microbial biomass and rice physiological indices in soil lead rice (*Oryza Sativa L*) system. Ecotoxicol Environ Saf. 67 (1): 67-74.

Zengin, F. K. and Munzuruglu. 2005. Effects of some heavy metals on content of chlorophyll, proline and some Antioxidant chemicals in bean (*phaseolus Vulgaris L*) seedlings. Department of Biology, Faculty of Science, Firat University, Elazig 23119, Turkey, ACTA Biological Cracoviensia series Botanica 47/2: 157-164.

Zhang, Z. W.; Moon, C. S.; Watanable, T. and Ikeda, S. M. 1997. Lead content of rice collected from various areas in the world. Soil Total environ. 191 (1-2): 169-175.

Zhi, Y.; Deng, Z.; Luo, M.; Ding, W.; Hu, Y. and Li, Y. 2015. Influence of Heavy Metals on Seed Germination and Early Seedling Growth in *Eruca sativa* Mill. **American Journal of Plant Sciences, 2015, 6, 582-590.** http://www.scirp.org/journal/ajps

Zimdahl, R. L. 1975. Entry and movement in vegetation of lead derived from air and soil sources. Paper presented at 68th Ann. Meeting of the Air pollution Control Association. Boston. Mass. June 15.

Zimdahl, R. L. and Kogerboe, R. K. S. 1977. Behavior of lead in soil. Environmental Science and technology 11: 1202 – 1206.

Table-5: Effects of different doses of lead (Pb) on growth and yield parameters of rice (variety: Bridhan-49) pot Experiment- 1 (a.)

Treatments	Denotation	Fresh wt.of Grain g/pot	Fresh wt.of shoot g/pot	Fresh wt.of Root g/pot	Dry wt.of Grain g/pot	Dry wt.of shoot g/pot	Dry wt.of Root g/pot	Shoot length (cm)
Bridhan - 49 Control	T_0	33.01 a	68.57 a	23.32 a	23.92 a	25.12 a	4.23 a	106.33 a
Bridhan - 49 + 50 ppm Pb	T_1	33.11 a	65.24 a	23.05 a	22.25 ab	23.17 ab	3.77 ab	106.00 a
Bridhan - 49 + 100ppm Pb	T_2	32.53 a	61.71 ab	20.18 b	20.30 ab	21.22 bc	3.69 ab	103.67 b
Bridhan - 49 + 150 ppm Pb	T_3	28.47 ab	57.84 b	19.73 b	19.13 b	20.19 c	3.34 ab	102.33 b
Bridhan - 49 + 200 ppm Pb	T_4	26.57 b	56.81 b	17.44 c	19.13 b	20.16 c	2.96 b	100.00 c
F - value		4.48	7.53	19.88	3.74	9.29	1.76	26.04
Significant at 5% level		**	**	**	**	**	NS	**

Treatments	Denotation	Root length (cm)	No. of tiller/3 plant	No. of Panicle	Panicle length (cm)	No.of grain/panicle	1000 grain wt. g/pot
Bridhan-- 49 Control	T_0	26.33 a	11.33 a	10.00 a	25.00 a	182 a	18.60 a
Bridhan - 49 + 50 ppm Pb	T_1	26.33 a	9.66 b	9.67 a	23.67 ab	178 a	17.63 ab
Bridhan - 49 + 100 ppm Pb	T_2	22.33 ab	9.33 b	9.33 ab	23.33 ab	167 b	16.90 ab
Bridhan - 49 + 150 ppm Pb	T_3	21.67 b	9.33 b	9.00 ab	23.00 b	159.33 bc	16.4 b
Bridhan - 49 + 200 ppm Pb	T_4	21.33 b	9.00 b	8.33 b	22.67 b	150.33 c	15.87 b
F - value		3.57	3.85	3.08	3.04	14.31	3.83
Significant at 5% level		**	**	NS	NS	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

**- significant at 5 % level

Table-6: Effects of different doses of lead (Pb) on mineral nutrition of rice (variety: Bridhan - 49). Pot Experiment -1(b).

Treatments	Denotation	Nitrogen (N) %			Phosphorus (P) %			Potassium (K) %		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bridhan- 49 Control	T_0	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
Bridhan - 49 + 50 ppm Pb	T_1	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
Bridhan - 49 +100 ppm Pb	T_2	0.374 a	0.302 b	0.649 a	0.241 bc	0.062 ab	0.219 abc	0.547ab	1.80 ab	0.187 ab
Bridhan - 49 +150 ppm Pb	T_3	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
Bridhan - 49 +200 ppm Pb	T_4	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
F- Value		4.62	91.69	85.12	16.99	2.79	5.18	4.03	2.57	1.81
Significant at 5 % level		**	**	**	**	NS	**	**	NS	NS

Treatments	Denotation	Calcium (Ca) %			Magnesium (Mg) %			Lead (Pb) ppm		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bridhan- 49 Control	T_0	0.446 a	0.403 a	0.028 a	0.213 a	0.152 a	0.096 a	42.5 d	7.5 d	1.96 c
Bridhan - 49 + 50 ppm Pb	T_1	0.392 ab	0.393 ab	0.028 a	0.192 ab	0.117 b	0.090 ab	206 c	7.5 d	2.68 c
Bridhan - 49 +100 ppm Pb	T_2	0.323 bc	0.360 ab	0.025 a	0.178 ab	0.107 b	0.084 bc	341 c	20.00 c	3.9 c
Bridhan - 49 +150 ppm Pb	T_3	0.278 cd	0.319 b	0.022 ab	0.174 ab	0.105 b	0.086 cd	613 b	30.00 b	9.0 b
Bridhan - 49 +200 ppm Pb	T_4	0.226 d	0.315 b	0.018 b	0.164 b	0.104 b	0.075 d	1577 a	43.17 a	32.13 a
F- Value		10.71	1.08	5.35	2.36	4.45	14.3	483	26	123
Significant at 5 % level		**	NS	**	NS	**	**	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

**- significant at 5 % level

Table:7- Effects of different amendments on growth, yield parameters of rice (variety: Bridhan-49) pot experiment- 2(a).

