

**EFFECTS OF ORGANIC AMENDMENTS ASSISTED PHYTOREMEDIATION
POTENTIAL OF LEAD CONTAMINATED SOIL BY MAIZE**



A THESIS

BY

MST. NURE FATEMA TONNI

Student No. 1501363

Session: 2022-2023

Semester: July-December 2023

MASTER OF SCIENCE

IN

SOIL SCIENCE

DEPARTMENT OF SOIL SCIENCE

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY

UNIVERSITY, DINAJPUR-5200

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*Submitted to the
Department of Soil Science
Hajee Mohammad Danesh Science and Technology University, Dinajpur
in partial fulfillment of the requirements for the degree of*

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Dedication

All the credits for the success of this study goes to my parents and teachers, who have been nothing but helpful and encouraging throughout the past several months. Their encouragement was invaluable to me.

ACKNOWLEDGEMENT

The author expresses her deepest sense of gratefulness to the Almighty that has enabled her to complete the present research work and to prepare this capacious thesis for the degree of Masters of Science (M. Sc.) in Soil Science.

*The author expresses sincere gratitude, profound respect and immense indebtedness to her **supervisor Dr. M. Abdulaha-Al-Baqy**, Department of Soil Science, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his continuous inspiration, scholastic and systematic supervision, in valuable advice and generous help for the completion of the research work. Without his help and supervision it would not have been possible to complete the dissertation within the stipulated period. Sincere appreciation is also due to his constructive criticism and meticulous corrections of thesis manuscript.*

*The author feels proud to express his whole hearted sense of respect and gratefulness to her **Co-supervisor, Prof. Dr. Md. Shahadat Hossain Khan**, Department of Soil Science, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his valuable suggestions, sincere help and intellectual instructions during the period of research work. She is also indebted to him for his encouragement and valuable criticism in the preparation of his credible dissertation.*

The author also feels very grateful to her research mates including Md. Al Mushabber Asif, Md. Imrul Kayes, Md. Mosiur Rahman, Farhana Rahman Rusha who have been a continuous support throughout the research journey from day one. Their skill, helpful attitude gives this research work a tremendous positive vibe.

And last from the core of heart the author feels duty bound to acknowledgement the blessing and incentives of her beloved parents for their blessings, inspirations, sacrifice and moral support and financial assistance, which encouraged and paved the way of higher studies.

The Authoress

ABSTRACT

Phytoremediation, the use of plants and their associated microbes for environmental cleanup, has gained acceptance in the past 10 years as a cost-effective, noninvasive alternative or complementary technology for engineering-based remediation methods. Plants can be used for pollutant stabilization, extraction, degradation, or volatilization. This study evaluated the effects of organic amendments to enhance phytoextraction of heavy metal lead (Pb) from artificially polluted soil by maize (*Zea mays*). The objective of this study was to investigate the impacts of altered soil chemical properties (soil pH, OM, cation exchange capacity, electrical conductivity, base cation (Ca, Mg, K and Na) on phytoremediation of Pb contaminated soil due to application of compost, biochar, ash, poultry litter and co-compost. The treatments were a) control with 200mg Pb, b) Pb contaminated soil with compost 100g (10%), c) Pb contaminated soil with ash 100g(10%), d) Pb contaminated soil with biochar 100g (10%), e) Pb contaminated soil with poultry litter 100g (10%), f) Pb contaminated soil with co-compost (10%) and replicate three times in a completely randomized design. The results indicated that the compost, poultry litter significantly enhanced the growth ratio and plant height of maize under Pb contaminated environment. Ash and biochar increased plant height same as control. Biochar and COMBI increased total amount of plant available P and N. Compost, ash, poultry litter showed the same effect on total phosphorus and nitrogen which was greater than the control. In case of soil pH, the sequence is: poultry litter > COMBI > compost > biochar > ash > control. For soil OM: compost > COMBI > biochar > control > poultry litter > ash. For soil EC: compost > poultry litter > COMBI > ash > biochar > control and soil CEC: compost > poultry litter > COMBI > biochar > ash > control. Moreover, compost enhanced base cations like Ca, Mg greater than ash, biochar, poultry litter, co-compost. Poultry litter accelerated base cations like K, Na compared to control. Therefore, it can be suggested that application of organic amendments like biochar, compost, ash, poultry litter, co-compost was the most suitable choice for the treatment of Pb contaminated soil phytoremediation.

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CHAPTER I

INTRODUCTION

Maize or Indian corn (called corn in some countries) is *Zea mays*, a member of the grass family Poaceae. It is a cereal grain which was first grown by people in ancient Central America. Approximately 1 billion tones are harvested every year. However, little of this maize is eaten directly by humans. Most is used to make corn ethanol, animal feed and other maize products, such as corn starch and corn syrup. Maize is a leafy stalk whose kernels have seeds inside. It is an angiosperm, which means that its seeds are enclosed inside a fruit or shell. Centuries of cross breeding have produced larger plants, and specialized varieties. People have long eaten sweet corn and popcorn with little processing, and other kinds after processing into flour for making cornbread, tortillas, and other artificial foods.

Soil contamination with heavy metals, particularly lead (Pb), has piqued the interest of scientific societies due to the deleterious consequences of Pb reaching people through the food chain (Ali *et al.* 2020). Unlike biological matter, heavy metals do not biodegrade and hence linger in the environment. It is widely established that many different foods pose health risks due to the presence of Pb in the environment as a result of metallurgical mining, processing, and smelting, uncontrolled artisanal gold mining and e-waste recycling (Luo *et al.* 2011).

Soil contamination of agricultural land throughout the world by heavy metals has become a serious problem. Heavy metals are toxic for plants and can inhibit plant growth, development, and productivity (Chernishuk DK *et al.*, 2020). Lead (Pb) is a classically deleterious heavy metal that threatens agro-ecosystem sustainability through anthropogenic activities such as mining, waste disposal, and the intensive use of pesticides and fertilizers (Adler *et al.*, 2016). Pb is easily accumulated in soil and is readily absorbed by plants, which

may cause harm to human health through the food chain (Deng *et al.*, 2014). Due to their detrimental effects on the eco-system, the remediation of Pb contaminated soils is therefore essential.

Therefore, the remediation of Pb contaminated soil is critical to ensure soil security and the sustainable development of agriculture (García-Delgado *et al.*, 2019). Soils through different mechanisms, such as metal immobilization in the soil, improve soil fertility and enzyme activity (Al-Wabel *et al.*, 2015). Soil enzymes are involved in nutrient cycling and availability to plants, and the enzymes activity can be used as an indicator of soil health.

Phytoremediation is the extraction or stabilization of heavy metals in soil using plants. Phytoremediation includes five major pathways- (i) uptake of heavy metal, (ii) bioaccumulation of heavy metal, (iii) immobilization of heavy metal, (iv) reduction of bioavailability of heavy metal, and (v) transformation of heavy metal into volatile forms (Shah and Daverey 2020). For Pd remediation, organic or inorganic amendments and/or phytoremediation have been widely studied by researchers worldwide. But the inorganic amendments application is unsustainable and has negative residual impacts on the environment. The phytoremediation strategy as in situ Pb remediation is affordable and environmentally beneficial. Compost derived from biowaste can be a promising amendment to remediate polluted soils. On the other hand, biochar, a byproduct of biomass pyrolysis, is a potential amendment for remediating Pb contaminated soils because to its large surface area and significant amounts of functional groups (Fan *et al.* 2020).

The literature search revealed that the plant species Maize is a superb hyperaccumulator. It is worth noting that different species and cultivar of Maize may accumulate different amounts of heavy metals. Additions to the soil, such as compost and biochar, may affect the soil's chemical, biological, and even physical characteristics (Bortoloti and Baron 2022).

The combined use of biochar and chicken manure had an additive effect and produced the largest increases in maize growth, leaves antioxidant enzymatic activity, and soil enzyme activity. Their combined use also led to the most significant decreases in maize tissues Pb and soil available Pb. These results suggest that a combination of biochar and compost was more effective at reducing soil Pb bioavailability and uptake by maize tissues, and increasing maize growth (Liu *et al.*, 2021).

Biochar is a stable carbonaceous enriched by-product with vital anti-decomposition and aromatic properties derived from pyrolysis/carbonization of organic residues, such as animal manure, cellulosic material, and agricultural wastes under limited oxygen condition (Pandey *et al.*, 2020). Biochar has received continued attention of the scientific community in terms of environmental remediation and protection due to its multifunctional groups, surface charge, high surface area, strong adsorption capacity, crystalline and pore structure.

