INVESTIGATION OF ORGANIC AMENDMENTS ASSISTED PHYTOREMEDIATION POTENTIALS OF LEAD CONTAMINATED SOILS BY MUSTARD (*Brassica napus)*

A THESIS

BY

ZAKEY RAJWANA

STUDENT NO. 1601363

SESSION: 2022-2023

SEMESTER: JULY-DECEMBER 2023

MASTER OF SCIENCE

IN

SOIL SCIENCE

DEPARTMENT OF SOIL SCIENCE

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

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DEPARTMENT OF SOIL SCIENCE

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DECEMBR 2023

DEDICATION

My parents and teachers deserve all the recognition for making my study a success; they have been nothing but supportive and helpful throughout the last few months. Their encouragement was invaluable to me.

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The Authoress

ABSTRACT

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. This study evaluated the synergistic effect of organic amendments to enhance phytoextraction of heavy metal lead (Pb) from artificially polluted soil by *Brassica napus.* The objective of this study was to investigated how the altered soil chemical properties (soil pH, OM, cation exchange capacity, electrical conductivity, base cation Ca, Mg, N, P, k) due to application of various amendments influence on phytoremediation of Pb contaminated soil. The treatments were a) control with 200 mg Pb, b) Pb contaminated soil with compost (10%), c) Pb contaminated soil with ash (10%), d) Pb contaminated soil with biochar (10%), e) Pb contaminated soil with poultry litter (10%), f) Pb contaminated soil with co-compost (10%) (COMBI), and replicate three times in a completely randomized design. The compost and poultry litter amendment enhance the growth and survival of *Brassica napus* under Pb contaminated environment. Compost and poultry litter significantly increased the plant height of *B. napus* and significantly increased total amount of plant available phosphorous. Application of compost, ash, and co-compost biochar enhanced total amount of soil available nitrogen. The highest Pb uptake was found in compost, poultry litter and co-compost biochar application. The maximum activity of soil nutrient element supplies (base cation Ca, K, Na, Mg) was obtained in the application of compost, poultry litter and co-compost biochar. The application of compost, biochar, ash, poultry litter and co-compost biochar (COMBI) significantly increased soil pH. Compost and poultry litter amendments enhanced soil organic matter (OM). Compost, poultry litter and COMBI significantly increased soil cation exchange capacity (CEC). Therefore, the obtained result revealed that application of organic amendments (poultry litter > compost > co-compost biochar (COMBI) > biochar > ash) was the most advantageous choice for the treatment of Pb contaminated soil phytoremediation.

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CHAPTER 1

INTRODUCTION

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.* 2022). The term "heavy metals" (HM) refers to trace elements that are essentially needed in extremely small quantities by plants and animals. These elements include micronutrients such as cobalt (Co), copper (Cu), chromium (Cr), manganese (Mn), and zinc (Zn); however, some are non-essential and can cause multiple soil pollutions due to anthropogenic activities. This is because HMs can have harmful effects on humans and are absorbed through the food chain from plants and animals (Rinklebe *et al.,* 2019; Ali *et al.,* 2019). HM are persistent in nature because they are permanent and do not degrade like organic materials do (Shi *et al.,* 2009).

Lead is a highly toxic metal that can have various harmful effects on living organisms. These include humans, particularly on the central nervous system, and microorganisms, which may experience reduced activity, population, and diversity (Dotaniya *et al.* 2020; Kumar *et al.* 2020). Lead is one of the most toxic metals found in the environment. Plants have been shown to exhibit a variety of hazardous symptoms when exposed to excessive lead in the soil. These include mineral nutrition disruption, water imbalance, blackening of the root system, chlorosis, stunted development, impacts on membrane structure and permeability, and suppression of photosynthesis. It has been demonstrated that Pb concentrations up to 900 mg kg^{-1} soil can harm soil microorganisms ecologically, impede soil enzymatic activity, and reduce rice biomass. A build-up of lead in human systems has been linked to alterations in the nervous system, reproduction, development, metabolism, and behavior. The necessity of reducing the bioavailability of lead in contaminated soils is shown by these documented occurrences of Pb contamination concerns. Lead (Pb) enrichment in soils has emerged as a major trace element concern on a global scale. Because of long-term uses, lead (Pb) is not biodegradable or thermo gradable and quickly builds up to dangerous levels in the soil. The International Agency for Research on Cancer has declared it to be a known carcinogen (Anonymous-IARC, 2011). Except in rare circumstances where aerial accumulation in the leaf is possible, plants primarily accumulate lead by root uptake from the soil (Hovmand *et al.,* 2009). Lead (Pb) can have a direct or indirect impact on a variety of physiological processes in plants, such as decreased growth, chlorosis of the leaves, deformed chloroplast ultrastructure, reduced uptake of vital nutrients, substitution of lead for divalent cations like Mg and Fe, inhibition of the synthesis of carotenoid and plastoquinone, mutagenicity instability of microsatellites, and inhibition of enzymatic catalysis in the Calvin cycle.

Phytoremediation, as described by Pulford and Watson (2003), is a low-cost, environmentally acceptable substitute for traditional physical and chemical remediation techniques. It involves using plants to either remove pollutants from the environment or render them harmless (Vishnoi and Srivastava 2008). Its applicability to locations contaminated by multiple types of pollutants is another benefit (Moosavi and Seghatoleslami 2013). Putting a plant will aerate the soil and encourage soil microbial activity, which is the basic idea behind phytoremediation (Pulford and Watson 2003). Phytoremediation is the extraction or stabilization of heavy metals in soil using plants. Phytoremediation, a widely used technique for cleaning up polluted environments, involves using plants of various growth types for heavy metal removal. There are four main ways that HMs are removed from soils through phytoremediation: (i) HM uptake; (ii) HM bioaccumulation; (iii) HM inactivation or immobilization in situ; (iv) reducing HM bioavailability and external transport; and (v) HM transformation into volatile forms and release into the atmosphere (Shah and Daverey, 2020). Researchers worldwide have extensively studied the use of different organic amendments, additives, and/or phytoremediation alone or in combination for HM remediation. The phytoremediation approach, known as in situ HM remediation, is thought to be both cost-effective and environmentally benign (Shah and Daverey, 2020). Many physical and chemical remediation techniques exist, including vitrification, chemical solidification, electro-kinetic remediation, soil washing, and so forth. However, these techniques are costly and reduce the fertility and quality of the soil (Shah and Daverey 2020). However, phytoremediation is an inexpensive and environmentally safe method of removing heavy metals from soil.

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. There are various phytoremediation classifications. A type of phytoremediation known as phytoextraction uses plants to remove heavy metals from soils to the roots and translocation to the shoots of the plants; these specific plants are known as hyperaccumulators. Soils with mild contamination are most suited for this type of phytoremediation. It could take several years to establish phytoextraction in substantially heavy metal-contaminated soils. Up till now, known hyperaccumulators have a poor biomass production rate, develop slowly, and are metal-specific. In the meanwhile, phytoextraction depends on the identification of suitable hyperaccumulators. Because of the poor translocation of Pb from plant roots to shoots and the low bioavailability of Pb in soil, the use of phytoextraction to remediate Pb-contaminated soil is limited. Because of these limitations, Phyto stabilization is thought to be a preferable solution for severely Pb and other heavy metal contaminated soils. The common view of phytoremediation is that it is a green technology that is affordable, efficient, and environmentally benign. It can also be used on a wide scale. By decreasing the bioavailability and mobility of pollutants in the environment, which can cause them to migrate to groundwater or enter the food chain, certain plants are employed in Phyto stabilization or Phyto immobilization. The availability of heavy metals for plants is thought to be a limiting element in the effectiveness of the phytoremediation process, regardless of the type of plant utilized in this procedure (Kayser *et al.,* 2000). According to recent research, a variety of factors influence the effectiveness of phytoremediation, independent of the type of plant. Applying both organic and inorganic modifiers to the soil alters the solubility of heavy metals, which leads to an accumulation of those metals in the plant and thus increases the amount of phytoremediation (Kayser *et al.,* 2000).