Treatments	Denotation	Fresh wt.of Grain g/pot	Fresh wt.of shoot g/pot	Fresh wt.of Root g/pot	Dry wt.of Grain g/pot	Dry wt.of shoot g/pot	Dry wt.of Root g/pot	Shoot length (cm)
Bridhan - 49 Control	T_0	33.01 b	66.57 ab	23.32 b	23.92 b	25.12 b	4.23 a	106.33 ab
Bridhan - 49 + 100 ppm Pb	T_1	32.53 b	61.70 b	20.18 b	20.30 b	21.22 c	3.77 a	103.67 b
Bridhan - 49 + 100 ppm Pb + cowdung	T_2	42.77 a	70.39 a	31.70 a	26.81a	28.71 a	5.07 a	108.00 a
Bridhan - 49+100 ppm Pb + poultry litter	T_3	36.18 b	63.84 ab	20.43 b	23.38 b	24.07 bc	3.86 a	105.67 ab
Bridhan - 49 + 100 ppm Pb + lime	T_4	37.61 ab	59.80 b	19.82 b	23.02 b	21.14 c	3.48 a	104.67 ab
F - Value		5.34	1.84	17.77	13.33	9.21	1.56	1.91
Significant at 5 % level		**	NS	**	**	**	NS	NS

Treatments	Denotation	Root length (cm)	No. of tiller/3 plant	No. of Panicle/3	Panicle length (cm)	No.of grain/panicl	1000 grain wt. g/pot
Bridhan - 49 Control	T_0	26.33 a	11.33 b	10.00 c	25.00 a	178.00 ab	18.60 a
Bridhan - 49 + 100 ppm Pb	T_1	21.67 ab	9.33 c	9.33 c	23.33 b	167.00 b	16.93 b
Bridhan - 49 + 100 ppm Pb + cowdung	T_2	25.00 ab	14.67 a	14.67 a	25.33 a	196.67 a	19.28 a
Bridhan - 49 +100 ppm Pb+poultry litter	T_3	21.00 ab	10.00 c	9.67 c	24.33 ab	196.00 a	18.39 a
Bridhan - 49 + 100 ppm Pb + lime	T_4	19.67 b	12.33 b	11.67 b	25.00 a	189.33 ab	18.16 a
F - Value		3.12	28.42	21.85	4.75	3.02	5.43
Significant at 5 % level		NS	**	**	**	NS	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT
NS- not significant at 5 % level
**- significant at 5 % level

Table -8: Effects of different amendments on mineral nutrition of rice (variety: Bridhan - 49) Pot experiment-2(b).

Treatments	Denotation	Nitrogen (N) %			Phosphorus (P)%			Potassium (K) %		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bridhan - 49 Control	T_0	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
Bridhan - 49 +100 ppm Pb	T_1	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
Bridhan - 49 + 100 ppm Pb + cowdung	T_2	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
Bridhan- 49 +100 ppm Pb + poultry litter	T_3	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
Bridhan - 49 + 100 ppm Pb + lime	T_4	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
F - Value		25.78	9.74	321.86	127.62	5.22	36.24	2.05	0.759	14.71
Significant at 5 % level		**	**	**	**	**	**	NS	NS	**

Treatments	Denotation	Calcium (Ca)%			Magnesium (Mg) %			Lead (Pb) ppm		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bridhan-49 Control	T_0	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
Bridhan - 49 +100 ppm Pb	T_1	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
Bridhan - 49 +100 ppm Pb + cowdung	T_2	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
Bridhan - 49 +100 ppm Pb + poultry litter	T_3	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
Bridhan - 49 + 100 ppm Pb + lime	T_4	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
F - Value		232.14	0.844	1.82	23.31	9.4	9.7	226.46	7.29	23.32
Significant at 5 % level		**	NS	NS	**	**	**	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT
NS- not significant at 5 % level
**- significant at 5 % level

Table-9: Effects of different varieties of rice on growth and yield parameters grown on soils contaminated with lead (Pb) pot experiment -3 (a).

Variety	Denotation	Fresh wt.of grain g/pot	Fresh wt.of shoot g/pot	Fresh wt.of root g/pot	Dry wt.of grain g/pot	Dry wt.of shoot g/pot	Dry wt.of root g/pot	Shoot length (cm)
Bridhan - 33 + 200 ppm Pb	V_1	20.06 b	53.51 b	14.66 b	11.92 c	19.06 b	2.13 b	118.50 a
Bridhan - 49 + 200 ppm Pb	V_2	26.59 a	56.81 b	17.44 ab	18.21 ab	20.18 b	2.96 b	100.00 c
Bridhan - 53 + 200 ppm Pb	V_3	19.78 b	54.4 b	18.50 ab	13.36 bc	16.38 b	2.20 b	103.50 b
Bridhan - 54 + 200 ppm Pb	V_4	28.53 a	87.15 a	19.80 a	21.85 a	29.94 a	4.19 a	117.67 a
F - Value		10.76	18.09	3.73	6.14	11.03	8.43	179.67
Significant at 5 % level		**	**	NS	**	**	**	**

Treatments	Denotation	Root length (cm)	No. of tiller/3 plant	No. of Panicle	Panicle length (cm)	No.of grain/panicl e	1000 grain wt g/pot
Bridhan - 33 + 200 ppm Pb	V_1	16.67 c	6.33 b	4.00 b	23.00 b	131.67 b	22.67 a
Bridhan - 49 + 200 ppm Pb	V_2	21.33 b	9.00 a	8.33 a	22.67 b	150.33 ab	15.87 b
Bridhan - 53 + 200 ppm Pb	V_3	21.00 b	8.00 ab	7.00 a	21.67 b	87.67 c	21.76 a
Bridhan - 54 + 200 ppm Pb	V_4	26.67 a	8.33 a	7.33 a	26.67 a	171.00 a	22.98 a
F - Value		16.76	5.4	7.37	4.41	20.86	17.75
Significant at 5 % level		**	**	**	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

**- significant at 5 % level

Table-10: Effects of different varieties of rice on mineral nutrition grown on soils contaminated with lead (Pb) Pot experiment - 3 (b).

Treatments	Denotation	Nitrogen (N) %			Phosphorus (P)%			Potassium (K) %		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bridhan - 33 + 200 ppm Pb	V_1	0.342 ab	0.241 b	0.534 c	0.200 a	0.133 a	0.171 b	0.626 ab	1.96 a	0.313 b
Bridhan - 49 +200 ppm Pb	V_2	0.297 b	0.241 c	0.558 b	0.180 ab	0.041 c	0.198 b	0.410 b	1.62 ab	0.170 c
Bridhan - 53 +200 ppm Pb	V_3	0.305 ab	0.141 c	0.461 d	0.168 ab	0.078 b	0.215 ab	0.600 ab	1.52 b	0.350 b
Bridhan - 54 +200 ppm Pb	V_4	0.383 a	0.295 a	0.703 a	0.128 b	0.054 b	0.254 a	0.742 a	1.95 a	0.560 a
F - Value		2.94	75.3	639.37	2.73	15.46	4.5	2.43	4.08	57.3
Significant at 5 % level		NS	**	**	NS	**	**	NS	**	**

Treatments	Denotation	Calcium (Ca)%			Magnesium (Mg) %			Lead (Pb) ppm		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bridhan - 33 + 200 ppm Pb	V_1	0.197 c	0.229 b	0.016 b	0.147 bc	0.124 ab	0.086 a	760.00 c	36.00 b	23.00 b
Bridhan - 49 + 200 ppm Pb	V_2	0.226 c	0.315 ab	0.018 b	0.164 ab	0.104 b	0.075 b	1577.00 a	43.17 a	32.12 a
Bridhan - 53 + 200 ppm Pb	V_3	0.350 b	0.310 ab	0.014 b	0.132 c	0.112 b	0.069 b	574.00 d	23.33 c	17.33 c
Bridhan - 54 + 200 ppm Pb	V_4	0.632 a	0.372 a	0.072 a	0.172 a	0.142 a	0.074 b	875.00 b	25.15 c	2.51 d
F - Value		44.46	4.5	84.45	7.29	5.13	6.53	3364.19	22.5	93.17
Significant at 5 % level		**	**	**	**	**	**	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

**- significant at 5 % level

Table-11: Effects of different doses of lead (Pb) on growth, yield parameters of wheat (variety: Bari wheat -26) pot experiment - 4 (a).