It is well documented that furfural residues (FRs) or electron transfer reactions typically occurred during the heating or pyrolysis of organic materials. Therefore, it is most probable that FRs would be produced during biochar production. Biochar can catalyze the redox reaction with contaminants due to the presence of FRs and can generate OH with a combination of hydrogen peroxide or O₂, which has attracted increasing interest among the scientific communities. FRs may mediate OH generation with the presence of dioxygen and reduction of pollutants without the need for external oxidants in biochar and other carbon-containing materials (Fang *et al.*, 2017).

Biochar application to soils can improve soil carbon sequestration, nutrition, and crop yield and can potentially reduce the bioavailability of soil pollutants (Li *et al.*, 2018). Feed stocks, including wood, sludges, crop residues, and manures which belong organic fertilizers, are used as biochar. However, using single amendments to remediate heavy metal-polluted

soils may not be effective, so co-application of several materials as soil amendments is becoming increasingly popular .Several studies have shown that the interaction of manure and biochar changes soil's physicochemical characteristics, immobilizes heavy metals, and reduces phytoavailability in mining areas (García-Delgado *et al.*, 2019; Lebrun *et al.*, 2019; Nandillon *et al.*, 2019).

Therefore, the aims of this study were:

- 1) To determine the effects of compost, biochar, poultry litter, ash, co-compost on Pb contaminated soil phytoremediation; and
- 2) To investigate how the altered soil chemical properties (pH, organic matter, cation exchange capacity) due to application of compost, biochar, poultry litter, ash, co-compost influence phytoremediation of Pb contaminated soil.

CHAPTER II

REVIEW OF LITERATURE

To the best of our knowledge, little research on the impacts of organic amendments assisted phytoremediation potential of lead contaminated soil by maize. However, some recent related works conducted globally and their findings are summarized below.

Muzammal *et al.*, (2023) investigated the biochar application in phytoremediation method resulted in the removal, degradation, or stabilization of heavy metals from soil media. Various other chemical, biological and physical techniques were used for the treatment of heavy metals-contaminated soils but biochar application to soils was proved to be a much better option than different conventional methods. Biochar when added to soil can enhance nutrient retention ability, soil structure, water holding capacity and microbial activity thus producing a favorable environment for the growth of plants. Efficient plants were selected for phytoremediation method which was based on their potential to sustain or uptake heavy metals without significant damage to their growth. They showed great potential to uptake and sustain high levels of heavy metals in their roots or aerial parts. The biochar application in soil along with phytoremediation reduced the bioavailability of heavy metals to plants thus restricting their significant uptake.

Houida *et al.*, (2023) conducted to study the impact of metal-tolerant plant growth-promoting bacteria (PGPB) isolated from the chloragogenous tissue of *Aporrectodea molleri*, which represents a unique habitat. They also investigated their effects on the growth of *Spinacia oleracea* under heavy metal stress and assess their potential for enhancing phytoremediation capabilities. The results showed that heavy metal stress considerably diminished root and shoot length, biomass, chlorophyll content, soil alkaline (and acid phosphatases and urease. They also reported that soil inoculation with bacteria isolates remarkably improved plant

growth and also earthworms are a reservoir of multi-beneficial bacteria that can effectively improve phytoremediation efficiency.

Rassaei, (2023) carried out the study to examine the impact of sugarcane bagasse biochar (SBB) on enhancing the development of maize in Cadmium (Cd) and Lead (Pb) polluted soil. SBB increased chlorophyll index, leaf area, plant height and dry weight of roots and shoots due to a decrease in the concentration of Cd and Pb in the roots and shoots. It can be concluded that SBB addition to HMs-contaminated soils is a suitable remedial action that will enhance plant growth.

Wang (Liu *et al.*, 2022) *et al.*, (2022) investigated the contributions of inoculation with the arbuscular mycorrhizal fungus (AMF) *Acaulospora mellea* and three soil amendments, i.e., hydroxyapatite (HAP), manure, and biochar,) to heavy metal phytoremediation using sweet sorghum grown on an abandoned agricultural soil, with environmentally realistic contamination in a plant growth chamber. The results showed that root colonization by indigenous AMF decreased by 28%-46% with HAP, but increased after manure and biochar applications as compared to the no amendment control (CK). Among the three soil amendments, HAP was the most effective in promoting plant growth and phytostabilization of Cd, Pb, and Zn and with amendments on the immobilization of Cd and Pb. In conclusion, soil amendments, particularly HAP, produced positive impacts and synergistic interactions with AMF on the phytostabilization of heavy metals using sweet sorghum.

de Lima Veloso *et al.*, (2021) investigated the soil availability, sequential extraction, and maize uptake of Cd, Pb, and Zn in a highly contaminated soil amended with rice straw biochar. They estimated that applying biochar increased the soil organic carbon, CEC, and P up to 27, 30, and 107 respectively. The sequential extraction showed that Pb and Zn in the original soil were retained mainly in residual fractions. Biochar rates increased the proportion of Cd in the organic fraction to 85%, while Pb and Zn were redistributed mainly into iron

oxides. The maize biomass increase, metal soil bioavailability decrease, and low metal concentration in shoots driven by biochar indicate that phytoattenuation using rice straw biochar and maize cultivation could reduce risks to humans and the environment in the polluted sites of Santo Amaro.

Q. Liu *et al.*, (2022) conducted a study to investigate the effects of five biochar derived from rice husk (RH), pig manure (PM), sewage sludge (SS), corn straw (Ca sixty-day pot experiment S), and wood chip (WC) and their respective combination with lime or compost on cadmium (Cd) immobilization and adsorption as well as physicochemical features and enzyme activities in contaminated soil. The results revealed that the sole application of PM, SS, and CS biochar had a positive impact on lettuce growth and photosynthetic pigments. In addition, mixing PM or SS biochar with compost further promoted lettuce growth due to higher soil fertility and enzyme activities. However, as compared to unamended soil, CS biochar-compost combination, RH, PM, SS, and CS biochar-lime combination highly reduced lettuce plant height and fresh weight.

Pandey *et al.*, (2022) investigated on organic wastes which had been used in agricultural operations as soil amendments. Various organic amendments are frequently utilized in agricultural operations because they have been known to improve soil health properties like water holding capacity, nutrient availability, porosity, etc. and biological properties like microbial activity. The result showed that Compost, when added to the soil as an amendment, had an immediate impact on various physicochemical properties like pH, OC, metal (loid) solubility etc. Organic waste amendments, when applied to heavy metal contaminated soils not only enhance its fertility properties but also diminish bioavailability and mobility of potentially toxic elements by promoting certain processes like complexation, sorption etc. The application of these amendments ameliorates the phytoremediation process in contaminated sites. Amendment of soil with compost enhanced the growth of plants as well

as favored the activity of soil microbiota. These two associates together to strengthen the process of phytoremediation, plant resilience towards stress as well increased the production of plant biomass.

Narayanan and Ma (2022) investigated that a number of anthropogenic and weathering activities accumulate heavy metals in soils, causing adverse effects on soil characteristics, microbial activity (diversity), agricultural practices, and underground aquifers. This study explored the potential for remediation of metal-contaminated soils using a biochar-based responsible approach. Plant-based biochar is an auspicious bio-based residue substance that can be used for metal-polluted soil remediation and soil improvement as a sustainable approach. Plants with rapid growth and increased biomass can meet the requirements for phytoremediation in large quantities. Recent research indicated significant progress in understanding the mechanisms of metal accumulation and contaminant movement in plants used for phytoremediation of metal-contaminated soil. Thus, this studies critically discusses the influence of plant and agricultural waste-based biochar on plant phytoremediation potential in metal-contaminated soils.

Medyńska-Juraszek *et al.*, (2022) carried out a greenhouse experiment to examine the effects of rabbit-manure-derived biochar (RBC) on Cu, Cr, Cd and Pb uptake by five green leafy vegetables (lettuce—*Lactuca sativa* L., spinach—*Spinacia oleracea* L., corn salad—*Valerianella locusta* L., kale—*Brassica oleracea* L., mustard greens—*Brassica juncea* L.) cultivated in compost substrate and soil amended with a 30% (v/w) mix of compost and biochar. The results indicated that the addition of biochar decreased Cu, Cr, Cd and Pb availability in the tested substrates, reducing the uptake of Cd in spinach by 61% and Pb in mustard greens by 73%. The application of RBC also had some adverse effects, such as enhanced accumulation of Cr by kale, lettuce and mustard greens cultivated in compost. Compost co-application with biochar to soil decreased the availability of metals, reducing the

content of Pb and Cd in tissues of the tested vegetables, while uptake of Cu and Cr was enhanced in spinach and lettuce by 20%. In conclusion, the application of compost and biochar can be beneficial in improving the quality of urban soil used for horticulture purposes.