By pyrolyzing biomass residues without oxygen, biochar is a carbonaceous substance. Because of its special qualities, which include high porosity and wide surface area, high cation exchange capacity (CEC), sorption capacity, and chemical recalcitrance, biochar has drawn a lot of attention in the field of environmental management. The amount of organic matter increases the cation exchange capacity (CEC) of the soil, which varies based on the organic components. In the presence of organic matter, increased soil aeration and enhanced soil physical structure can foster the growth of plant biomass and phytoremediation. It has also been demonstrated that organic matter improves water efficiency. Using compost to raise soil nutrients and microorganisms linked with stimulation in dehumidified soil is an efficient way to boost the effectiveness of bioremediation in oil-contaminated areas, with various benefits including the creation of rich, fertile soil following the refining process. Most plant species absorb less divalent metal when biochar is added (Karami *et al.,* 2011; Zhang *et al.,* 2013; Rees *et al.,* 2016). This may result from direct metal sorption on biochar, indirect impacts, or a decrease in soil metal mobility when biochar is present (Houben *et al.,* 2013). Enhancing the soil's texture and biomass can be accomplished by adding compost and biochar to the soil. Additionally, it has the potential to increase soil biological activity (Paz-

Ferreiro *et al.,* 2014). Composting can enhance plant development and boost soil microbial activity.

The byproduct of biomass pyrolysis with little oxygen supply is biochar. For two reasons, adding biochar to the soil has gained more and more public attention. First off, biochar is perfect for storing carbon in soil due to its chemical stability. Second, because it quickly boosts soil fertility and plant growth by delivering and keeping nutrients while also enhancing the physical and biological characteristics of the soil, biochar is frequently referred to as a soil conditioner. Furthermore, a number of findings indicate that adding biochar to soil may aid in lowering the Phyto availability of heavy metals. These factors have led to the suggestion that using biochar is a sustainable way to encourage the regeneration and revegetation of damaged areas. Thus, applying biochar to soils polluted with metals could have two benefits: first, it could enhance soil conditions, enabling the development of energy biomass and biofuel; second, it could trap carbon by burying a portion of the biomass generated.

Nevertheless, the enhanced accumulation of heavy metals in plants due to biochar cannot be fully explained by the increased nutrition in the soil and root growth. Plant concentration and biomass were both important factors in the accumulation of heavy metals in plants (Li *et al.,* 2019). Plant uptake of heavy metals may also be hampered by variables including the type of plant, heavy metal speciation, soil characteristics, etc. (Paz-Ferreiro *et al.,* 2014). Thus, it is imperative to investigate the connections between plant growth, heavy metal accumulation in plants, alterations in soil nutrition, and the features of heavy metal speciation following biochar amendment.

Brassica napus (Rapeseed) also known as oilseed rape, is a bright-yellow flowering member of the family Brassicaceae. Cultivated mainly for its oil-rich seed, which naturally contains appreciable amounts of erucic acid. The term "canola" denotes a group of rapeseed cultivars that were bred to have very low levels of erucic acid and which are especially prized for use as human and animal food. One of the first known vegetable oils is rapeseed oil, but traditionally, its high erucic acid content which damages heart muscle and glucosinolate content have limited its use. Erucic acid can make up as much as 54% of rapeseed oil. The US Food and Drug Administration has usually acknowledged as safe canola oil, also known as low-erucic-acid rapeseed oil (LEAR oil), which is food-grade oil obtained from rapeseed cultivars. Government laws restrict canola oil to 2% erucic acid by weight in the US and 2% in the EU, with additional restrictions for baby food. It is thought that newborn humans are not harmed by these low erucic acid levels.

The literature search revealed that the plant species *Brassica* is a superb hyperaccumulator. Additions to the soil, such as compost and biochar, may affect the soil’s chemical, biological, and even physical characteristics (Bortoloti and Baron 2022). As a result, changes in the soil environment may impact plant heavy metal accumulation. The use of soil amendments, Pb tolerant and fast-growing plants to accomplish mitigation of Pb in soil and minimize migration of Pb contaminated soil might be an alternate remediation strategy for soil polluted with high level of Pb. Therefore, the aim of this study is to determine the impact of compost and biochar on phytoremediation of Pb contaminated soils.

Objectives of the research

The specific objectives of the study were as follows-

a) To determine the effects of organic amendments on Pb contaminated soil phytoremediation; and

b) To investigate the altered soil chemical properties (pH, organic matter, cation exchange capacity) due to application of organic amendments influence phytoremediation of Pb contaminated soil.

CHAPTER 2

REVIEW OF LITERATURE

To the best of our knowledge, very little research on assessment of compost and biochar assisted phytoremediation potentials of lead contaminated soils by *Brassica napus*. However, some recent related works conducted globally and their findings are summarized below:

Rathika *et al.,* (2021) investigated that both natural and artificial amendments can enhance the heavy metal phytoextraction from contaminated soils using hyperaccumulation and/or non-hyperaccumulation plants. This study assessed the synergistic effect of charcoal (BC) and EDTA to improve *Brassica juncea's* phytoextraction of lead (Pb) from synthetically polluted soil. The BC and EDTA modification improved *B. juncea's* growth and ability to survive in a Pb-stressed environment. The combined addition of BC and EDTA (22.2 mg g^{-1}) compared to the separate amendments of BC (12.8 mg g^{-1}) and EDTA (12.2 mg g^{-1}) significantly enhanced *B. juncea* biomass and significantly increased the total chlorophyll content. When EDTA and biochar were used together, Pb absorption increased to 60.2 mg/g from 10.0 mg/g under control. BC + EDTA (60.2 mg g^{-1}) was discovered to be the order of Pb uptake. BC (22. 0 mg g^{-1}), control (10.0 mg g^{-1}), EDTA (23.5 mg g^{-1}), and. The combination application of EDTA and BC produced the highest levels of SOD (35.2 1.2 U mg^{-1}), POD (47.0 1.8 U mg^{-1}), and CAT (28.0 1.0 U mg^{-1}). According to the results, using BC and EDTA together was preferable than using each amendment alone for the treatment of Pb-contaminated soil.

Shi *et al.,* (2022) conducted a study on mining activities produce significant amounts of mine tailings, which typically contain high concentrations of heavy metal contaminants that not only seriously impair the local and neighboring soil ecosystems but also negatively impact human health through the food chain. Phytoremediation is viewed as an inexpensive, longlasting, and ecologically beneficial form of repair. Plants struggle to survive, meanwhile, due to deteriorating soil pH, a lack of organic matter, a poor ability to retain water, and compaction. By enhancing the physical, chemical, and biological qualities of soil, biochar, a soil conditioner, can encourage plant growth while also enhancing phytoremediation in contaminated tailings. This review describes the effects of biochar's physicochemical characteristics on phytoremediation; phytoremediation is considered eco-friendly, durable, and economically viable method of restoring the environment. However, following soil acidity, a deficiency in organic material, inadequate water retention, and compression pose challenges for plant viability. Biochar, a substance that can enhance the quality of soil, has the potential to boost the growth of plants by enhancing the physical, chemical, and biological traits of the soil.