Treatments	Denotation	Fresh wt.of Grain g/pot	Fresh wt.of shoot g/pot	Fresh wt.of root g/pot	Dry wt.of grain g/pot	Dry wt.of shoot g/pot	Dry wt.of Root g/pot
Bari wheat -26 Control	T_0	10.7 b	6.50 a	1.80 a	9.81 b	5.65 a	1.41 a
Bari wheat -26 +50 ppm Pb	T_1	13.7 a	6.06 ab	1.50 ab	12.36 a	5.61 a	1.28 a
Bari wheat -26 +100 ppm Pb	T_2	10.48 b	6.06 ab	1.21 bc	9.10 b	5.60 a	1.11 a
Bari wheat -26 +150 ppm Pb	T_3	9.55 b	5.51 bc	1.10 bc	8.20 b	4.89 b	0.783 b
Bari wheat -26 +200 ppm Pb	T_4	9.12 b	5.01 c	1.01 c	7.50 b	4.51 c	0.697 b
F - Value		5.36	11.52	6.08	6.35	33.38	11.12
Significant at 5 % level		**	**	**	**	**	**

Treatments	Denotation	Shoot length(cm)	Root length (cm)	No. of tiller/3 plants	No. of Panicle / 3 plants	1000 grain wt. g/pot
Bari wheat -26 Control	T_0	78.67 a	13.33 a	7.67 a	7.67 a	42.93 a
Bari wheat -26 +50 ppm Pb	T_1	77.33 b	13.33 a	7.33 a	7.33 ab	40.80 b
Bari wheat -26 +100 ppm Pb	T_2	77.02 bc	10.66 b	6.70 a	6.67 ab	40.60 b
Bari wheat -26 +150 ppm Pb	T_3	75.10 d	10.30 b	6.67 a	6.67 ab	39.80 bc
Bari wheat -26 +200 ppm Pb	T_4	74.33 e	9.50 b	6.33 a	6.33 b	39.06 c
F - Value		1249.92	5.72	0.386	2.7	10.74
Significant at 5 % level		**	**	NS	NS	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

**- significant at 5 % level

Table -12: Effects of different doses of lead (Pb) on mineral nutrition of wheat (variety: Bari wheat-26) pot experiment -4(b).

Treatments	Denotation	Nitrogen (N) %			Phosphorus (P)%			Potassium (k)%	
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot
Bari wheat -26 Control	T_0	0.643 a	0.83 a	2.02 a	0.127 a	0.054 a	0.466 a	0.45 a	1.99 a
Bari wheat -26+50 ppm Pb	T_1	0.596 b	0.64 b	1.93 a	0.121 a	0.041 ab	0.441 b	0.46 a	1.99 a
Bari wheat -26+100 ppm Pb	T_2	0.570 bc	0.51 c	1.82 a	0.108 ab	0.035 bc	0.423 c	0.27 b	1.85 ab
Bari wheat -26+150 ppm Pb	T_3	0.556 c	0.46 cd	1.73 a	0.013 b	0.025 bc	0.398 d	0.21 b	1.60 b
Bari wheat -26+200 ppm Pb	T_4	0.512 d	0.41 d	1.21 b	0.071 c	0.019 c	0.210 e	0.17 b	1.15 c
F - Value		17.11	55.59	5.44	11.78	6.25	448.94	7.73	17.55
Significant at 5 % level		**	**	**	**	**	**	**	**

Treatments	Denotation	Calcium (Ca)%			Magnesium (Mg) %			Lead (Pb) ppm	
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot
Bari wheat -26 Control	T_0	0.79 a	0.53 a	.028 a	0.192 a	0.091 a	0.093 a	54.86 e	19.0 c
Bari wheat -26+50 ppm Pb	T_1	0.67 ab	0.51ab	.026 a	0.178 a	0.086 b	0.092 a	72.83 d	24.67 c
Bari wheat -26+100 ppm Pb	T_2	0.61 bc	0.50 ab	0.026 a	0.128 b	0.080 c	0.090 ab	183.6 c	38.0 b
Bari wheat - 26+150 ppm Pb	T_3	0.57 bc	0.43 a	0.020 b	0.124 b	0.076 d	0.070 b	215.0 b	42.66 b
Bari wheat -26+200 ppm Pb	T_4	0.51 c	0.38 b	0.018 b	0.122 b	0.071 e	0.070 b	647.8 a	54.0 a
F - Value		6.49	2.48	6.66	55.58	201.53	3.5	4485	44.58
Significant at 5 % level		**	NS	**	**	**	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level
**- significant at 5 % level

Table - 13: Effects of different amendments on growth and yield parameters of wheat (variety: Bari wheat -26) pot experiment - 5 (a).

Treatments	Denotation	Fresh wt.of grain g/pot	Fresh wt.of shoot g/pot	Fresh wt.of root g/pot	Dry wt.of grain g/pot	Dry wt.of shoot g/pot	Dry wt.of root g/pot
Bari wheat -26 Control	T_0	10.70 bc	6.50 ab	1.80 ab	9.81 bc	5.65 b	1.41 a
Bari wheat -26 +100 ppm Pb	T_1	10.48 c	6.06 b	1.21 b	9.10 c	5.60 b	1.11 b
Bari wheat -26 +100 ppm Pb +cowdung	T_2	14.56 a	7.58 a	2.41 a	13.28 a	7.08 a	2.06 a
Bari wheat -26 +100 ppm Pb + poultry litter	T_3	14.56 a	7.32 ab	1.73 ab	12.01 ab	6.80 a	1.14 b
Bari wheat -26 +100 ppm Pb + lime	T_4	12.26 abc	6.55 ab	1.35 b	11.2 ab	6.19 ab	1.17 b
F - Value		5.12	2.43	2.64	5.24	5.34	9.4
Significant at 5 % level		**	NS	NS	**	**	**

Treatments	Denotation	Shoot length(cm)	Root length (cm)	No. of tiller/3 plant	No. of Panicle / 3 plants	1000 grain wt. g/pot
Bari wheat -26 Control	T_0	78.67 b	13.33 bc	7.67 a	7.67 a	42.93 b
Bari wheat -26 +100 ppm Pb	T_1	77.33 b	10.67 d	6.67 a	6.67 a	40.60 b
Bari wheat -26 +100 ppm Pb +cowdung	T_2	80.50 a	15.33 a	7.67 a	7.67 a	43.53 ab
Bari wheat -26 +100 ppm Pb + poultry litter	T_3	79.00 ab	14.33 ab	7.33 a	7.5 a	43.20 b
Bari wheat -26 +100 ppm Pb + lime	T_4	78.01 b	12.67 c	7.33 a	7.5 a	46.43 a
F - Value		4.22	12.81	0.326	1.7	4.73
Significant at 5 % level		**	**	NS	NS	**

in a column donot differ significantly from each other at 5 % level by DMRT
NS- not significant at 5 % level
**- significant at 5 % level

Table-14: Effects of different amendments on mineral nutrition of wheat (variety: Bari wheat-26) pot experiment - 5 (b).