Rathika *et al.*, (2021) evaluated the synergistic effect of biochar (BC) and EDTA to enhance phytoextraction of heavy metal lead (Pb) from artificially polluted soil by *Brassica juncea*. The BC and EDTA amendment enhanced the growth and survival of *B. juncea* under Pb stress environment. BC and EDTA significantly increased the biomass of *B. juncea* and significantly increased the total chlorophyll content in the combined amendment of BC and EDTA (22.2 mg/g) compared to the individual amendment of BC (12.8 mg/g) and EDTA (12.2 mg/g) respectively. They revealed that the combined use of BC and EDTA was the most advantageous option for the treatment of Pb contaminated soil as compared to individual amendments.

Azeem *et al.*, (2021) discovered the effects of SB on soil properties, bioavailable Zn and Cd and their geochemical fractions, bacterial community composition and activity, and the response of plant attributes (pigments and antioxidant activity). Results showed that the SBH added at 10% (SBH10) increased soil organic carbon, total nitrogen, and phosphorus, and also increased the oxidizable and residual Zn and Cd fractions. Additionally, SBH10 enhanced urease and phosphates activities, but reduced dehydrogenase and β -glucosidase activities. In conclusion, SB immobilized Zn and Cd in smelter-affected soils, enhanced the bacterial abundance and microbial function (urease, phosphates), and improved plant growth.

Mehmood *et al.*, (2021) conducted a compost-mediated As phyto remediation potential of maize in the two different textured soils (sandy loam soil and clay loam soil) at varying As (0–120 mg kg⁻¹) and compost (0–2.5%) levels under glasshouse conditions. Results revealed

that in the absence of compost maize plants grown at different soil As levels (0–120 mg kg⁻¹) accumulated 1.20–1.71 times more As from sandy loam soil than that of clay loam soil. Arsenic phytoremediation potential of the maize plants was found to be economical for sandy loam soil with 1% compost level and for clay loam soil at 2.5% compost level, suggesting soil type specific dose dependence of compost for As phytoremediation programs.

Ghosh and Maiti, (2021) investigated on the application of biochar assisted phytoremediation in HM contaminated mine spoil and mechanisms of metal immobilization by biochar, potential plants and contaminated biomass disposal methods. Availability of biochar feedstock and production conditions, optimization of application rate, application techniques, selection of suitable hyperaccumulators and cost optimization of bulk biochar production were the key to a successful biochar-based HM remediation of mine tailings and coalmine spoil. For a holistic biochar-phytoremediation technique, incineration and pyrolysis could be effectively dispose contaminated biomass.

Irfan *et al.*, (2021) experimented biochar and compost's comparative effect on Pb, Cd, and Cr immobilization in soil, photosynthesis, and growth of maize plants. It is concluded that both biochar and compost decreased heavy metals availability in the soil, reducing toxicity in the plant. However, biochar was most effective in reducing heavy metals content in soil and plant compared to compost. In the future, more low-cost, eco-friendly soil remediation methods should be developed for better soil health and plant productivity.

Liu L. *et al.*, (2021) conducted this study to evaluate the additive effects of biochar and chicken manure on maize growth in Pb-contaminated soils. The results showed that all biochar and/or chicken manure treatments significantly ($P < 0.05$) increased maize plant height, biomass, and superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT) activity but decreased the malondialdehyde (MDA) content. These results indicated that amending the soil with biochar and/or chicken manure could alleviate Pb's phytotoxicity. The

biochar and/or chicken manure treatments remarkably decreased the Pb concentration in maize roots, stems, leaves, bioconcentration factor (BCF), translocation factor (TF), and available Pb concentration in the soil.

Li *et al.*, (2021) investigated the effects of bamboo biochar (BBC) as soil amendment on growth and phytoremediation potential of *Salix psammophila* in soil heavily polluted by Cd and Zn. Bamboo biochar was added to soil which significantly increased the organic matter, available potassium (K) content, while decreased the hydrolyzable nitrogen (N) content and the levels of total and bioavailable HMs in soil. BBC amendment stimulated the accumulation of Cu, Cd and Zn in plant tissues, meanwhile, Cd and Zn accumulation were more evident amended soil treatment.

Menhas *et al.*, (2021) investigated the potential of *Cronobactersakazakii*-Ethylenediaminetetraacetic acid (EDTA) assisted phytoremediation potential of *Zea mays* L. to remediate lead (Pb)-contaminated soils. The *C. sakazakii* exhibited various stress tolerance mechanisms via plant growth promoting (PGP) traits, intrinsic extracellular enzyme production and antibiotic resistance. A greenhouse experiment was conducted to examine the dual effects of plant growth promoting endophytic bacteria (PGPEB)-chelator synergy in maize plants under different Pb contaminated soil regimes.

Obasi *et al.*, (2021) investigated the effects of organic manures amendments of crude oil polluted soil on the growth and performance of maize (*Zea mays* L.) under potted environment at the botanic garden of University of Port-Harcourt, Nigeria. Result showed that crude oil pollution impaired the maize seed germination, growth and development. Organic manures amendments of polluted-soil significantly improved ($P < 0.05$) maize plant agronomic characteristics with combined manures especially poultry-manure + cow-dung showing highest improvement than other combined or single manure treatment.

Mwilola *et al.*, (2020) assessed this study to experiment the potential of chicken manure (CM), triple superphosphate (TSP) and a blended fertilizer (BF; consisting of Nitrogen, Phosphorous and Potassium (NPK) fertilizer and composted chicken manure) to reduce lead (Pb), zinc (Zn) and cadmium (Cd) in soils and their accumulation in maize grown near the Kabwe mine. Maize was grown to maturity and its HM concentrations and associated health risk indices were calculated. All soil amendments decreased bioavailable soil Pb concentrations by 29–36%, but only CM decreased Zn, while the amendments increased or had no effect on Cd concentrations compared to the control. The hazard quotients for Pb and Cd were much greater than one, indicating a high risk of possible exposure to toxic levels by people consuming maize grain grown in this area. This study demonstrated the significant potential of manure and phosphate-based amendments to reduce Pb and Zn, and to some extent Cd, uptake in maize grain and consequently reduce associated health risks.

Simiele *et al.*, (2020) experimented this study to assess the effect of two different modalities of biochar amendment application (top third of the tube and all tube height) combined with iron sulphate addition on the physico-chemical properties of a mining polluted soil and the growth and metal (loid) uptake of three Salicaceae species. A 1.5year mesocosm experiment under field condition was conducted using a former tin mine contaminated by arsenic, amended with biochar and iron sulphate and vegetated with three Salicaceae species. Results showed that the combination of biochar and iron sulphate improved soil characteristics by increasing pH and electrical conductivity and reducing soil pore water metal (loid) concentrations. Between the two biochar application methods, the addition of biochar on the all tube height showed better results. But for such contaminated soil, biochar in combination with iron sulphate, had no positive effect on plant growth, for all species tested and especially when incorporating on the top third of the tube. Finally, *S. purpurea* presented high root metal

(loid) concentrations associated to the better growth compared to *P. euramericana* and *S. viminalis*, making it a better candidate for phytostabilization of the studied soil.

Wyszkowski and Brodowska, (2020) aimed to determine the possibility to increase the effect of different amendments (compost, bentonite and zeolite) on the shoot yield and the concentration of trace elements in shoots of maize (*Zea mays* L.) on soil contaminated with Cu. Compost, bentonite and zeolite increased the yield of shoots and reduced the concentration of Cu, Co, Mn, Fe and Zn in shoots of maize. Bentonite had a more positive effect than compost and zeolite on the yield of shoots and the concentration of Co, Mn and Zn in shoots of maize. The effect of these amendments on the Cu and Fe concentration in shoots of maize was reverse. A reverse effect of these amendments (especially bentonite and zeolite) on the Ni concentration in plants was observed. The amendments applied to soil, especially compost, increased the BCF of Ni and, to a small degree, BCF of Cu in shoots of maize, compared to the control series. Compost, zeolite and especially bentonite are very good amendments in the restoration of maize growth in polluted area.

Q. Wang *et al.*, (2020) conducted a field experiment at a tropical site in Hainan Province, China, that had been subjected to soil pollution by Cd and Pb from past mining activities. It was concluded that the mixed amendments containing biochar, HAP, manure, and plant ash can be useful in decreasing Cd uptake by maize. The amendment in this study likely operated through a combination of soil chemical changes and by influencing the soil-microbe-plant interaction.