Gong *et al.,* (2019) found that phytoremediation has been utilized to treat cadmium (Cd)-contaminated river sediments, the effectiveness of the remediation process still has to be increased. This study used biochar (TB) made from tea waste to help with the phytoremediation of Cd-contaminated sediments. The findings demonstrated that TB at concentrations of 100, 500, and 1000 mg kg^{-1} increased Cd accumulation and translocation in ramie seedlings by modifying the speciation of Cd in sediments and the subcellular distribution of Cd in plant cells. TB at low concentrations reduced oxidative stress and Cd-induced toxicity in ramie seedlings by fostering plant development. The application of TB also encouraged the urease, phosphatase, and catalase-producing microorganisms' activity in the Cd-contaminated sediments. These results showed that biochar, at low concentrations, might increase the efficacy of phytoremediation and reduce the toxicity of Cd to plants and microorganisms in Cd-contaminated sediments. This study offers a cutting-edge technological method for reducing the dangers of heavy metals using waste biomass.

Zhou *et al.,* (2020) observed that the removal of polluted plants restricts the application of phytoremediation. So, they looked into getting rid of sunflowers that were contaminated after finding out how they cleaned up heavy metals using sesame rotation showed 0.07% efficiency in extracting lead (Pb), 1.37% efficiency in extracting zinc (Zn), 1.10% efficiency in extracting copper (Cu), and 6.12% efficiency in extracting cadmium (Cd). Contaminated sunflower stalks were subjected to pyrolysis at various temperatures. The biochar created at a temperature of 300 degrees Celsius was removed using a two-step method (removing acids from the biochar and causing metals to settle in a high pH environment). At a pH level of 1, 65.67% of the Cadmium (Cd) and a significant amount of potassium (K) were extracted. After the process of acid-extraction, modify the pH of the filtered solution to 10. At this point, the metals were formed into solids and subsequently isolated from the potassium-enriched solution. As a result, pyrolysis has the capability to treat polluted remains, and the biochar extracts can be reused as fertilizer for farming in other locations. Therefore, a scheme of alternating oil crops, which not only generates financial advantages, but also permits local agriculturalists to utilize polluted soils.

Kiran & Prasad, (2019) found that lead pollution in the soil is a major worldwide issue that has a negative impact on the growth of crops. Pot experiments were carried out to evaluate the effectiveness of Prosopis biochar and rice husk ash in promoting plant growth and reducing Pb movement in *Ricinus communis*. The physico-chemical analysis of both the additives was conducted based on the weight of the substances when they were dry. Young plants of R. *communis* were cultivated in soil that was spiked with different amounts of lead (0, 400, and 800 mg kg^{-1}). This soil was then supplemented with biochar from the Prosopis *juliflora* plant and ash from rice husks at concentrations of 0%, 2.5%, and 5% (by weight) of the soil. The plants were left to grow for a period of 60 days. The inclusion of biochar and rice husk ash in soils enhanced the ability of R. *communis* to withstand pb, enhanced the soil acidity level, boosted nutrient absorption, and increased the action of antioxidant enzymes. The addition of biochar greatly improved plant growth features (such as height, leaf size, number of branches, and number of leaves) by a significant margin ($p < 0.05$). Protein content increased by 72% and chlorophyll content increased by 38-52%. The addition of RHA had a less pronounced effect, with a 10-31% increase in chlorophyll content and a 77% increase in protein content, compared to plants that were not amended. The utilization of RHA in soil led to a more steady reduction in the buildup of Pb in the root, stem, and foliage compared to PJB. Applying PJB at a concentration of 5% reduced the buildup of Pb in roots by 59%, while the use of RHA resulted in an 87% decrease in Pb levels in roots. The two separate changes considerably decreased the amount of lead in the soil and lowered the harm caused by oxidation, as shown by the decreased levels of proline, malondialdehyde (MDA), and hydrogen peroxide (H_2O_2) in plants.

Bortoloti & Baron, (2022) conducted a study on one of the biggest environmental concerns is the presence of hazardous heavy metals (HMs) like lead (Pb), zinc (Zn), arsenic (As), mercury (Hg), cadmium (Cd), and chromium (Cr) in soils and water bodies. Plants are utilized in a process known as phytoremediation, which uses the botanical species *Brassica* to clean up contaminated environments. Our goal was to clarify the physiological and biochemical potential use of various species in the genus Brassica to bioremediate and tolerate the deleterious effects of these environmental contaminants on their metabolism. *Brassica spp*. have been reported as potential phytoremediators and hyperaccumulators. Because these species exhibit effective phytoremediation techniques as phytoextraction, phytostabilization, and phytovolatilization. In addition to having an effective enzymatic and non-enzymatic defense mechanism that reduces the oxidative damage brought on by an excess of reactive oxygen species (ROS), these species also have physiological processes that facilitate the absorption, translocation, and accumulation of toxic heavy metals (HMs) into low-activity cell organelles. *Brassica* species' phytoremediation of toxic heavy metals (HMs) is a promising technique; however, more research is needed to determine the viability and applicability of agronomic techniques that support the production of high plant biomass, tolerance, and structuring of the hyperaccumulation network of these contaminants over larger areas (cropping areas).

Ogundiran *et al.,* (2018) analyzed that seedlings of Moringa oleifera were moved to the treated soils after two weeks and started the greenhouse experiments. The measurement of the size of plants such as their height, width of their stems, the amount of leaves they have, and their total mass was conducted at both 4 and 8 weeks. The roots and stems of plants were examined. Seeds of the Moringa oleifera tree could not grow when they were planted in soils that were polluted and treated to remove the pollution. The young plants died completely in fully and three-fourth portions, but managed to survive in one-fourth and half portions of modified polluted and regular soils. It was able to withstand Pb pollution of up to 8600 mg kg^{-1}. The levels of lead in the roots and stems of the plants after 8 weeks varied from 930 to 2100 mg/kg and 420 to 1120 mg kg^{-1} respectively for both levels of pollution, showing that *M. oleifera* can accumulate lead. Compost and recycled horse bedding improved the growth of *M. oleifera* roots and shoots. The mixture of decomposed organic matter and *M. oleifera* enhanced the effectiveness of removing Pb from plants. The pairing of GSB and *M. oleifera* enhanced the effectiveness of Pb phytostabilisation. The use of compost, rice RHB, and GSB with *M. oleifera* can be suggested for the treatment of soil contaminated with lead using plants.

Gu *et al.,* (2020) evaluated that the most prevalent and pervasive heavy metal pollution in Chinese cropland is cadmium (Cd). Although phytoremediation is thought to be a viable strategy for cleaning up Cd-contaminated soil, remediation effectiveness still has to be improved. Heavy metal soil remediation uses biochar, a commonly made and researched amendment medium. Beta vulgaris var. cicla L. (Beta vulgaris) was grown in a greenhouse pot trial in this study to examine the effects of cornstalk biochar on Cd accumulation. To investigate the mechanism by which the cornstalk biochar enhanced Cd accumulation in Beta vulgaris, the Cd availability, speciation, and nutrients in soil, biomass, and Cd chemical forms in the root of the plant were examined. The addition of biochar decreased the content of DTPA-extractable Cd and promoted root development. The findings of the 5% biochar amendment showed that the Beta vulgaris root dry weight increased to 267%, the Cd accumulation in the Beta vulgaris climbed to 206%, and the Cd content in the leaves and roots increased by 36% and 52%, respectively, compared to the Beta vulgaris without biochar treatment. Additionally, after applying 5% biochar to the soil, the total amount of Cd that was bound to organic matter and residual Cd increased by 38%, whereas the amount of Cd that was bound to Fe-Mn oxides reduced by 40%. The ratio of Cd extracted with NaCl to C extracted with HAc increased to 166% with the addition of 5% biochar, indicating that Cd may primarily attach to the root cell wall. According to our research, Beta vulgaris may remove Cd from soil, and a biochar amendment can increase the effectiveness of phytoremediation. A approach that shows promise for the remediation of Cd-contaminated soil is the combination of phytoremediation with biochar amendment.