Treatments	Denotation	Nitrogen (N) %			Phosphorus (P)%			Potassium (k)%		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bari wheat -26 Control	T_0	0.643 c	0.830 b	2.02 b	0.127 d	0.054 b	0.466 b	0.45 a	1.99 b	0.58 b
Bari wheat -26 +100 ppm Pb	T_1	0.570 d	0.507 c	1.82 b	0.108 e	0.035 c	0.423 c	0.27 b	1.85 bc	0.52 b
Bari wheat -26 +100 ppm Pb +cowdung	T_2	0.818 a	1.01 a	2.88 a	0.196 a	0.109 a	0.532 a	0.60 a	2.93 a	0.74 a
Bari wheat -26 +100 ppm Pb + poultry litter	T_3	0.793 a	0.921 ab	2.59 a	0.176 b	0.095 a	0.471 b	0.55 a	2.78 a	0.60 b
Bari wheat -26 +100 ppm Pb + lime	T_4	0.761 b	0.852 b	2.14 b	0.161 c	0.061 b	0.412 c	0.45 a	1.69 c	0.60 b
F - Value		128.4	41.3	14.68	187.18	46.8	84.47	6.67	90.54	5.78
Significant at 5 % level		**	**	**	**	**	**	**	**	**

Treatments	Denotation	Calcium (Ca)%			Magnesium (Mg) %			Lead (Pb) ppm		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bari wheat -26 Control	T_0	0.79 c	0.53 bc	0.028 b	0.192 c	0.091 ab	0.093 a	54.87 e	19.0 b	6.72 c
Bari wheat -26 +100 ppm Pb	T_1	0.61 d	0.50 c	0.026 b	0.128 e	0.080 c	0.090 a	183.6 a	38.0 a	15.60 a
Bari wheat -26 +100 ppm Pb +cowdung	T_2	0.69 cd	0.55 bc	0.028 b	0.243 a	0.087 b	0.100 a	105 d	12.77 b	5.0 c
Bari wheat -26 +100 ppm Pb + poultry litter	T_3	0.98 b	0.60 b	0.023 b	0.203 b	0.088 b	0.091 a	135.0 b	20.43 b	12.76 ab
Bari wheat -26 +100 ppm Pb + lime	T_4	1.47 a	0.74 a	0.033 a	0.178 d	0.095 a	0.094 a	117.5 c	15.67 b	10.15 b
F - Value		73.72	13.72	12.33	165.36	6.92	0.355	203.08	18.29	22.41
Significant at 5 % level		**	**	**	**	**	NS	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

**- significant at 5 % level

Table -15: Effects of different varieties of wheat on growth and yield parameters grown on soils contaminated with lead (Pb) pot experiment - 6 (a).

Wheat variety	Denotation	Fresh wt.of grain g/pot	Fresh wt.of shoot g/pot	Fresh wt.of root g/pot	Dry wt.of grain g/pot	Dry wt.of shoot g/pot	Dry wt.of root g/pot
Shotabdi + 200ppm Pb	V_1	12.31 a	7.86 a	1.56 b	11.41 a	6.93 a	1.10 a
Prodip + 200 ppm Pb	V_2	11.42 a	7.12 a	2.18 a	10.73 a	6.04 a	1.16 a
Bari wheat -26 + 200 ppm Pb	V_3	9.12 a	5.01 b	1.01 c	7.50 b	4.51 b	0.69 b
F - Value		2.79	16.45	20.36	5.16	11.46	6.8
Significant at 5 % level		NS	**	**	**	**	**

Wheat variety	Denotation	Shoot length(cm)	Root length (cm)	No. of tiller/3 plan	No. of Panicle / 3 plants	1000 grain wt. g/pot
Shotabdi + 200ppm Pb	V_1	78.33 a	14.0 a	7.67 a	7.67 a	49.17 a
Prodip + 200 ppm Pb	V_2	76.33 a	15.66 a	5.33 b	6.0 b	41.89 b
Bari wheat -26 + 200 ppm Pb	V_3	74.33 a	9.5 b	6.33 b	6.33 ab	39.06 b
F - Value		3.03	43.75	12.33	4.2	14.26
Significant at 5 % level		NS	**	**	NS	**

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

NS- not significant at 5 % level

**- significant at 5 % level

Table-16: Effects of different varieties of wheat on mineral nutrition grown on soils contaminated with lead (Pb) pot experiment - 6(b).

Wheat variety	Denotation	Nitrogen (N) %			Phosphorus (P)%			Potassium (k)%		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Shotabdi + 200ppm Pb	V_1	0.509 b	0.292 b	1.44 a	0.129 a	0.020 a	0.216 b	0.22 a	1.79 a	0.41 a
Prodip + 200 ppm Pb	V_2	1.07 a	0.361 a	1.56 a	0.086 b	0.015 a	0.473 a	0.20 a	1.72 a	0.30 b
Bari wheat -26 + 200 ppm Pb	V_3	0.512 b	0.407 a	1.22 b	0.071 b	0.019 a	0.210 b	0.17 a	1.15 b	0.45 a
F - Value		314.21	13.22	5.16	30.33	0.249	7.14	0.213	103.03	14.01
Significant at 5 % level		**	**	**	**	NS	**	NS	**	**

Wheat variety	Denotation	Calcium (Ca)%			Magnesium (Mg) %			Lead (Pb) ppm		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Shotabdi + 200ppm Pb	V_1	1.12 a	0.48 a	0.034 a	0.190 a	0.130 a	0.084 a	316 c	24 c	16 c
Prodip + 200 ppm Pb	V_2	0.50 b	0.35 b	0.017 b	0.186 a	0.11 a	0.077 ab	517 b	41 b	27.26 b
Bari wheat -26 + 200 ppm Pb	V_3	0.51 b	0.38 b	0.018 b	0.122 b	0.121 a	0.070 b	647 a	54 a	35.67 a
F - Value		273.65	5.83	18.2	14.86	4.02	8.16	332.25	31.33	26.98
Significant at 5 % level		**	**	**	**	NS	**	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT
NS- not significant at 5 % level
**- significant at 5 % level

Table-17: Effects of different doses of lead (Pb) on growth and yield parameters of maize (variety: Bari maize-9) pot experiment- 7(a).