Hasan *et al.*, (2019) investigated a detailed discussion on the mechanisms undertaken by three important chemical amendments that are widely used in enhancing phytoremediation (i.e., EDTA, EGTA, and SDS) to support plant growth as well as soil phytoremediation. A core part of this review focuses on the recent advances that have been made using chemical

amendments in assisting metal phytoremediation. The result showed that chemical amendments can improve the metal accumulation in different plant parts without actually affecting the growth of the plant.

Kiran and Prasad, (2019) conducted pot experiments to assess the efficacy of Prosopis biochar and rice husk ash for plant growth and mitigating Pb translocation in *Ricinus communis*. Physio-chemical characterization of both the amendments was carried out on a dry weight basis. Addition of biochar and rice husk ash to soils increased the Pb tolerance in *R. communis*, improved soil pH, nutrient intake, and antioxidant enzymatic activities. The biochar amendment significantly ($p < 0.05$) increased plant growth parameters (height, leaf diameter, nodes, and leaf number), protein (72%) and chlorophyll contents (38–52%), as did RHA to a lesser extent (increase of 10–31% in chlorophyll and 77% protein content) compared to unamended plants. Soil usage of RHA resulted in a more consistent decrease in Pb accumulation in the root, shoot, and leaf relative to PJB. The research findings concluded the amendments can be used as a stress regulator in mitigating Pb toxicity, which is important for all economic crop plants, including *R. communis*.

Lebrun *et al.*, (2019) carried out this study to define the best amendment to use on the field. This was done by studying how the addition of three different amendments (biochar, compost and iron grit), alone or in combination, could affect: (i) soil physio-chemical properties, (ii) *Salix viminalis* growth, and (iii) metal (loid) stabilization. A 69 day-mesocosm study was thus set up using a former mine technosol, the three amendments applied alone or combined, and *S. viminalis* cuttings. The results showed that biochar and/or compost improved the soil fertility and the soil pore water characteristics, with reductions of acidity, metal (loid) mobility and toxicity, while iron grit amendment presented negative effects on such parameters. Such ameliorations allowed better plant growth and higher biomass production.

In addition, stress indicators (leaf pigment content and root guaiacol peroxidase activity) showed a reduction in plant stress following biochar and/or compost application. Finally, among the different treatments, the use of compost or a biochar-compost combination showed better results in terms of improvement of soil conditions, increase in plant growth and reduced translocation of metal (loid)s towards upper parts, making these two treatments a valuable option for a field trial.

Alaboudi *et al.*, (2019) found the effect of biochar manufactured from agriculture residues for the stabilization of lead, cadmium and chromium (Pb, Cd and Cr) in artificially contaminated soil. Addition of biochar significantly increased the soil reaction (pH), organic matter (OM) and nutrient content of nitrogen, phosphorus and potassium (N, P and K). Moreover, the addition of biochar considerably decreased the solubility of Pb and Cd in terms of water soluble, exchangeable (extracted by ammonium nitrate), physiological based extraction test (PBET) and toxicity characteristics leaching procedure (TCLP) extracts. On the other hand, addition of biochar might facilitate Cr solubility through the transformation of Cr(III) into Cr(VI) due to increasing soil pH, and increased its uptake by maize plant. The phytotoxicity test revealed that biochar significantly increased maize biomass (shoots and roots), biochar application decreased Pb and Cd toxicity by immobilizing them into more stable forms and improved soil quality.

Ahmad *et al.*, (2018) conducted a greenhouse pot experiment to investigate the application effects of BC and P-loaded biochar (BCP) on growth and availability of P and heavy metals to maize (*Zea mays* L.) plants grown in contaminated mining soil. Applying BCP increased the soil available P, while BC and BCP significantly decreased the soil labile heavy metals compared to control. Likewise, heavy metals in exchangeable and reducible fractions were transformed to more stable fraction with BC and BCP applications. The highest application

rate of BCP (3%) was most effective treatment in enhancing plant growth parameters (shoot and root lengths and dry matter) and uptake of P and heavy metals by 2–3 folds. However, based on metal uptake and phytoextraction indices, total heavy metals extraction by maize plants was very small for practical application. It could be concluded that using P-loaded biochar as a soil additive may be considered a promising tool to immobilize heavy metals in contaminated mining areas, while positive effects on the biomass growth of plants may assist the stabilization of contaminated areas affected by wind and water erosion.

Asilian *et al.*, (2018a, 2018b) carried out a greenhouse experiment was to evaluate the effectiveness of different microbial inoculations and surfactant levels on the phytoremediation of a Pb-polluted calcareous soil by maize. The results showed that application of surfactant increased both root and shoot dry matter yields. Microbial inoculations, however, had no significant effect on the root or shoot dry matter yield. Microbial inoculation and surfactant levels enhanced Pb phytoremediation mostly through phytostabilisation of this metal by maize.

Ogundiran *et al.*, (2018) investigated the germination, growth, tolerance and Pb accumulation potentials of *Moringa oleifera* in compost and biochar amended Pb-contaminated soils for possible phytoremediation. *Moringa oleifera* seeds planted in the contaminated and amended contaminated soils failed to germinate. Compost and RHB enhanced *M. oleifera* roots and shoots production. The combination of compost and *M. oleifera* improved Pb phytoextraction efficiency. The combination of GSB and *M. oleifera* improved Pb phytostabilization efficiency. Utilization of compost, rice RHB and GSB with *M. oleifera* may be recommended for phytoremediation of Pb-contaminated soil.

González-Chávez *et al.*, (2017) conducted a greenhouse experiment to determine the growth and physiological response, metal uptake, and the phytostabilization potential of a nontoxic

Jatropha curcas L. genotype when grown in multimetal-polluted conditions. Plants were established on a mine residue (MR) amended or not amended with corn biochar (B) and inoculated or not inoculated with the mycorrhizal fungus *Acaulospora* sp. (arbuscular mycorrhizal fungus, AMF). *J. curcas* was highly capable of growing in an MR and showed no phytotoxic symptoms. After *J. curcas* growth (105 days), B produced high desorption of Cd and Pb from the MR; however, no increases in metal shoot concentrations were observed. Therefore, *Jatropha* may be useful for phytostabilization of metals in mine tailings. The use of B is recommended because improved MR chemical properties conducted to plant growth (cation-exchange capacity, organic matter content, essential nutrients, electrical conductivity, water-holding capacity) and plant growth development (higher biomass, nutritional and physiological performance).

Ali *et al.*, (2017) assisted a pot experiment to examine the phytoremediation potential of *Streptomyces pactum* (Act12) + biochar in order to assist phytoremediation by sorghum in soil contaminated by smelters/mines in Feng County (FC), The results showed that root uptake of Zn and Cd was reduced by 45 and 22%, respectively, while the uptake of Pb and Cu increased by 17 and 47%, respectively. The shoot and root dry weight and chlorophyll content improved after Act12 inoculation. β -glucosidase, alkaline phosphatase and urease activities in soil improved and antioxidant activities (POD, PAL, PPO) decreased after application of Act12 + biochar due to a reduction in stress from PTEs. BCF, TF and MEA confirmed the role of Act12 in the amelioration and translocation of PTEs. PCA analysis showed a correlation between different factors that affect the translocation of PTEs. Overall, Act12 promoted the phytoremediation of PTEs. Field experiments on Act12 + biochar may provide new insights into the rehabilitation and restoration of soils contaminated by mines.

Wang *et al.*, (2017) experimented a study on two kinds of biochar, one derived from corn straw and one from pig manure, were studied as carriers of a mutant genotype from *Bacillus subtilis* (B38) for heavy metal contaminated soil remediation. After amendment with biochar, the heavy metal bioavailability decreased. Moreover, the heavy metal immobilization ability of the biochar was enhanced by combining it with B38. The simultaneous application of B38 and pig manure-derived biochar exhibited a superior effect on the promotion of plant growth and the immobilization of heavy metals in soil. The plant biomass increased by 37.9% and heavy metal concentrations in the edible part of lettuce decreased by 69.9–96.1%. The polymerase chain reaction-denaturing gradient gel electrophoresis (PCR-DGGE) profiles revealed that pig manure-derived biochar could enhance the proliferation of both exotic B38 and native microbes. These results suggest that B38 carried by pig manure-derived biochar may be a promising candidate for the remediation of soils contaminated by multiple heavy metals.

Chirakkara *et al.*, (2016) provided an overview of phytoremediation studies where the soil was contaminated with just one type of pollutant (heavy metals or organics) and then critically evaluates the applicability of phytotechnology for the remediation of contaminated sites where the soil is polluted by a mixture of organic and heavy metal contaminants. New effective phytoremediation strategies could be designed for remediation of co-contaminated sites using: (a) plants species especially adapted to grow in the contaminated site (hyperaccumulators, local plants, transgenic plants); (b) endophytic bacteria to enhance the degradation in the rizhosphere; (c) growth and microbial soil amendments to increase the contaminants bioavailability [chelating agents and (bio)surfactants].