Li *et al.,* (2019) observed that in a greenhouse experiment, Solanum nigrum L. and biochar/attapulgite as soil amendments were used to test an improved phytoremediation method for multi-metal contaminated mine tailings. The ideal chemical proportions for amendment materials were proposed as 10% attapulgite (MA2) and 10% biochar (MB2). Plant length and fresh weight were much higher in the MA2/MB2-applied treatments than they were in the non-amended group, demonstrating that the amendments could reduce metal phytotoxicity. With MA2 and MB2 application, metal uptake in plant leaves was less than with the non-amended treatment. However, MA2 and MB2 treatment greatly boosted metal uptake in plant roots. The function of MA2 and MB2 nearly achieved a plateau in the seventh month, according to the temporal fluctuation of metal translocation in the soil-to-plant system. Following the application of MA2, metal removal rates were higher than those of MB2, and in the following order: Cu (39.6%) comes in front of Zn (35.0%), Cd (34.1%), Hg (32.1%), Pb (31.8%), and Mn (19.1%). In terms of metal phytostabilization, the interaction between S. nigrum L. and MA2/MB2 proved to be very successful, and MA2 was superior to MB2**.**

Jahantab *et al.,* (2020) evaluated that the effectiveness of cleaning up soils contaminated with chromium (Cr) and zinc (Zn), this research was conducted to evaluate the ability of *Bromus tomentellus* for phytoremediation using biochar and municipal waste compost additives. Three degrees of soil amendment (%0: Control; no organic fertilizer, 1% biochar and compost, 2% biochar and compost) were put to contaminated soil. It also establishes whether artificial neural networks (ANN) may be used to mimic the extraction process. The pH, Electrical Conductivity (ECe), Cation Exchange Capacity (CEC), and Sodium Adsorption Ratio (SAR) of the polluted soil were all measured. Following the verification of the used artificial neural network, the impact of composting municipal trash and treating biochar on the absorption of heavy metals in various plant sections was examined. Additionally, the neural network's ability to add amending materials to the soil increased from 2% in experimental data to 5% in predictive data. The Group Method of Data Handling (GMDH) and artificial neural network were useful for over-predicting data because the neural network was trained for heavy metals in soil and plants, which resulted in the amount of Correlation coefficient (R^2) value in most cases being greater than 0.9 and close to 1. The findings showed that increasing the compost fraction also increases Zn absorption. Zn (274.82 mg kg^{-1}) and Cr (26.66 mg kg^{-1}) concentrations were maximum when 0.8% compost and 0.52%

biochar were added, respectively. By adding 1% compost, the highest Cr content for compost (25.19 mg kg^{-1}) was found.

Y. Zhang *et al.,* (2023) found that the use of hyperaccumulators for the bioremediation of heavy metal removal from sediment is a promising and environmentally beneficial technique. However, there is still room for improvement in the effectiveness of phytoremediation for several heavy metal-contaminated sediments. In order to investigate the potential contribution of BC and FA to the hyperaccumulator ryegrass (*Lolium perenne* L.)'s ability to remove cadmium (Cd), zinc (Zn), and lead (Pb) from sediments, a 30-day incubation experiment was carried out. According to the findings of the BCR (Community Bureau of Reference) investigation, BC and FA enhanced the fractions of Cd and Zn that were bioavailable while lowering the bioavailability of Pb in the polluted sediments. According to metal accumulation studies, BC and FA were selective in enabling ryegrass to remove heavy metals from sediments in the presence of heavy metal. In comparison to CK, ryegrass was more effective in extracting Cd and Zn from the sediment after co-treatment with BC and FA. Their levels in the roots and stems increased by 50.7% and 143.6% for Cd and 70.2% and 29.9% for Zn, respectively. The Pb content in ryegrass stems and roots, on the other hand, reduced by 62.1% and 59.9%, respectively. These findings demonstrated the potential of BC and FA in assisting ryegrass phytoremediation of heavy metals in sediments by increasing Cd and Zn accumulation in ryegrass due to the increased bioavailable Cd and Zn, and decreasing Pb accumulation in ryegrass due to the decreased bioavailable Pb.

Lebrun *et al.,* (2021) analyzed that due to human activity, metal (loid)s are present at several sites. These metal (loid)s cause ecosystems to become contaminated, endangering both the environment and public health. There are a number of methods that may be applied to lessen these harmful effects of pollutants, and among them, phytoremediation has drawn a lot of interest. The current study's goal was to evaluate Populus euramericana, a cultivar known as the Dorskamp cultivar, for its ability to phytoremediate metal(loid)s on a technosol (former mining site) that was heavily contaminated, primarily with Pb and As, and amended with biochars of various particle sizes. Technosol was blended with four different hardwood-derived biochars (with varying particle sizes) in a 46-day mesocosm glasshouse pot experiment to study the effects of biochar application rate and particle size on soil pore water (SPW) characteristics, poplar growth, and metal(loid) distribution and concentrations in the plant organs. The findings demonstrated that all of the tested biochars significantly affected a number of SPW physico-chemical characteristics. In particular, the addition of biochar decreased accessible Pb concentrations but had no impact on As. Under these circumstances, Populus growth in modified technosol rose whenever rate and size of biochar were utilized. The following was revealed by metal(loid) concentrations and repartition in plant organs: Depending on the type of biochar utilized, there was (1) a larger root concentration with less aerial part translocation for Pb and (2) mostly a root sequestration for As. We determined that *P. euramericana*, Dorskamp, and the biochar with the smallest particle size were the best instruments for Pb stabilization in post-mining polluted soils.

Shah *et al.,* (2022) investigated in the current study, the effects of banana peel biochar on soil enzymatic activity and phytoremediation of Cd-contaminated soil were assessed using the design of experiments (Taguchi's technique). For two components, namely metal and biochar concentrations at their three levels (0, 5, and 20 mg kg^{-1} for metals and 0, 100, and 200 mg kg^{-1} for biochar), a L9 orthogonal array with nine experimental runs was used. Analysis of variance was also carried out to determine the most important factor impacting phytoremediation and soil enzyme activity. The findings of this study revealed that biochar concentration contributed more than metal concentration to the rise in stem height, root length, urease, and dehydrogenase enzymes in contrast to biochar concentration, the metal concentration had a greater impact on the amount of chlorophyll, proline, alkaline phosphatase, Cd uptake, and accumulation in root and shoot. Cd uptake in the shoot (99.31%), Cd uptake in the root (99.24%), Cd accumulation in the shoot (94.66%), and Cd accumulation in the root (88.22%) were all substantially (p 0.05) influenced by metal concentration. On the other hand, whereas the banana peel biochar augmentation boosted the metal uptake in *Bidens pilosa*, the effect of biochar addition was less than that of metal. It is determined that the combination use of heavy metal accumulator plants and banana peel biochar can be a practical option for enhancing phytoremediation of heavy metal-contaminated soil.

Saum *et al.,* (2018) this study has analyzed the utilization of burnt carbon, biochar, as a soil enhancer is potentially exciting for enhancing the process of using plants to clean soil that has been polluted by substances derived from petroleum. To investigate this topic, the study in question compared the impact of biochar, plants (young mesquite trees), compost, and mixtures of these treatments on the speed at which oil breaks down in a polluted soil and the quantity of bacteria that can break down oil. The existence of mesquite plants greatly improved the breakdown of oil in all situations, except when biochar was used alone without compost. The highest level of oil breakdown occurred in the soil that had mesquite trees planted in it and was improved with compost (44% of the light hydrocarbon part). The most likely number tests indicated that biochar generally decreased the size of the group of organisms that can break down oil. The findings of this research indicate that adding biochar to soils contaminated with petroleum does not enhance the speed of bioremediation. On the other hand, the utilization of foliage and the incorporation of decomposed matter into the earth are verified as significant methods for environmental purification.