Treatments	Denotation	Fresh wt.of grain g/pot	Fresh wt.of shoot g/pot	Fresh wt.of root g/pot	Dry wt.of grain g/pot	Dry wt.of shoot g/pot
Bari maize - 9 Control	T_0	96.89 a	75.35 a	31.32 a	69.33 a	36.44 a
Bari maize - 9 + 50 ppm Pb	T_1	52.09 b	70.14 ab	25.22 ab	31.70 b	32.25 ab
Bari maize - 9 + 100 ppm Pb	T_2	40.74 bc	60.81 ab	21.09 bc	24.16 bc	30.61 ab
Bari maize - 9 + 150 ppm Pb	T_3	30.30 c	54.57 bc	15.74 bc	21.01 bc	29.40 ab
Bari maize - 9 + 200 ppm Pb	T_4	28.49 c	45.0 c	14.40 c	17.73 c	26.00 b
F - Value		42.8	6.51	5.21	26.44	1.84
Significant at 5 % level		**	**	**	**	NS

Treatments	Denotation	Dry wt.of Root (g)	Shoot length(cm)	Root length (cm)	1000 grain wt. g/pot
Bari maize - 9 Control	T_0	8.12 a	160.33 a	34.0 a	168.67 a
Bari maize - 9 + 50 ppm Pb	T_1	7.01 ab	139.0 b	32.33 a	155.67 b
Bari maize - 9 + 100 ppm Pb	T_2	5.25 bc	131.67 b	30.67 a	148.67 c
Bari maize - 9 + 150 ppm Pb	T_3	4.02 c	122.67 bc	29.0 a	144.67 c
Bari maize - 9 + 200 ppm Pb	T_4	3.33 c	112.67 c	28.0 a	117.33 d
F - Value		10.41	11.06	0.489	117.68
Significant at 5 % level		**	**	NS	**

Means followed by the same letters in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

**- significant at 5 % level

Table -18: Effects of different doses of lead (Pb) on mineral nutrition of maize (variety-Bari maize-9) pot experiment -7(b).

Treatments	Denotation	Nitrogen (N) %			Phosphorus (P)%			Potassium (k)%		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bari maize - 9 Control	T_0	0.441e	0.353 c	1.16 d	0.284 a	0.104 a	0.332 a	1.30 a	1.46 a	0.53 a
Bari maize - 9 + 50 ppm Pb	T_1	0.678 d	0.364 c	1.39 c	0.251 b	0.099 ab	0.296 b	0.99 b	1.44 ab	0.48 ab
Bari maize - 9 + 100 ppm Pb	T_2	0.711 c	0.393 b	1.56 b	0.157 c	0.089 b	0.276 c	0.80 c	1.35 b	0.43 b
Bari maize - 9 + 150 ppm Pb	T_3	0.931 b	0.493 a	1.92 a	0.102 d	0.034 c	0.215 d	0.45 d	0.88 c	0.40 b
Bari maize - 9 + 200 ppm Pb	T_4	0.949 a	0.162 d	1.41 c	0.086 d	0.022 c	0.205 d	0.18 e	0.65 d	0.40 b
F - Value		1881	744	43.14	237.48	80.88	134.25	187.61	130.09	3.98
Significant at 5 % level		**	**	**	**	**	**	**	**	**

Treatments	Denotation	Calcium (Ca)%			Magnesium (Mg) %			Lead (Pb) ppm		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bari maize - 9 Control	T_0	0.713 a	1.43 a	0.0053 a	0.140 a	0.253 a	0.083 a	32.5 e	16.0 c	4.5 c
Bari maize - 9 + 50 ppm Pb	T_1	0.696 a	0.778 b	0.0050 a	0.113 b	0.250 b	0.078 ab	42.5 d	24.0 bc	5.10 c
Bari maize - 9 + 100 ppm Pb	T_2	0.550 b	0.621 c	0.0043 a	0.113 b	0.186 c	0.073 bc	51.50 c	26.0 ab	7.64 c
Bari maize - 9 + 150 ppm Pb	T_3	0.540 b	0.621 c	0.0040 a	0.110 b	0.183 c	0.070 bc	57.23 b	30.0 ab	11.04 b
Bari maize - 9 + 200 ppm Pb	T_4	0.353 c	0.553 d	0.0040 a	0.056 c	0.163 d	0.066 c	66.70 a	34.0 a	14.4 a
F - Value		318.11	893	2.01	46.38	126.57	6.25	53.55	6	17.01
Significant at 5 % level		**	**	NS	**	**	**	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT
NS- not significant at 5 % level
**- significant at 5 % level

Table -19: Effects of different amendments on growth and yield parameters of maize (variety: Bari maize-9) pot experiment - 8 (a).

Treatments	Denotation	Fresh wt.of grain g/pot	Fresh wt.of shoot g/pot	Fresh wt.of root g/pot	Dry wt.of grain g/pot	Dry wt.of shoot g/pot
Bari Maize -9 Control	T_0	96.89 a	75.35 bc	31.32 a	69.33 a	36.44 b
Bari Maize -9 + 100 ppm Pb	T_1	40.73 c	60.81 c	21.09 a	24.16 d	30.61 b
Bari Maize -9 + 100 ppm Pb + cowdung	T_2	87.34 a	98.07 a	26.18 a	55.76 b	42.21 a
Bari Maize -9 + 100 ppm Pb + Poultry litter	T_3	65.16 b	78.63 b	23.19 a	45.27 bc	38.24 ab
Bari Maize -9 + 100 ppm Pb + lime	T_4	60.62 b	74.94 bc	21.21 a	37.75 c	39.39 ab
F - Value		32.15	7.21	1.96	20.15	2.52
Significant at 5 % level		**	**	NS	**	NS

Treatments	Denotation	Dry wt.of root g/pot	Shoot length(cm)	Root length (cm)	1000 grain wt. g/pot
Bari Maize - 9 Control	T_0	8.12 a	160.33 a	34.0 a	168.67 b
Bari Maize - 9 100 ppm Pb	T_1	5.25 b	131.67 b	30.67 a	148.67 c
Bari Maize - 9 +100 ppm Pb + cowdung	T_2	5.99 b	161.0 a	42.0 a	184.67 a
Bari Maize - 9 +100 ppm Pb + Poultry litter	T_3	5.91 b	141.67 b	36.67 a	175.0 b
Bari Maize-9 + 100 ppm Pb + lime	T_4	5.24 b	144.0 b	35.0 a	150.0 c
F - Value		6.06	7.31	1.05	55.48
Significant at 5 % level		**	**	NS	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

Table -20: Effects of different amendments on mineral nutrition of maize (variety: Bari maize-9) pot experiment - 8(b).