Rizwan *et al.*, (2016) reviewed the toxic effects of Cd and its management by maize plants. Exogenous application of organic and inorganic amendments had been used for enhancing Cd

tolerance of maize. The proper selection of cultivar and agronomic practices combined with amendments might be successful for the remediation of Cd-contaminated soils with maize. However, there might be the risk of food chain contamination by maize grains obtained from the Cd-contaminated soils. Thus, maize cultivation could be an option for the management of low- and medium-grade Cd-contaminated soils if grain yield was required. On the other hand, maize can be grown on Cd-polluted soils only if biomass is required for energy production purposes. The result concluded that long-term field trials had been required, including risks and benefit analysis for various management strategies aiming Cd phytomanagement with maize.

Shafiqh *et al.*, (2016) experimented the influences of humic acid (HA) and four plant growth regulators, i.e. gibberellic acid, salicylic acid, 3-indoleacetic acid, and 6-benzylaminopurine on the phytoremediation of Pb by maize were investigated in a pot trial on a Pb-contaminated soil. It had been found that foliar spray of 6-benzylaminopurine and salicylic acid significantly increased mean root dry matter but none of growth regulators had a significant effect on that of shoot. The result showed that among the four plant growth regulators evaluated, salicylic acid was the most effective in enhancing phytoremediation.

Vigliotta *et al.*, (2016) conducted the study to shed light on the interaction among plant-HM-chelant-rhizobacterial community a pot experiment was set up. Maize plants were grown on uncontaminated, multi-metal (copper and zinc) contaminated and chelants artificially amended soils. A high concentration of HMs was detected in the different maize organs; chelants improved the accumulation capacity of the maize plants. The rhizosphere bacterial community isolated from control plants showed the largest biodiversity in terms of bacterial genera. However, the addition of HMs reduced the number of taxa to three: *Bacillus*, *Lysinibacillus* and *Pseudomonas*. The effects of HM treatment were counteracted by the

addition of chelants in terms of the genetic biodiversity. Furthermore, several bacterial strains particularly resistant to HMs and chelants were isolated and selected.

Qiao *et al.*, (2015) investigated on the positive benefits from biochar application for contaminated soil remediation, but remain ambiguous with regard to the benefits of simultaneous AMF inoculation on reduction of heavy metal bioavailability. The results showed that biochar significantly decreased the heavy metal concentrations and their bioavailability for plants, and both biochar had similar such effects. AMF inoculation of corn plants had little effect on heavy metal bioavailability in either control or biochar amended soil, and no interaction between biochar and AMF was observed. Changes in DTPA extractable metals following biochar addition to soil were correlated with metal uptake by plants, whereas pore water metal concentrations were not predictive indicators.

Freitas *et al.*, (2014) carried out to evaluate the performance of *Sorghum bicolor* and *Chrysopogonzi zanioides* in the citric acid-assisted phytoextraction of Pb in a field experiment setup in an area contaminated by automotive battery waste. Induction assisting of the removal of Pb from soil by the both species were tested, phytoextraction without the application of chelating agents was not viable for remediation of the study area. Sorghum grown in soil amended with silicate slag combined with the application of the chelating agent commercial citric acid was the recommended phytoextraction program for the remediation of an area with moderate Pb contamination.

Hechmi *et al.*, (2013) conducted the experiment to investigate the single and interactive effect of cadmium (Cd) and pentachlorophenol (PCP) on growth of *Zea mays* L, PCP, and Cd removal from soil. Growth response of *Zea mays* L is considerably influenced by interaction of Cd and PCP, significantly declining with either Cd or PCP additions. The dissipation of PCP in soils was notably affected by interactions of Cd, PCP, and plant presence or absence.

With the increment of Cd level, residual pentachlorophenol in the planted soil tended to increase. The pentachlorophenol residual in the presence of high concentration of Cd was even higher in the planted soil than that in the non-planted soil.

Zhang *et al.*, (2013) conducted this experiment to study on the impact of biochar on the environmental fate and mobility of heavy metals and organic pollutants in contaminated soils and its implication for remediation of contaminated soils. Further research directions were identified to ensure a safe and sustainable use of biochar as a soil amendment for remediation of contaminated soils.

CHAPTER III

MATERIALS METHODS

This chapter describes the experimental components of the research, including the materials and methods used. This section contains a concise description of experimental soil collection, incubation study preparation, experimental design, collection and preparation of soil samples after pot study, chemical methods and statistical analysis.

3.1 Collection and preparation of soil sample:

Soil was collected from the field which is located at 25⁰ 42' 27" N and altitude of 88⁰ 39' 32"E in Research Field 1 of the Department of Soil Science at Hajee Mohammad Danesh Science and Technology University, Dinajpur with a mean temperature of 26 °C. This study region was impacted by the southwest monsoon. The average yearly rainfall in this area is 1479 mm and the months of June and July are the wettest in this district. From November 2022 until February 2023, the experiment was run. Maize is the experimental crop. Samples of soil were collected from the topmost layer of the field, which ranged in depth from 0 to 20 cm. After being collected, the samples were subjected to air-drying for a period of one week.

Following this, a thorough grinding procedure was conducted to ensure that the soil particles were able to successfully pass through a sieve with a pore size of 1 mm, which was necessary for the subsequent pot experiment. In order to preserve the integrity and mitigate the risk of contamination, the processed samples were meticulously preserved in polythene packets, which provided an optimal medium for the subsequent pot experiment.

Table 1: Basic soil chemical properties

Soil location	pH	OM	EC	Ca	Mg	K	Na
		%	cmolkg ⁻¹				
Dinajpur	4.7	0.55	0.02	4.7	3.9	0.12	0.32

Table 2: Basic soil physical properties:

Particle size distribution	Value
Sand (%)	49.6
Silt (%)	21.6
Clay (%)	28.8
Textural class	Sandy clay loam

3.2 Collection and preparation of amendments

The rice husk, sourced from the rice mill located in Basher hat, Dinajpur, was meticulously gathered and subsequently fed into the pyrolyzing chamber of a biochar kiln that was constructed locally. Following this, the biochar kiln was fired, and the temperature was raised to 400 °C for a period of three hours. After undergoing the thermal process, the biochar was permitted to undergo natural cooling and was kept undisturbed overnight until it reached the surrounding temperature. The biochar underwent a process of fine grinding prior to its application in the field. The experiment employed locally accessible compost that was expressly procured for the purpose of this study. The poultry litter was obtained from a poultry farm situated in Basher hat. It was then subjected to the process of sun drying and finely grinding to prepare it for use in agricultural fields.

Furthermore, ash obtained from the combustion of rice husk was also procured from a rice mill. The primary emphasis of this experiment is centered on the co-composted biochar, which is derived from the combination of biochar, poultry litter, ash, and compost in equal proportions of 1:1:1:1. The components were meticulously blended together, with the addition of a small amount of water.

Subsequently, the mixture was securely enveloped with a polythene sheet and allowed to undergo a composting process for a duration of one week, so promoting optimal decomposition. Following that, the mixture was subjected to a drying process in order to make them suitable for use in the field.