Lebrun *et al.,* (2018) found that during the growth of the industrial age, the levels of ecological contamination caused by natural and artificial substances rose and turned into a problem impacting the entire globe. Specifically, ex-manufacturing locations frequently exhibit elevated amounts of metal (loid)s. These contaminations have negative consequences not just on the surroundings but also on human well-being, since impurities can infiltrate the food cycle. Phytoremediation is an eco-friendly and inexpensive method to fix these areas. Nevertheless, it can be challenging for plants to grow in such harsh soils due to their extreme characteristics, both in terms of physical properties and chemical composition. Therefore, changes, such as biochar and earth for gardening, need to be utilized. Biochar, produced by heating biomass in an oxygen-deprived environment, has positive effects on the quality of soil and the development of plants, as well as its ability to absorb metals and metalloids. The goals of this research were to examine the impacts of two natural additives, biochar and soil from gardens, separately or together, on the physical and chemical characteristics of a soil that was previously used for industry and the development of two types of willow plants (*Salix alba* and *Salix viminalis*) and assess the ability of these two willow species to stabilize the soil. In this objective, a greenhouse trial was conducted, utilizing garden soil at 50% (volume/volume) and/or biochar at 2 or 5% (weight/weight). The findings indicated that biochar did not enhance the physical and chemical characteristics of the soil, nor did it have any impact on the plant measurements such as weight and the concentration of metallic substances in their organs. In conclusion, *S. alba* had lesser amounts of metal(loid) in the aboveground sections compared to S. *viminalis*, linked to a positive development, making it a preferable option for stabilizing the examined soil using plants.

Su *et al.,* (2023) conducted that the contamination of soil with lead is now a significant worldwide problem that is negatively impacting the forest environment. This research was performed to examine how the presence of corn straw affects the ability of *Populus deltoides* to clean up soil contaminated with Pb. Women and men P. *deltoides* plant parts were exposed to dirt contaminated with 900 milligrams per kilogram of lead and treated with 5% (volume per volume) corn straw biochar for a period of 90 days. Under lead stress, the inclusion of biochar greatly enhanced the overall growth of plants by 29% in females and 26% in males. However, in the absence of biochar, the females experienced a notable 11% decrease in biomass accumulation, while the males faced a 3% decrease under Pb stress. Women displayed a greater absorption and buildup of Pb in their roots and leaves, while men accumulated more Pb in their roots and stems and displayed a heightened capacity to counteract oxidation. Adding biochar decreased lead toxicity in both male and female P. *deltoides*. This occurred by trapping lead ions in the soil, lowering lead absorption and movement, enhancing nutrient absorption, and enhancing the variety and strength of the soil bacteria population. In short, the males with the inclusion of biochar showed encouraging potential as options for cleaning up soil contaminated with Pb. This research offers fresh understandings regarding the ways that males and females react differently to Pb stress when there is the addition of biochar.

L. Zhou *et al.,* (2022) investigated that this research intended to assess the different chemical forms of manganese in *Phytolacca acinosa* Roxb. Remnants at various temperatures of heat treatment and how they impact the effectiveness of removing lead Pb(II) and tetracycline (TC) contaminants. The findings showed that the temperature at which pyrolysis occurs is an important factor when it comes to the portion and accessibility of manganese and other harmful metals in the resulting biochar. Based on these results, a pyrolysis temperature below 450 °C could be the most appropriate choice for reusing the biochar without any possible harm. The biochar made with an increased amount of manganese from the phytolaccaceae plant (PSB450) had a stronger attraction to lead (II) (279.33 mg g^{-1}) and TC (47.51 mg g^{-1}) compared to the original biochar when tested separately. This was mainly because the pyrolysis process led to the creation of manganese oxides and minerals. The results of binary adsorption indicated that lead (II) would act as a connection between PSB450 and TC through a chemical reaction within a small range of concentrations, thereby helping them to clean contaminants together. This research offered an effective substitute method for recycling Mn-polluted organic matter.

Manori *et al.,* (2021) conducted that the feasibility of pine needle biochar as a soil amendment to promote the growth of *Bidens pilosa* L. and enhance its ability to phytoextract the cadmium from soil. Pot experiments (50 d) were designed as control experiment (C); metal treatment (MT), 20 mg Cd kg^{-1}; biochar treatment (BT100 or BT200), 100 or 200 mg kg^{-1}; and metal-biochar treatment (MBT100 or MBT200), 20 mg Cd kg^{-1} and 100 or 200 mg biochar kg^{-1}. The Cd (20 mg kg^{-1}) or biochar treatment (100 mg kg^{-1}) increased the dry weight and root length of *B. pilosa*. The biochar amendment enhanced the metal concentration in root and shoot of the plant. The plant could accumulate 39.47±5.44 mg Cd kg^{-1} in shoots (MT), which increased to 45.96±17.3 mg Cd kg^{-1} and 55.01±5.65 mg Cd kg^{-1} under biochar treatment sets MBT100 and MBT200, respectively. The Cd uptake by *B. pilosa* in MT, MBT100, and MBT200 treatments were 67.81 µg/plant, 78.58 µg/plant, and 76.13 µg/plant, respectively. The biochar amendments increased the proline concentrations while decreased the chlorophyll content in leaves indicating the stress on the plant. Overall, the result indicates that soil amended with pine needle biochar at 100 mg kg^{-1} increased the phytoremediation ability of *B. pilosa*.

Chirakkara & Reddy, (2015) carried out a pot trails to examine the impacts of biochar and compost addition on the process of purifying a mixture of polluted soil through the use of sunflower, oat, and rye grass plants. A combination of polluted soil was created by blending the soil with 50 mg kg^{-1} naphthalene, 100 mg kg^{-1} phenanthrene, 500 mg kg^{-1} lead, 50 mg kg^{-1} cadmium, and 200 mg kg^{-1} chromium. A series of tests were carried out using soil mixed with 50 g kg^{-1} of biochar and another set of tests using soil mixed with 200 g kg^{-1} of compost. The changed soils were put in containers and plants were cultivated in them for 61 days. The control group consisted of plants grown in soil without any contamination or amendments and plants grown in soil with contamination but no amendments. The modification in the growth traits of oat plant and rye grass due to the amendments was not noteworthy. Sunflower showed improved germination and growth traits in treated soil as opposed to untreated soil. The sprouting and development features and amount of plant material were superior in soil treated with compost compared to soil treated with biochar in sunflower plants. The presence of additives improved the removal of Cd and Pb from the soil for all the plants, but the addition of additives did not have an effect on the removal of Cr. In cultivated grounds, levels of PAH were decreased due to the existence of alterations. The findings indicate that using biochar and compost additives can enhance the qualities of plant growth and improve the process of using plants to clean up mixed contaminated soils.

Rodríguez-Vila *et al.,* (2014) examined that Chemical degradation has occurred in the soils of a depleted copper mine in Touro, Galicia, Spain. A three-month greenhouse experiment was conducted to ascertain the impact of vegetation and amendments on the chemical properties of a mine soil and on the uptake of metals by plants. *Brassica juncea* L. was planted on soil that had been modified with varying proportions of compost and biochar mixture. The findings demonstrated that Cu had contaminated the untreated settling pond soil. Modifications and mustard planting raised the concentrations of C and TN in the soil, lowered the extreme acidity of the soil, and decreased the pseudo total concentration of this metal. The amounts of Co, Cu, and Ni that are CaCl2-extractable were likewise lowered by both treatments. The additions raised the soil's pseudototal zinc concentration, which was supplied by the applied compost. Additionally, the results demonstrated that mustards were effective at extracting nitrogen from soil, indicating that *B. juncea* L. is a useful phytoextractor of nitrogen in mine soils.