Treatments	Denotation	Nitrogen (N) %			Phosphorus (P)%			Potassium (k)%		
		Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bari maize - 9 Control	T_0	0.441 d	0.353 e	1.16 c	0.284 a	0.104 d	0.332 b	1.30 a	1.46 a	0.52 a
Bari maize - 9 +100 ppm Pb	T_1	0.711 b	0.393 d	1.56 b	0.157 c	0.089 e	0.276 d	0.803 c	1.35 ab	0.43 ab
Bari maize - 9 +100 ppm Pb +cowdung	T_2	0.491 c	0.998 a	1.88 a	0.275 a	0.191 a	0.346 a	0.840 c	1.45 a	0.48 ab
Bari maize - 9 +100 ppm Pb + poultry litter	T_3	0.519 c	0.674 b	1.61 b	0.175 c	0.158 b	0.319 c	0.780 c	1.33 b	0.41 b
Bari maize - 9 +100 ppm Pb + lime	T_4	0.805 a	0.454 c	1.44 b	0.213 b	0.131 c	0.212 e	1.20 b	1.41 ab	0.47 ab
F - Value		586	1336	20.38	91.55	85.26	223.03	97.03	2.8	2.29
Significant at 5 % level		**	**	**	**	**	**	**	NS	NS

Treatments	Denotation	Calcium (Ca)%			Magnesium (Mg) %			Lead (Pb) ppm		
		Root	*Shoot*	*Grain*	*Root*	*Shoot*	*Grain*	*Root*	*Shoot*	*Grain*
Bari maize - 9 Control	T_0	0.713 a	1.43 b	0.0053 a	0.140 ab	0.263 b	0.083 b	32.5 c	16.0 c	4.5 d
Bari maize - 9 +100 ppm Pb	T_1	0.550 b	0.610 d	0.0043 a	0.110 c	0.186 c	0.073 b	51.50 b	26.0 a	7.64 a
Bari maize - 9 +100 ppm Pb +cowdung	T_2	0.713 a	0.933 c	0.0053 a	0.147 ab	0.337 a	0.090 b	32.1 c	17.0 bc	1.17 e
Bari maize - 9 +100 ppm Pb + poultry litter	T_3	0.360 c	0.876 c	0.0041 a	0.156 a	0.233 bc	0.171 a	65.0 a	24.33ab	6.32 c
Bari maize - 9 +100 ppm Pb + lime	T_4	0.720 a	2.20 a	0.0053 a	0.127 b	0.183 c	0.110 ab	50.11 b	29.0 a	7.01 b
F - Value		559.95	177.92	2.7	7.7	14.38	2.69	44.28	5.35	939.04
Significant at 5 % level		**	**	NS	**	**	NS	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT
NS- not significant at 5 % level
**- Significant at 5 % level

Table -21: Effects of different doses of Lead (Pb) on Pb conc. (ppm) in root , shoot , and grain of Rice , Wheat and Maize in pot experiment.

Crops	Treatments	Denotation	Pb concentration ppm		
			Root	*Shoot*	*Grain*
Rice	**Control**	T_0	42.5 e	7.5 h	1.97 i
	50 ppm Pb	T_1	206.0 d	7.5 h	2.68 hi
	100 ppm Pb	T_2	341.0 c	20 fg	3.93 ghi
	150 ppm Pb	T_3	613.0 b	30.0 cde	9.0 ef
	200 ppm Pb	T_4	1577.0 a	43.17 b	32.13 ab
Wheat	**Control**	T_0	54.86 e	19 fg	6.72 fgh
	50 ppm Pb	T_1	72.83 e	24.67 ef	7.84 efg
	100 ppm Pb	T_2	183.6 d	38 bc	15.6 c
	150 ppm Pb	T_3	215 d	42.66 b	30.42 b
	200 ppm Pb	T_4	647.8 b	54 a	35.67 a
Maize	**Control**	T_0	32.5 e	16 g	4.5 ghi
	50 ppm Pb	T_1	42.5 e	24.0 efg	5.1 fghi
	100 ppm Pb	T_2	51.5 e	26.0 def	7.67 efg
	150 ppm Pb	T_3	57.23 e	30.0 cde	11.04 de
	200 ppm Pb	T_4	66.7 e	34 cd	14.4 cd
F - Value			649.42	24.82	69.54
Significant at 5 % level			**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT
NS- not significant at 5 % level
**- significant at 5 % level

Table -22 : Effects of different amendments on Pb conc. (ppm) in root , shoot and grain of Rice , Wheat and Maize in pot experiment.

Crops	Treatments	Denotation	Pb concentration ppm		
			Root	*Shoot*	*Grain*
Rice	Control	T_0	42.5 ij	7.5 g	1.97 hi
	100 ppm Pb	T_1	341.0 a	20.0 cdef	3.93 fg
	100 ppm Pb +cowdung	T_2	210.0 d	7.0 g	2.03 hi
	100 ppm Pb + poultry litter	T_3	291.0 b	7.5 g	3.80 fg
	100 ppm Pb + lime	T_4	229.0 c	7.5 g	3.0 gh
Wheat	Control	T_0	54.87 hi	19.0 cdef	6.72 d
	100 ppm Pb	T_1	183.67 e	38 a	15.6 a
	100 ppm Pb +cowdung	T_2	105.0 g	12.77 fg	5 ef
	100 ppm Pb + poultry litter	T_3	135.0 f	20.43 cde	12.76 b
	100 ppm Pb + lime	T_4	117.5 g	15.67 ef	10.16 c
Maize	Control	T_0	32.5 j	16 ef	4.5 fg
	100 ppm Pb	T_1	51.5 hi	26.0 bc	7.64 d
	100 ppm Pb +cowdung	T_2	32.1 j	17.0 def	1.17 i
	100 ppm Pb + poultry litter	T_3	65.0 h	24.33 bcd	6.32 de
	100 ppm Pb + lime	T_4	50.11 hi	29 b	7.01 d
F - Value			**415.95**	**15.27**	**57.41**
Significant at 5 % level			**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

**- significant at 5 % level

Table-23: Effects of lead on growth and yield parameters of wheat varieties (Shotabdi , Prodip and Bari wheat -26) Field experiment 1(a).