Table 3. Properties of organic amendments

Sample	Physical condition	Color	pH	EC	N	P	K	S	Ca	Mg	Na
				dS m ⁻¹	%						
Compost	Dust	Gray	8.64	1.48	1.96	1.11	1.76	0.52	6.12	0.7	0.48
Ash	Dust	Ash	9.16	0.2	0.46	1.56	0.68	0.39	2	0.6	0.32
Biochar	Dust	Black	8.55	0.07	0.47	0.21	0.64	0.37	0.03	0.3	0.33
Poultry Litter	Dust	Brown	7.98	0.94	1.33	1.18	1.2	0.48	6.5	1.1	0.62
Co composted Biochar	Dust	Gray	8.29	0.86	1.82	1.31	1.7	0.5	6.2	1.12	0.77

Here,

EC = Electrical conductivity

N = Nitrogen

P = Phosphorus

K = Potassium

S = Sulphur

Ca = Calcium

Mg = Magnesium

Na = Sodium

3.3 Experimental design

The following seven treatments were considered for pot study:

- a) Control soil treated with 200 mg Pb per 750 g soil
- b) Pb contaminated soil with 100g compost (10%)
- c) Pb contaminated soil with 100g ash(10%)
- d) Pb contaminated soil with 100g biochar (10%)
- e) Pb contaminated soil with 100g poultry litter (10%)
- f) Pb contaminated soil with 220g Co-compost (10%)

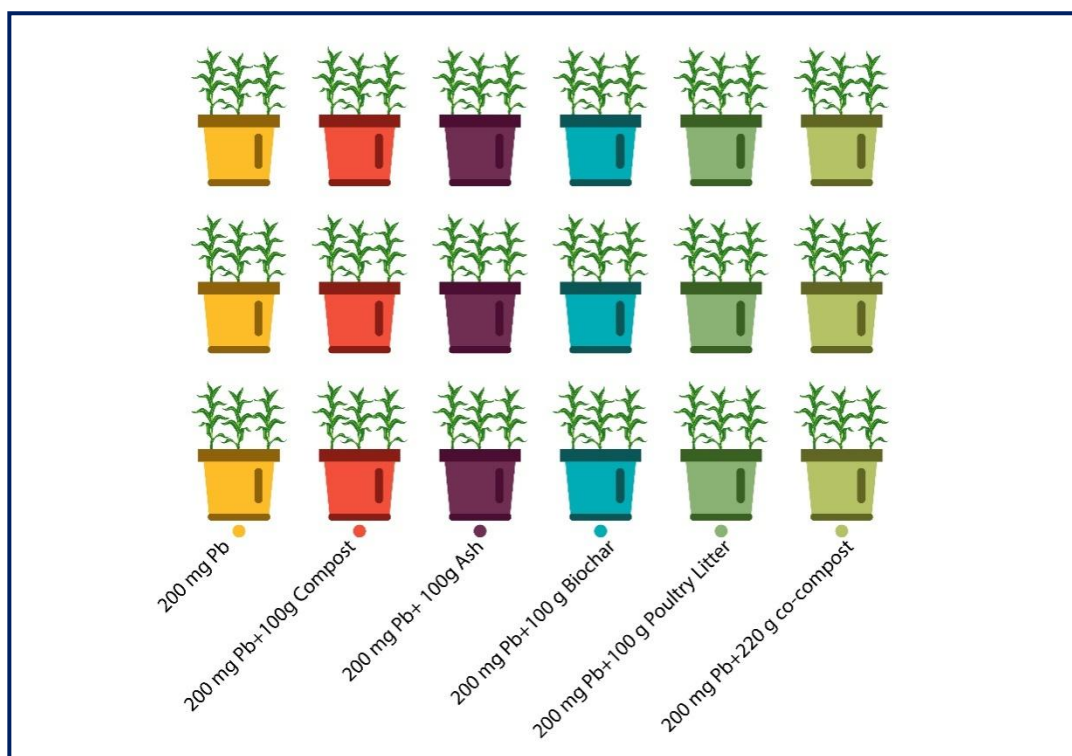


Figure 1. Graphical presentation of experimental setup

The treatments were arranged in a completely randomized design with three replications for the pot study.

3.4 Pot preparation

Each 750g of air-dried soil sample treatment was placed in plastic pot. Then compost, biochar, ash, poultry litter, co-compost were added at a ratio of 10% (100g) to each pot and

thoroughly mixed according to the treatments mentioned earlier. The pot study was established in a net house at the Department of Soil Science, HSTU. *Maize* was used as the test crop.

3.5 Sowing of seed

The seeds were primed with 10% H₂O₂ and allowed for germination in an incubator at 25⁰C. After that, four uniform germinated seeds were transferred to a plastic pot having 750 g soil. After one week, one seedling was removed to confirm the uniformity among the plants in each treatment. Sufficient watering was given regularly to maintain the 70% of the field water holding capacity during the growing period.

3.6 Harvesting

The plants were harvested after 30 days of seedling emergence. The height of the plants was measured for each corresponding treatment. The maize shoots and roots were harvested. Shoots were washed with distilled water, oven-dried at 105⁰C for 30 minutes, and later at 80⁰C to the constant weight.

3.7 Analyses of plant samples

Plant samples were digested with nitric acid and Pb accumulation was determined using inductively coupled plasma mass spectrometry.

3.8 Analyses of soil sample

Chemical characteristics of pre-harvest and post-harvest soil samples were examined in the Soil Science Department laboratory at HSTU, Dinajpur. The study focused on the following chemical parameters of soil: pH, Organic matter (OM), Cation exchange capacity (CEC), exchangeable K⁺, Na⁺, Ca²⁺ and Mg²⁺ contents.

3.9 Particle size analysis of soil

Particle size analysis of the soil was done by hydrometer method. The textural class was determined by plotting the values of % sand, % silt and % clay using Marshall's Triangular co-ordinate as designated by USDA.

3.10 Soil pH

The pH was determined by glass-electrode pH meter in a Soil: water ratio 1:2.5. The pH of the soil was measured using a glass electrode pH meter in a 1:2.5 w/v ratio (Pansu and Gautheyrou, 2006).

3.11 Soil OM

Soil organic matter was measured by the dichromate method and cation exchange capacity was determined using the ammonium acetate method at pH 7.0. (Pansu & Gautheyrou, 2006)

3.12 Cation Exchange Capacity (cmolkg^{-1})

The CEC was measured by the ammonium acetate method at pH 7.0 (Pansu & Gautheyrou, 2006)

3.13 Available Ca and Mg (cmolkg^{-1})

Soil exchangeable base cations were extracted with 1.0 ammonium acetate at PH 7.0 (Pansu and Gautheyrou, 2006). Ca^{2+} and Mg^{2+} were measured by using atomic absorption spectrophotometer.

3.14 Available Na and K (cmolkg^{-1})

K^+ and Na^+ were measured by using flame photometer.

3.15 Statistical analyses

All the statistical analyses were performed with SPSS (version 22.0, USA), and the graphs were drawn with Origin (version OriginPro 2018, USA). All data were presented as the mean of three replicates with standard deviation. Using a multivariate general liner model, an analysis of variance (ANOVA) was conducted to identify the differences and interactions between the treatments.

CHAPTER IV

RESULTS AND DISCUSSION

The current experiment was plotted to investigate the impacts of biochar, compost, ash, on phytoremediation potential of lead contaminated soil. Data on different parameters were analyzed statistically and the result has been presented in tables, graphs and figures. The results of the present study have been demonstrated and discussed with possible interpretations under the following headings.

4.1. Effects of organic amendments on soil pH

From the above table, it could be found that pH value of soil was the highest in poultry litter treatment whereas the lowest value was in control. The pH value of co-compost was more significant than those of compost, ash and biochar.

4.2 Effects of organic amendments on soil OM

Based on the above table, it could be determined statistically significant difference among the treatments in case of organic matter. The highest organic matter value was assessed from compost treatment and ash had the lowest OM value. Co-compost resulted in higher OM than the treatment of biochar, poultry litter and control.

4.3 Effects of organic amendments on soil EC

From the above table, there were significant differences among the treatments based on soil EC. Compost had the most significant EC value. Similar data was found for both control and biochar treatment which were the lowest. Poultry litter had higher EC than ash and co-compost treatment.

Table 4. Effect of different amendments on pH, OM, EC, CEC, Ca, Mg, K and Na

SL	Treatments	Base cations							
		pH	OM %	EC	CEC	Ca	Mg	K	Na
		cmolkg ⁻¹							
1	Control	5.54±.13e	0.77±.02c	0.05±.01c	12.43±.12e	4.01±.17d	3.60±.26a	0.17±.04ab	0.26±.06c
2	Compost	7.69±.01c	2.30±.03a	0.71±.05a	43.70±.09a	8.71±.69a	3.63±.84a	0.15±.03bc	0.55±.23b
3	Ash	7.03±.04d	0.73±.03c	0.08±.01c	18.77±.03d	3.26±.01e	1.56±.04bc	0.13±.01bc	0.33±.04c
4	Biochar	7.13±.03d	0.82±.03bc	0.05±.01c	18.80±.09d	3.67±.14de	1.35±.12c	0.12±.01c	0.34±.03c
5	Poultry litter	8.13±.09a	0.74±.59c	0.37±.02b	34.29±.16b	6.56±.31c	2.27±.25b	0.20±.02a	0.88±.04a
6	Co-compost	7.89±.01b	1.22±.06b	0.34±.01b	31.21±.08c	7.61±.18b	3.47±.38a	0.16±.02abc	0.60±.07b

Here,

OM = Organic matter

EC = Electrical conductivity

CEC = Cation exchange capacity

Ca = Calcium

Mg = Magnesium

K = Potassium

Na = Sodium

4.4 Effects of organic amendments on soil CEC

Based on the above table, it could be identified that, the treatments showed statistically differences in case of soil CEC. Compost acquired the most significant value of CEC and control had the lowest value. Almost similar data were found both in ash and biochar. Poultry litter had higher significant CEC value than co-compost.