Haji Najafi *et al.,* (2016) found that the impact of Biochar on the level of lead (Pb) in maize plants (*Zea mays* L.) this experiment using a design where the treatment groups are randomly assigned and repeated three times. Lead (Pb) was present at levels of zero, 50, 100, and 200 mg kg^{-1} in lead sulfate salt supplies, referred to as P0, P1, P2, and P3 respectively. Additionally, treatments included the addition of Biochar, which is charcoal made from almond wood, at ratios of zero, 20, and 40%, denoted as B0, B1, and B2 respectively. The treatment without biochar had the highest weight of shoots when exposed to 50 mg of lead per kilogram, with a value of 1.431. Conversely, the treatment without biochar and 200 milligrams of lead per kilogram had the lowest weight of shoots, with a value of 0.261 at the root. The treatment with 100 mg of lead per kilogram and 40% biochar had the lowest lead concentration at the root, with a value of 1.368 mg kg^{-1}. The control without lead and 20% biochar had the lowest lead concentration in the root, with a value of 0.617 mg kg^{-1}. The treatment with 200 mg of lead per kilogram (and no biochar) had the highest lead concentration in the stems, with a value of 1.239 mg kg^{-1}. The treatment without lead and with 20% biochar had the lowest lead concentration in the stems, with a value of 1.001 g. The treatment with 40% biochar had the highest lead concentration in the leaves, with a value of 1.941 mg kg^{-1}. The treatment with 100 mg of lead per kilogram and 40% biochar had the lowest lead concentration in the leaves, with a value of 0.166 mg kg^{-1}.

Wang *et al.,* (2023) observed that pyrolysis procedure is a useful way to deal with phytoremediation residue. In this study, hydroponics was used to prepare Ni-enriched biomass, which was then pyrolyzed at various temperatures (300-700 °C). Ni was stabilized in biochar mostly as a result of carbonate precipitation at low pyrolysis temperatures (below 500 °C). However, at high pyrolysis temperatures (over 500 °C), the produced phosphate and aluminosilicate were crucial for immobilizing Ni in charcoal. Additionally, the components of Ni in biochar that are oxidizable (F3) and residual (F4) increased as the pyrolysis temperature rose, suggesting that a higher pyrolysis temperature could effectively lower the bioavailability of Ni in biochar. According to the findings of investigations using deionized water, acidification, oxidation, and toxic characteristic leaching process (TCLP), pyrolysis temperature was the main factor in Ni stability in biochar. The ecological risk analyses further demonstrated that pyrolyzed Ni-enriched biochar could lessen the possible ecological dangers and environmental toxicity of Ni. Overall, this investigation would reveal more sensible guidelines for the long-term preservation of phytoremediation residues.

Du *et al.,* (2019) conducted that as a hyperaccumulator, *Symphytum officinale* L. was pyrolyzed into biochar at 350, 550, and 750 °C, respectively. PTEs might be enhanced using biochars, however Cd significantly volatilized at 750 °C. A variety of sequential and single extractions, as well as biochar oxidation techniques, were carried out to simulate various environmental circumstances in order to assess the environmental acceptability of biochar. When the temperature rose above 550 °C, the amount of PTEs released under varied situations sharply decreased, suggesting PTEs may change into more stable forms at higher temperatures. Thus, lowering biochar phytotoxicity, preventing biochar leaching, and enhancing biochar environmental safety can all be achieved by raising the pyrolysis temperature. Additionally, the biochar's economic feasibility analysis supported its viability. The results of this study showed that biochar pyrolyzed. Results from this study showed that biochars made from *Symphytum officinale* L. at temperatures greater than 550 °C may be acceptable to the environment, which is advantageous for biochar application.

Samsuri *et al.,* (2020) conducted a study on the phytoavailability of heavy metals in contaminated soils is reduced by a variety of amendments, but recently, the application of biochar has drawn significant attention. The phytoavailability of Cd and Pb by mustard plants grown on the soils was assessed in this study after two particle sizes of oil palm empty fruit bunch biochar (EFBB) were applied at 0, 0.5, or 1% (w/w) to soils contaminated with either metal. The particle sizes were <50 µm (F-EFBB) and >2 mm (C-EFBB). The application of EFBB at 1% considerably boosted plant growth characteristics in Cd-soil when compared to the control, according to the results. On plant growth indices in Pb-soil, however, the application rate of EFBB had no discernible effect. The amounts of Cd and Pb in the plant root and shoot varied significantly amongst soils that received varying EFBB particle sizes. When compared to the other treatments, the 1% F-EFBB treatment produced the lowest concentrations of Cd in the shoot (115.200 mg kg^{-1}) and Pb in the root and shoot (4196.000 and 78.467 mg kg^{-1}, respectively). Consequently, it is possible to reduce the phytoavailability of Cd and Pb in polluted soils by applying F-EFBB at high rates.

Houben *et al.,* (2013) investigated that growing rapeseed (*Brassica napus* L.), a typical biofuel crop, and liming (CaCO3) or adding biochar (1%, 5%, and 10%, mass fraction) to soils contaminated with heavy metals were used to investigate phytoremediation. With increasing quantities of biochar amendment, bioavailable metal concentrations (0.01 mol L^{-1} $CaCl_2$ extraction) declined. In the addition of 10% biochar, the reduction for Cd, Zn, and Pb was 71%, 87%, and 92%, respectively. Twelve weeks after planting, all of the plants grown on the untreated and biochar-amended soils had perished, whereas the plants on the soil with the other treatments had grown properly. Treatment with 10% biochar was just as effective at lowering metal concentrations in shoots as liming, but the biomass output tripled as a result of soil fertility improvement. Consequently, biochar absorption into metal-contaminated soils could enable the cultivation of bioenergy crops without infringing on agricultural fields, in addition to C sequestration. Although more research is required, we propose that the gathered biomass might also be utilized as a feedstock for pyrolysis to create new biochar and bioenergy, which would further reduce CO_2 emissions.

Narayanan and Ma, (2022) examined that this study critically evaluated the possibility of remediating metal-contaminated soils with a responsible biochar-based method. An excellent bio-based residue material that may be used for soil improvement and repair of metal-polluted soil using a sustainable method is plant-based biochar. Large-scale phytoremediation requirements can be met by plants with rapid growth and increasing biomass. The mechanisms of metal accumulation and contaminant mobility in plants utilized for phytoremediation of metal-contaminated soil have been significantly improved, according to recent research. The development and biomass of plants are decreased by excessive contamination, which is harmful to the phytoremediation process and has significant hyperaccumulating potential. Native or wild plants cultivated in metal-polluted soil can benefit from the development and phytoremediation abilities of biochar made from various plant sources. Carbon-enriched biochar promotes the growth of local microorganisms by balancing pH and offering nutritional assistance. Thus, the effect of plant and agricultural waste-based biochar on plant phytoremediation capacity in metal-contaminated soils is critically discussed in this research.

Soudek *et al.,* (2017) found that the level of PAH in biochar from four different origins was investigated, and naphthalene, phenanthrene, fluoranthene, and pyrene were detected as the main substances. The most plentiful inorganic elements were potassium, calcium, magnesium, sodium, aluminum, iron, and manganese, with strontium and barium also showing large increases. The pH level of biochar from every origin was highly basic. The absorption properties for toxic metals (Cadmium, Copper, and Lead) were also examined for the various categories of biochar. The adsorption data for bamboo-derived biochar can be well described using a Langmuir isotherm, with maximum capacities for adsorbing Cd (II), Cu (II), and Pb (II) at 20.16, 7.83, and 70.92 mg g^{-1}. Rice husk-derived biochar has adsorption capacities of 18.80, 13.85, and 200 mg g^{-1} for the same metals. Ash tree-derived biochar has capacities of 11.63, 20.08, and 123.46 mg g^{-1}, while beech tree-derived biochar has capacities of 15.11, 10.86, and 196.08 mg g^{-1}. Sorghum seed sprouting was assessed to determine the impact of biochar on the harmfulness of heavy metals. By using biochar, the harmfulness of cadmium, copper, and lead was decreased. Biochar made from bamboo was not as effective in decreasing the harmfulness of cadmium and copper when compared to other forms of biochar. In terms of lead, the biochar derived from rice husk showed the lowest effectiveness in reducing its toxicity.