variety	Treatments	Denotation	Fresh wt.of grain g/plot	Fresh wt.of shoot g/plot	Fresh wt.of root g/plot	Dry wt.of grain g/plot	Dry wt.of shoot g/plot	Dry wt.of root g/plot	Shoot length (cm)	Root length (cm)	No. of tiller	No. of Panicle	1000 grain wt g/plot	yield t/ha
Shotabdi	Control	V^0_1	269.2 a	206.3 a	45.50 a	257.6 a	167.5 a	22.60 ab	77 a	12.67ab	145 a	145 a	46.03a	2.89 a
	50 ppm Pb	V^1_1	231.4 c	163.4 c	26.44 c	221.5 c	135.1 b	14.60cde	69 bc	9.66bcd	121 b	121 b	43.50 ab	1.97 abc
	100 ppm Pb	V^2_1	198.4 d	144.1 d	20.57 c	185.5 d	119.2 b	13.20 ef	65 c	8.0 d	110 cd	110 cd	42.2 b	1.89 abc
Prodip	control	V^0_2	256.5 b	175.3 b	50.2 a	234.5 b	151.7 a	26.5 a	76.0 a	13.67 a	115 bc	135 a	43.9ab	2.73 ab
	50 ppm Pb	V^1_2	197.5 d	132.6 e	35.60 b	192.2 d	125.3 b	16.54cd	71.67abc	10.0bcd	104 d	104 d	43.20 ab	1.96 abc
	100 ppm Pb	V^2_2	189.3 d	99.44 f	23.44 c	161.1 e	89.2 c	13.30 ef	68.67bc	9.0cd	95e	90 e	41.10 bc	1.73 bc
Bari wheat-26	control	V^0_3	272.6 a	176.5 b	48.44 a	258.1a	154.6 a	19.86 bc	74.3 ab	11.33 abc	140 a	135 a	42.09 b	2.40 abc
	50 ppm Pb	V^1_3	195.5 d	141.3 d	20.20 c	161.2 e	122.7 b	10.25 g	70.30abc	10.33 bcd	104 d	115bc	41.80 b	1.69 ab
	100 ppm Pb	V^2_3	173.3 e	137.2 de	19.30c	158.2 e	118.6b	9.60 g	64.67bc	9.0 cd	95 e	100 d	38.91 c	1.33 c
F - Value			128.27	164.4	31.35	159.36	20.78	10.47	4.2	4.06	38.5	30.4	5.02	2.52
Significant at 5 % level			**	**	**	**	**	**	**	**	**	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT
NS- not significant at 5 % level
**- significant at 5 % level

Table - 24: Effects of lead (Pb) on N, P, K, Ca, Mg and Pb concentration of wheat varieties (Shotabdi , Prodip and Bari wheat -26) Field experiment-1 (b).

variety	Treatments	Denotation	Nitrogen (N) %			Phosphorus (P)%			Potassium (K) %		
			Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Shotabdi	Control	V^0_1	0.803 b	0.425 a	2.09 a	0.102 a	0.075 a	0.418 b	0.54 a	1.53 b	0.59 a
	50 ppm Pb	V^1_1	0.509 e	0.223 c	1.78 bc	0.083 b	0.059 b	0.393 c	0.47 b	1.50 b	0.51 abc
	100 ppm Pb	V^2_1	0.491 e	0.151 e	1.43 e	0.077 bc	0.058 b	0.371 d	0.45 c	1.31 c	0.49 bc
Prodip	Control	V^0_2	1.03 a	0.407 b	2.02 a	0.083 b	0.033 de	0.315 e	0.33 d	1.66 a	0.59 a
	50 ppm Pb	V^1_2	0.538 d	0.234 c	1.77 bc	0.068 cd	0.031 de	0.278 f	0.27 e	1.17 d	0.56 abc
	100 ppm Pb	V^2_2	0.458 f	0.202 d	1.62 d	0.056 d	0.026 e	0.215 g	0.183 f	1.17 d	0.51 abc
Bari wheat-26	Control	V^0_3	0.743 c	0.433 a	1.81 b	0.083 b	0.047 c	0.491 a	0.72 a	1.50 b	0.57 ab
	50 ppm Pb	V^1_3	0.372 g	0.224 c	1.65 cd	0.071 bc	0.041 cd	0.427 b	0.47 c	1.20 d	0.50 bc
	100 ppm Pb	V^2_3	0.365 g	0.198 d	1.29 f	0.064 cd	0.038 cde	0.409 ab	0.23 ef	1.12 d	0.48 c
F - Value			1116	831	36.38	9.45	8.21	187.73	72.12	32.34	2.82
Significant at 5 % level			**	**	**	**	**	**	**	**	**
variety	Treatments	Denotation	Calcium (Ca)%			Magnesium (Mg) %			Lead (Pb) ppm		
			Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Shotabdi	Control	V^0_1	0.095 cd	0.934 a	0.029 ab	0.183 ab	0.225 a	0.123 a	72.5 f	14.0 c	5.15c
	50 ppm Pb	V^1_1	0.078 e	0.678 b	0.026 ab	0.153 abc	0.165 b	0.109 abc	160.5 d	20.0 bc	12.30 bc
	100 ppm Pb	V^2_1	0.036 f	0.461 d	0.026 ab	0.135 bc	0.134 cd	0.101 bcd	310.2 c	30.71 b	20.5 a
Prodip	Control	V^0_2	0.129 b	0.551 c	0.027 ab	0.205 a	0.156 bc	0.121 ab	35.0 i	20.0 bc	6.52 bc
	50 ppm Pb	V^1_2	0.084 de	0.429 de	0.017 b	0.179 abc	0.124 d	0.102 bcd	67.5 fg	22.0 bc	7.68 bc
	100 ppm Pb	V^2_2	0.021 g	0.361 ef	0.014 b	0.174 abc	0.124 d	0.089 cd	332.5 b	27.0 ab	21.51 a
Bari wheat-26	Control	V^0_3	1.12 a	0.413 de	0.039 a	0.155 abc	0.0907 e	0.108 abc	50.0 gh	18.0 bc	9.2bc
	50 ppm Pb	V^1_3	0.099 c	0.407 de	0.026 ab	0.148 abc	0.083 e	0.094 cd	95.0e	24.33 bc	13.31 b
	100 ppm Pb	V^2_3	0.073 e	0.322 f	0.021 b	0.116 c	0.074 e	0.086 d	515.0 a	45.0 a	23.50 a
F - Value			6638	67.11	2.15	1.95	27.24	4.37	561	4.44	9.08
Significant at 5 % level			**	**	NS	NS	**	**	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT
NS- not significant at 5 % level
**- significant at 5 % level

Table-25: Effects of lead (Pb) on growth, yield and mineral nutrient concentration of maize (variety: Bari maize-9) Field experiment-2.