4.5 Effects of organic amendments on Ca

Based on the above table there was clearly indication of statistically significant different of different amendments on presence of Ca base cation. Soil with compost had much higher exchangeable Ca in comparison to control treatment. Exchangeable Ca was decreasing at the sequence of compost co-compost poultry litter control biochar ash.

4.6 Effects of organic amendments on Mg

Exchangeable cation Mg was found highest in compost treatment which is similar to control and co compost treatments. Biochar and ash were found significantly lower in comparison of control treatment. Table 1 showed there was no positive variation found with the addition of different organic amendment in comparison of control.

4.7 Effects of organic amendments on K

K was found highest in treatment poultry litter. Similar values were showed in soils incorporated with control and co-compost treatment. The lowest amount of K was found in biochar treatment

4.8 Effects of organic amendments on Na

In table 4 among all treatments, there was a statistically significant difference in case of Na concentration. The highest value found in poultry litter treatment and the lowest one was found in control treatment. Similar data was showed in ash and biochar treatments. Biochar did not show any significantly difference from control treatment.

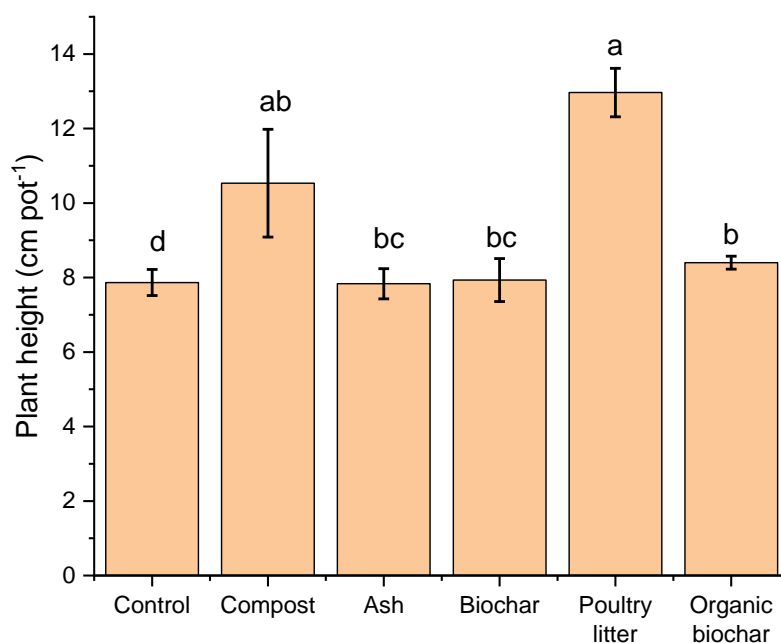


Figure 2. Plan height due to different soil amendments. Vertical bar indicates the standard error of mean

4.9 Effects of soil amendments on plant height

According to the graph, the vertical bar plot showed that treatment identified as poultry litter had a statistically significant difference compared to the other treatments (fig. 2). The plants in the poultry litter had a precise height measurement which was the highest. While examining the graph, it became evident that compost, ash and biochar have comparable statistical patterns, yet the numerical value linked to compost was significantly greater.

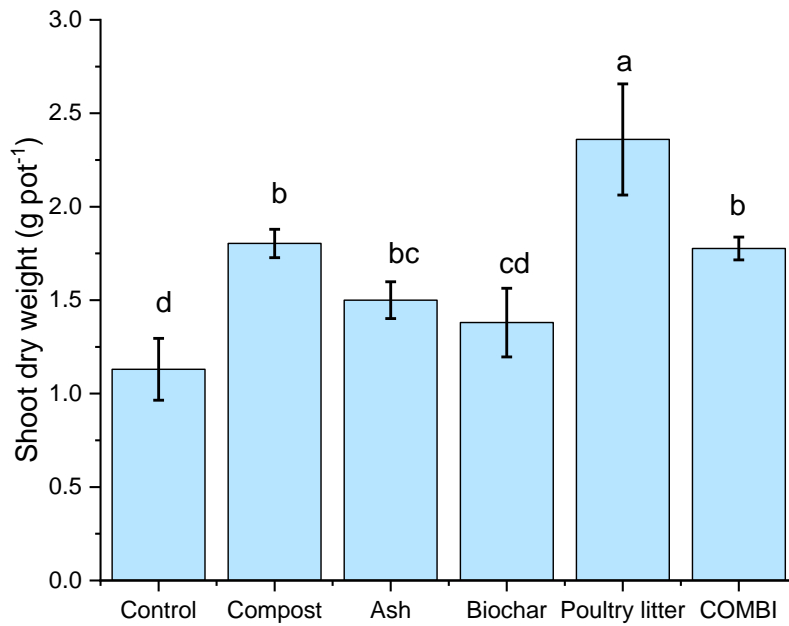


Figure 3. Shoot dry weight due to different soil amendments. Vertical bar indicates the standard error of mean

4.10 Effects of soil amendments on shoot dry weight

Based on the graph, it could be inferred that there was a statistically difference in shoot dry weight. The greatest value found in the poultry litter treatment. The control treatment displayed the lowest shoot dry weight. Compost treatment resulted in almost same as COMBI and greater than the ash AND biochar treatment.

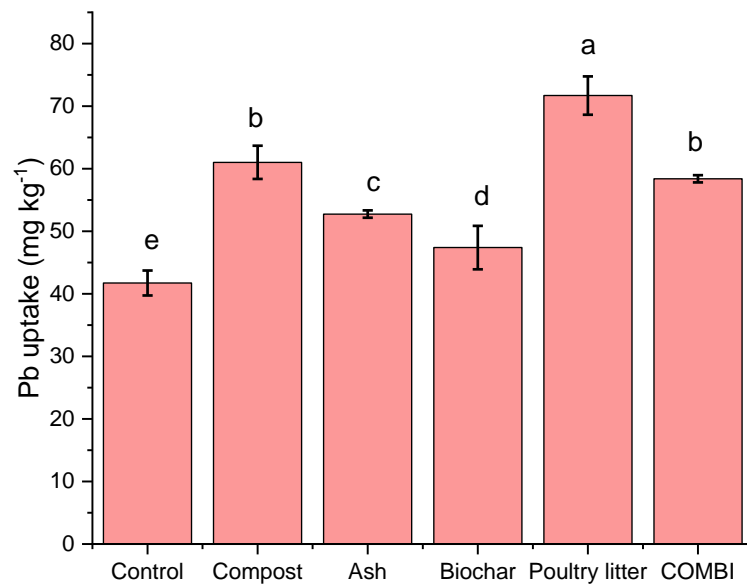


Figure 4. Pb uptake due to different soil amendments. Vertical bar indicates the standard error of mean.

4.11 Effects of soil amendments on Pb uptake

Based on the graph, it could be determined that poultry litter showed the highest effect on Pb uptake whereas control showed the lowest. Compost resulted in a higher Pb uptake compared to ash, biochar and COMBI.

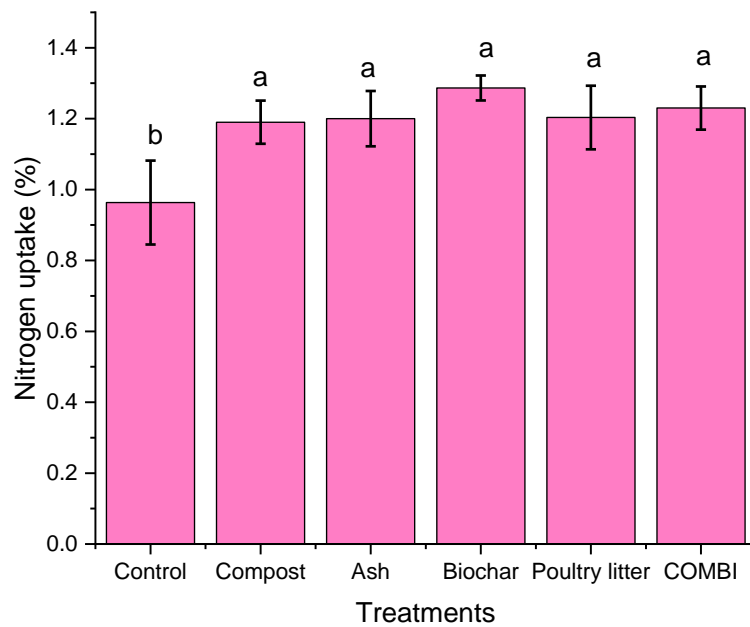


Figure 5. The N uptake by maize plants for different soil amendments. Vertical bar indicates the standard error of mean.