Zhen *et al.,* (2019) observed that the cleanup of soil contaminated with petroleum hydrocarbons using a unique plant called *Spartina anglica* was improved by using a mixture of biochar and rhamnolipid. Examples of soil contaminated with petroleum (10, 30 and 50 g kg^{-1}) were treated with biochar (BC), biochar combined with rhamnolipid (BC+RL), and biochar modified with rhamnolipid (RMB), correspondingly. After 60 days of growth, the percentage of total petroleum hydrocarbons (TPHs) removed from soil that was not planted (UP), soil that was planted (P), soil that was planted and had BC added (P-BC), soil that was planted and had BC and RL added (P-BC + RL), and soil that was planted and had RMB added (P-RMB) were 8.6%, 19.1%, 27.7%, 32.4%, and 35.1% respectively, for soil with a TPHs concentration of 30 g kg^{-1}. In comparison to UP, the growth of *Spartina anglica* resulted in a notable reduction in the levels of C8–14 and tricyclic PAHs. In addition, the use of BC and RMB reduced the harmful effects of petroleum hydrocarbons on *Spartina anglica* by enhancing the growth of plants, including an increase in plant size, root health, and the amount of chlorophyll present. This led to a rise in the abundance of bacteria and a type of fungus that forms a mutualistic relationship with plants, known as mycorrhizal symbiotic fungus, when biochar and RMB were applied to the soil.

Puga *et al.,* (2015) this study has analyzed that biochar has the ability to store significant quantities of heavy metals because of its expansive surface area, among other properties. In the present study, biochar made from sugarcane straw and produced at a temperature of 700 degrees Celsius was added to mine soil that was contaminated with heavy metals. The biochar was added at concentrations of 1.5%, 3.0%, and 5.0% by weight. Jack bean and *Mucuna aterrima* were cultivated in pots containing a soil polluted with minerals and soil mixed with biochar. Water in the pores was examined to evaluate the impact of biochar on the ability of zinc to dissolve, while the soils were inspected using DTPA extraction to verify the levels of metal that can be used immediately. Using BC reduced the levels of Cd, Pb, and Zn that were present in the soil contaminated by the mine. This resulted in a steady decrease of Zn concentration in the water within the soil. The BC amendment decreased the absorption of Cd, Pb, and Zn by plants, with the jack bean taking in more Cd and Pb compared to M. *aterrima*. This research suggests that using biochar when restoring mine soil could lower the levels of heavy metals in plants. In addition to this, signs of high metal levels were only missing in plants that were grown in pots containing biochar. The decrease in metal availability and other changes to the soil caused by using biochar may help create a plant cover on mine soil, which can assist in cleaning up the area and lowering potential harm.

Fellet *et al.,* (2014) found that using biochar as a supplement could potentially help lower the chances of pollutants spreading. The primary aim of the study was to confirm how various biochar types made from different sources (pruning leftovers, fir tree pellets, and manure pellets) affect the substrate conditions, with the goal of enhancing plant growth to stabilize mine waste. The SEM/EDX analysis revealed various formations in regards to the level of pores and particles, along with the elemental composition. Flowers utilized in the container experiment were *Anthyllis vulneraria* subsp. *polyphylla* (Dc.) Nyman, *Noccaea rotundifolium* (L.) Moench subsp. (Dc.) Nyman, *Noccaea rotundifolium* (L.) Moench subsp. The plant *cepaeifolium* and *Poa alpina* L. subsp. are similar. Alpine. The biochars were used in three amounts: 0, 1.5, and 3% by weight. Even though to varying degrees, the biochars caused notable alterations in the materials regarding acidity, electrical conductivity, cation exchange capacity, and availability of the metals. The biochar made from animal waste pellets and trimming leftovers decreased the levels of Cd and Pb in the plant shoots. The first one also resulted in an increased amount of plant material produced, reaching its highest point at the dosage of 1.5%. Holds significant promise as an additive for plant-based restoration of contaminated sites, but its impacts vary based on the origin of the raw material it is made from. The qualities of the material that needs to be processed are important for choosing the appropriate biochar.

Li *et al.,* (2022) examined the impact of biochar made from bamboo on the growth and accumulation of metals in *Salix* plants in soil that was contaminated with multiple metals. The study compared the effects in both non-flooded and flooded conditions. Willow branches were grown in pots with highly polluted soil containing Cadmium (Cd) and Zinc (Zn) for a period of 120 days. Four different treatments were applied, which included a treatment without flooding, a treatment with flooding, a treatment without flooding but with the addition of 3% BBC (BBC/soil, w/w), and a treatment with flooding and 3% BBC addition. The BBC and flooding had a considerable impact on reducing the amount of metals available in soils ($P < 0.05$). The inclusion of BBC significantly increased the amount of Cd in leaves when there was no flooding (94.20%) and when there was flooding (32.73%), but it had a minimal impact on roots. The BBC greatly increased the transportation of Cd and Zn from roots to aboveground parts by 68.85% and 102.27% respectively, compared to not adding BBC under non-flooded conditions. However, there were no significant changes under flooded conditions. Even though the amount of plant material remained mostly unaffected, BBC caused a notable increase in the concentration of Cd and Zn in the entire plant by 52.53% and 28.52% when not flooded, but had no noticeable effect when the conditions were flooded. In combination, BBC improved the ability of *Salix* to remove Cd and Zn pollutants from highly contaminated non-flooded soil, but this impact was reduced when the soil was flooded.

Gonzaga *et al.,* (2022) conducted a study on biochar has the potential to improve the process of using plants to clean up copper-contaminated soils by enhancing soil condition and fostering better plant development. Our research examined how biochar made from orange bagasse (OBB) and coconut husk (CHB), as well as different amounts of copper in the soil (0.17 mg kg^{-1}-CLS; 100 mg kg^{-1} -CTS), affected the growth of *Brassica juncea* plants, their ability to absorb copper, and their physiological response. We assessed the amount of plant matter, copper, nitrogen, and phosphorus in plants, as well as the level of chlorophyll and its temporary fluorescence. The growth of plants was poor without biochar, suggesting that the elevated Cu concentration was not the sole restricting factor. Biochar (OBB and CHB) enhanced the weight of shoots by 300–574% and the weight of roots by 50–2900%, and enhanced the amount of chlorophyll and photosynthetic activity by 6–16%. Both types of biochar were effective in the soil with low levels of copper, as they boosted the growth of plants, increased the amount of copper in their shoots, and improved the rate at which copper was transported throughout the plant. In the soil with a high amount of copper, both types of organic matter added to the soil improved the growth of plants and their ability to absorb copper, while also decreasing the amount of copper in their shoots and their overall ability to transport copper within their system.