variety	Treatments	Denotation	Fresh wt.of Grain g/plot	Fresh wt.of shoot g/plot	Fresh wt.of root g/plot	Dry wt.of grain g/plot	Dry wt.of shoot g/plot	Dry wt.of root g/plot	Shoot length (cm)	Root length (cm)	1000 grain wt g/plot	yield t/ha
Bari Maize-9	control	V^{0}_{4}	682.2 a	832.2 a	188.31 a	435.7 a	751.6 a	108.13 a	231.0 a	22.33 a	231.5 a	6.82 a
	50 ppm Pb	V^{1}_{4}	658.5 b	500.3 b	107.16 b	406.2 b	461.9 b	56.50 b	228.0 a	17.0 b	214.6 b	6.61 a
	100 ppm Pb	V^{2}_{4}	599.3 c	476.2 b	88.53 c	373.6 c	389.2 c	34.30 c	226.0 a	13.33 b	182.0 c	5.32 a
F - Value			136.47	139.9	281.1	60.14	995.6	104.08	0.543	14.55	922.61	1.28
Significant at 5 % level			**	**	**	**	**	**	NS	**	**	NS

variety	Treatments	Denotation	Nitrogen (N) %			Phosphorus (P)%			Potassium (K) %		
			Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bari Maize-9	control	V^{0}_{4}	0.556 b a	0.807 a	1.53 c	0.098 a	0.119 a	0.337a	0.96 a	1.36 a	0.43 a
	50 ppm Pb	V^{1}_{4}	0.574 a	0.638 b	1.81 b	0.083 a	0.074 b	0.310 b	0.84 b	1.30 a	0.42 a
	100 ppm Pb	V^{2}_{4}	0.574 a	0.562 c	1.93 a	0.064 b	0.056 c	0.290 c	0.47 c	1.17 b	0.38 a
F - Value			7.04	799.69	89.65	14.76	66.74	23.84	90.32	22.34	3.15
Significant at 5 % level			**	**	**	**	**	**	**	**	NS

variety	Treatments	Denotation	Calcium (Ca)%			Magnesium (Mg) %			Lead (Pb) ppm		
			Root	Shoot	Grain	Root	Shoot	Grain	Root	Shoot	Grain
Bari Maize-9	control	V^{0}_{4}	0.236 a	0.849 a	0.064 a	0.104 a	0.325 a	0.083 a	25.0 c	17.0 a	5.06 c
	50 ppm Pb	V^{1}_{4}	0.213 b	0.485 b	0.011 a	0.102 b	0.229 b	0.075 a	67.5 b	24.0ab	8.75 b
	100 ppm Pb	V^{2}_{4}	0.165 c	0.393 c	0.006 a	0.096 b	0.153 c	0.069 a	92.5 a	26.0 b	14.47 a
F - Value			241.04	25.01	2.09	5.37	39.01	0.574	134.37	7.12	7.76
Significant at 5 % level			**	**	NS	**	**	NS	**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

**- significant at 5 % level

Table -26: Effects of different doses of lead (Pb) on Pb conc. (ppm) in root, shoot, and grain of different wheat varieties and one Maize variety in the field. experiment.

Crops	Treatments	Denotation	Pb concentration (ppm)		
			Root	Shoot	Grain
Shotabdi	Control	V^0_1	72.5 f	14.0 d	5.15 e
	50 ppm Pb	V^1_1	160.5 d	20.0 bcd	12.30 bcd
	100 ppm Pb	V^2_1	310.2 c	30.71 b	20.5 a
Prodip	Control	V^0_2	35 hi	20.0 bcd	6.52 de
		V^1_2	67.5 fg	22.0 bcd	7.68 cde
	100 ppm Pb	V^2_2	332.5 b	27.0 bcd	21.51 a
Bari wheat-26	Control	V^0_3	50.0 h	18.0 bcd	9.2 bcde
	50 ppm Pb	V^1_3	95.0 e	24.33 bcd	13.31 bc
	100 ppm Pb	V^2_3	515.0 a	45.0 a	23.50 a
	Control	V^0_4	17.0 i	17.0 cd	5.06 e
Bari maize-9	50 ppm Pb	V^1_4	67.5 fg	24.0 bcd	8.75 bcde
	100 ppm Pb	V^2_4	92.5 e	26.0 bc	14.47 b
F - Value			607.03	4.39	10.07
Significant at 5 % level			**	**	**

Means followed by the same letter in a column donot differ significantly from each other at 5 % level by DMRT

NS- not significant at 5 % level

**- significant at 5 % level

Table- 27: Toxicity levels of Heavy metal

Heavy metal	Toxicity
Fe, Mn, Mo	Low toxicity
Zn, Ni, Cu, Co, Cr	Average toxicity
As, Ag, Sb, Cd, Hg, Pb	High toxicity

Source: (Thakur, 2006b).

Table- 28: Concentration of heavy metals (µg/gm dry matter) Lithosphere, Soils and Plants.

Heavy metals	Lithosphere*	Soil**	Plants***
Cd	0.32	0.06	0.2-0.8
Co	40	8	0.05-0.5
Cr	200	100	0.2-1.0
Cu	70	20	4-15
Fe	50000	38000	140
Hg	0.5	0.03	0.015
Mn	1000	850	15-100
Mo	2.3	2	1-10
Ni	100	40	1
Pb	16	10	0.1-10
Sn	40	10	0.3
Zn	80	50	8-100

Source: *-Goldschmidt, 1959

**- Bowen, 1966

***- Allaway, 1968.

Table- 29: Some major sources of heavy metals and other hazardous substances

Major source/industry	As	CH	Cr	Cu	Pb	Hg	Zn	MO	Cd
Battery					*	*	*		*
Tannery/Leather			*					*	
Pharmaceutical		*				*		*	
Chemical manufacturing		*	*	*		*		*	
Textile			*	*				*	
Pesticide industry		*			*	*	*	*	
Paper and pulp						*		*	
Electrical			*	*			*		*
Explosive	*			*	*	*		*	
Mining	*		*	*	*	*	*	*	*
Print and dye			*	*	*	*	*		*
Petrolium	*	*	*		*				

Here,
CH=Chlorinated Hydrocarbon
MO=Miscellaneous Organics

Source- **Schmidtke, 1980.**

Table- 30: Metal concentration (mg/kg) in soils of different industrial sites within and Dhaka

Location	Cu	Mn	Zn	As	Ni	Cr	Hg	Pb	Cd
Hazaribagh	115	263	330	2.13	25	25014	0.17	44.2	Tr
Tongi	27.3	476	2026	2.60	37	48.3	3.41	19.6	0.32
Tejgaon	47	119	200	2.81	194	54.1	0.63	70.0	163
Narayangang	60	371	109	3.15	85	75	1081	174	0.70
Kanak	50	362	168	3.68	94	109	2.15	171	0.50
Enayetnagar	47	392	142	5021	146	110	1.63	185	0.70
Bholail	53	534	116	4.27	84	92	1.49	183	0.60
Pagla	25	550	525	3.35	201	Tr	Tr	725	Tr

Here, tr = Trace concentration of heavy metal

Source: Ullah *et al.,* 1999.

Table- 31: Critical levels (mg/kg) for heavy metals in plants.

Element	**Plants in general** (ppm) *	Soils (ppm))**
Lead (Pb)	10-20	100
Cadmium (Cd)	5-10	3
Chromium (Cr)	1-2	100
Copper (Cu)	15-20	100
Mercury (Hg)	0.5-1	2
Nickel (Ni)	20-30	50
Zinc (Zn)	150-200	300
Cobalt (Co)	10-20	50

Source: * - Lake *et al.,* 1984; Sauerbeck, 1982.
**- Kloke, 1980.