4.12 Effects of soil amendments on N uptake

Based on the graph, it could be found that biochar had the most significant effect on N uptake. Compost and ash possessed the same effect but greater than those of poultry litter and COMBI. Control treatment showed the lowest significant effect.

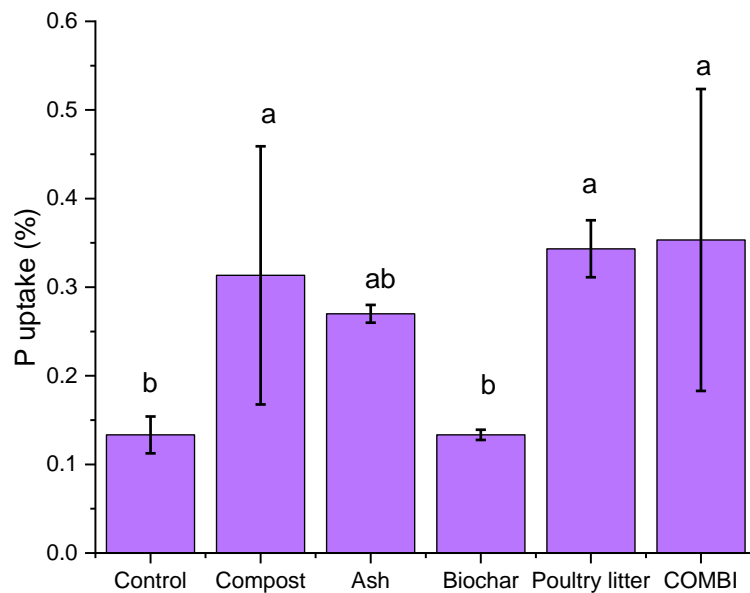


Figure6.P uptake due to different soil amendments. Vertical bar indicates the standard error of mean.

4.13 Effects of soil amendments on P uptake

Based on the graph, it could be determined that COMBI showed the most significant effect on P uptake. Control and biochar showed similar data which were the lowest. Poultry litter had the effect greater than ash and compost treatment.

CHAPTER- V

SUMMARY AND CONCLUSION

5.1 Summary

Lead (Pb) is a crucial plant nutrient, but its availability is limited because it is a nonrenewable resource. Phytoremediation technology is an eco-friendly technology. Because of its low cost, sustainability, ease of application, and less detrimental effects on the environment, phytoremediation is becoming more and more popular as a remediation method. It involves using plants to remove or stabilize heavy metals from the soil. The purpose of this study was to examine the impacts of organic amendments assisted phytoremediation potential of lead contaminated soil. The treatments included a) control, b)compost c)ash, d) biochar, e)poultry litter and f)co-compost. Each treatment was replicated three times in a completely randomized design.

The results revealed that the compost, poultry litter significantly enhanced the growth ratio and plant height of *Zea mays* under Pb contaminated environment. Ash and biochar increased plant height same as control. In case of soil pH, the sequence is: poultry litter> COMBI> compost> biochar> ash> control. For soil OM: compost>COMBI> biochar> control>poultry litter> ash. For soil EC: compost>poultry litter>COMBI> ash>biochar> control and soil CEC: compost>poultry litter>COMBI>biochar>ash>control. Biochar and COMBI increased total amount of plant available P and N. Compost, ash, poultry litter showed the same effect on total P and N which was greater than the control. However, compost enhanced base cations like Ca, Mg greater than ash, biochar, poultry litter, co-compost. Poultry litter enhanced base cations like K, Na compared to control.

5.2 Conclusion:

From the results of the study, it may be concluded that :

1. The synergistic technique of applying organic amendments with accumulators to repair Pb contaminated environments is both feasible and promising.
2. The most beneficial option for the treatment of Pb contaminated soil phytoremediation was the application of organic amendments Poultry litter > compost > co-composted biochar (COMBI)> ash > biochar

5.3 Recommendation:

1. Poultry litter assisted phytoremediation is suggested for lead contaminated soil.
2. Further research work with other crop species need to be used instead of maize to determine the effects of organic amendments influence phytoremediation on Pb contaminated soil

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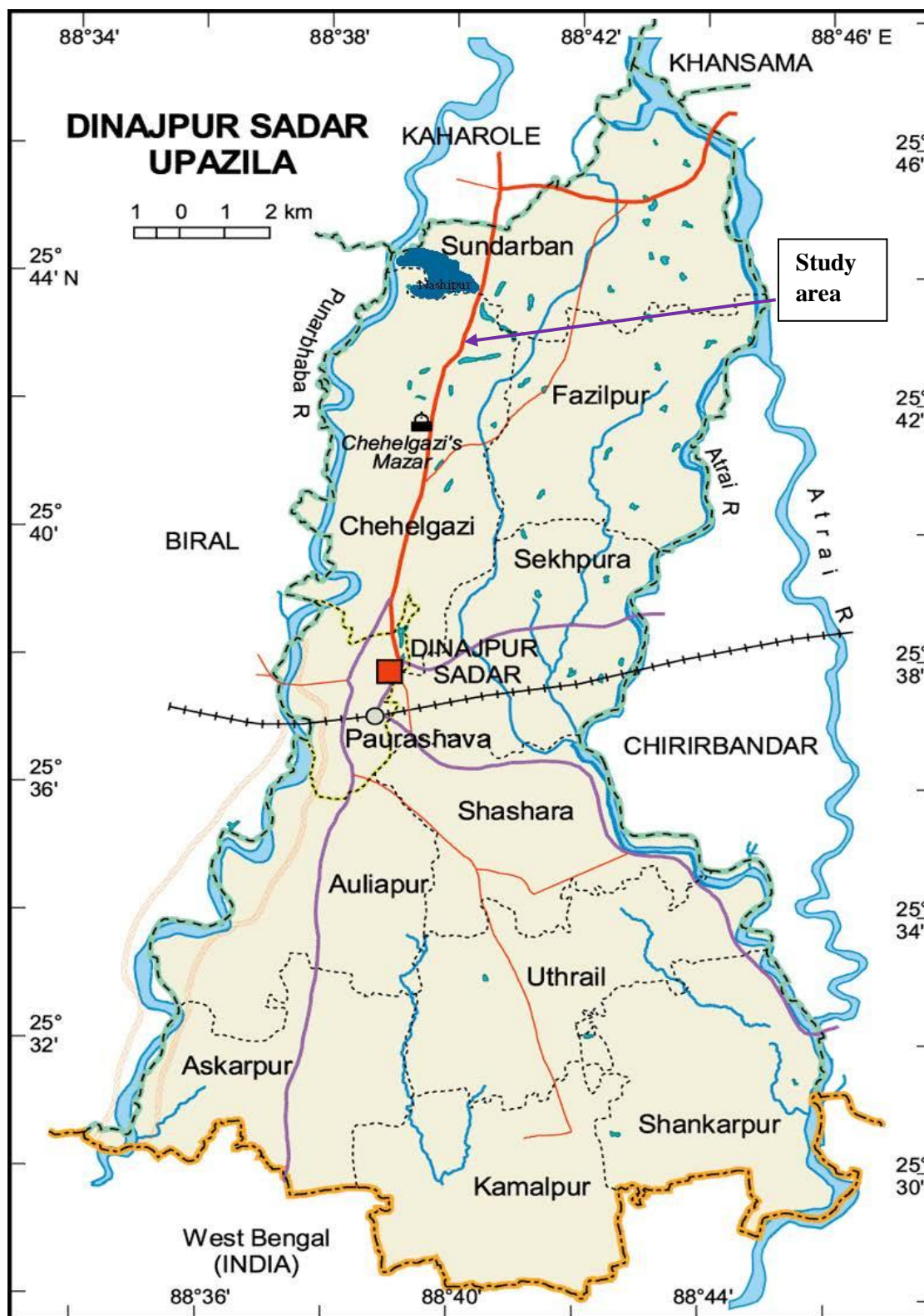
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APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research plot)



Appendix II. Monthly recorded air temperature, relative humidity, and rainfall during the research period (From November 2022 to February 2023).

Year	Month	**Temperature (⁰ C)		**Relative Humidity (%)	**Rainfall (mm)
		Minimum	Maximum		
2022	November	26.0	32.1	84	387.7
	December	25.1	31.5	85	383.8
2023	January	22.2	31.1	82	115.1
	February	16.5	28.9	78	7.0

**Monthly average

Source: Bangladesh Meteorological Department.

Appendix III. Some picture of the experimental site