Shaheen *et al.,* (2023) observed that the ability of biochar (BC) to prevent potentially harmful substances (PTEs) from moving in polluted soils has been examined and assessed, there has not been a review specifically examining how BC could improve the effectiveness of phytoremediation in PTE-contaminated soils. Thus, the main objective of this study is to thoroughly examine the impacts of BC on the movement, extraction, stabilization, and remediation of toxic elements in polluted soils. Possible ways in which BC and PTEs in soils can interact are also examined thoroughly. We talk about the benefits and difficulties of different methods, including possible environmental effects, of using BC on soils polluted with PTEs. The characteristics of BC (such as surface functional groups, mineral content, ionic content, and π-electrons) control its effect on the movement and containment of potentially toxic elements (PTEs), which is intricate and highly dependent on the specific element involved. This evaluation shows the conflicting impacts of BC on PTE movement and emphasizes potential chances to utilize BC as a mobilizing substance to improve the phytoremediation of soils contaminated with PTEs.

Moradi *et al.,* (2021) analyzed that biochar, when used as a soil enhancer, has the ability to manage the accessibility of toxic metals in polluted soils and decrease the likelihood of these metals being transferred to the food chain. The aim of the research was to examine how biochar made from different types of waste (apple pruning, grape pruning, or wheat straw) at varying levels (0%, 2%, and 5% by weight) affected the growth of lettuce and the availability of lead (Pb) in a Pb-contaminated calcareous soil. The crops were gathered two months after planting and the weight of the plants, the concentration of lead (Pb), the factor of transfer (TF), the factor of biological concentration of the above-ground and underground parts (BCF), and the availability of lead in the soil were recorded. When Pb levels were increased to the maximum, the amount of Pb that could be extracted by NH4NO3 was decreased by 24.6% and 51.8% when biochar was applied at rates of 2% and 5%, respectively, in comparison to the control. The use of biochar reduced the amount of lead in lettuce leaves. The biggest decrease was seen with 5% of AB (44.0%), GB (30.5%), and SB (23.8%) when the level of lead was the highest. The current results offer new proof on the positive impacts of the biochar's that were tested, particularly SB, on the growth of lettuce in a soil containing high levels of Pb contamination.

Yoshii *et al.,* (2020) evaluated that elevated amounts of lead (Pb) in the dirt is a significant problem in the town of Kabwe, Zambia. Phytoremediation is a successful method to restore the essential functions of the soils. Phytoremediation can be enhanced by using nearby soil enhancers like chicken manure. The objective of this research is to discover the right mix of a Pb hyperaccumulator that is found in the local area, lemongrass (*Cymbopogon citratus* (DC.) Stapf.), and soil additives in order to reduce the pollution caused by Pb. The experiment lasted for 78 days and involved using lemongrass along with three different soil additives - chicken manure, chicken manure charcoal, and urea. The soil used for the experiment was contaminated with Pb. Despite this, dent corn was able to be grown and harvested. The plant species known as *Zea mays var. indentata* (Sturtev.) L.H. Bailey), was cultivated for a period of two weeks. The mixture of chicken droppings and lemongrass showed the best outcome, decreasing the amount of lead in dent corn by 19%. This was in contrast to the dent corn grown on regular soil without any additives. By cultivating lemongrass in the soil of Kabwe using chicken dung, the interchangeable soil Pb was diminished by 70%. The increase of lemongrass without chicken poop decreased the movable soil lead by 20%. In summary, lemongrass effectively decreased Pb levels when used together with chicken waste.

M. Zhang *et al.,* (2018) investigated that the addition of biochar to phytoremediation could potentially reduce the harmful effects of pollutants on microorganisms in the soil. The impact of the rate at which biochar is added on enzyme activities related to soil nitrogen (N) release and changes to the fungal community in the process of phytoremediation is still unclear. The main objective of this research was to investigate the impact of using *Medicago sativa* L. (a type of alfalfa) for phytoremediation, either alone or in combination with biochar, on soil protease and chitinase activities, as well as the composition of the fungal community. Additionally, the study aimed to establish any connections between the changes in microbial parameters and the different rates of biochar addition. The use of alfalfa plants improved the activity of soil protease enzymes, and the effects of adding biochar to the phytoremediation process were not consistently linked to changes in the levels of functional genes. Compared to the blank control, the use of alfalfa plants for phytoremediation led to higher amounts of fungi and increased diversity of fungal communities. This was observed when alfalfa was used alone or in combination with biochar. Furthermore, in comparison to phytoremediation alone, the proportions of phylum *Zygomycota* were also enhanced by the inclusion of biochar. The entire fungal community in the soil did not show significant changes when only alfalfa phytoremediation was used, but there were noticeable changes when alfalfa phytoremediation was combined with the addition of 3.0% or 6.0% biochar. This research indicated that the use of alfalfa plants for phytoremediation could improve the activities of enzymes that help release nitrogen from organic matter. Additionally, the amount of biochar added to the soil influenced the impact on the fungal community during the alfalfa phytoremediation process.

Sharma *et al.,* (2023) found that different economic and ecological approaches are needed to repair the soils that have been polluted with heavy metals. Phytoremediation is a new method that is gentle, affordable, and visually attractive. Several proteins in plants that bind to metals are highly involved in the process of phytoremediation for heavy metals. These proteins consist of metallothioneins, phytochelatins, metalloenzymes, metal-activated enzymes, as well as various proteins that store, transport, and regulate the movement of metals. Plants are altered genetically to improve their ability to cleanse the environment through phytoremediation. In *Arabidopsis*, the presence of the mercuric ion-binding protein from *Bacillus megaterium* enhances the ability to gather metals. The effectiveness of plants in phytoremediation is also improved when supported by microorganisms, biochar, and/or substances. Eliminating toxic elements from farmland without jeopardizing food production is extremely difficult. As a consequence, there is a great need for crops that can absorb harmful metals and ensure sufficient food supply. This article outlines the importance of plant proteins and the interaction between plants and microorganisms in the treatment of soil polluted by toxic metals. Technological methods in biology or altering genes can also be utilized to address the issue of excessive metal pollution.

Rassaei *et al.,* (2023) conducted a study on a pot trial with a random block pattern was conducted to investigate the effects of biochar made from sugarcane bagasse on supporting the growth of corn in soil contaminated with Cadmium and Lead. The factors involved were growing corn in a type of soil called sandy clay loam. Two different tests were conducted, one for Cd and one for Pb. The levels of SBB used were 0%, 2%, and 4% by weight. The levels of Cd used were 0 mg kg^{-1}, 40 mg kg^{-1}, and 80 mg kg^{-1} of soil from $CdSO_4$.8 H2O. The levels of Pb used were 0 mg kg^{-1}, 400 mg kg^{-1} and 800 mg kg^{-1} of soil from $PbSO_4$. Using one instance of SBB at 40 and 80 mg kg^{-1} Cd-soil had a notable impact on the dry weight of roots and shoots. The weight of roots increased by 21.0% and 57.14%, while the weight of shoots increased by 17.14% and 32.36%, respectively, when compared to the control group. Using a single dose of SBB at 400 and 800 mg kg^{-1} in soil contaminated with Pb led to significant increases in the weight of roots and shoots. The roots showed a growth increase of 39.55% and 57.46% compared to the control, while the shoots had a growth increase of 12.71% and 26.29%, respectively. SBB enhanced chlorophyll levels, leaf size, height of plants, and amount of dry matter in roots and shoots as a result of reducing the levels of Cd and Pb in roots and shoots. It can be inferred that adding SBB to soils contaminated with HMs is a suitable solution that will improve the growth of plants.

CHAPTER 3

MATERIALS AND METHODS

3.1 Collection and preparation of soil samples

Soil was collected from the field which is located in Research Field 1 of the Department of Soil Science at Hajee Mohammad Danesh Science and Technology University, Dinajpur. According to the area's annual mean temperature ranged from 19 °C in January to 31°C in August with a mean 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. Mustard 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 soil's structural 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.

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.

3.3 Characterization of soil amendment

Table 1. Morphological characteristics of the soil

Morphology	**Characteristics**
Location	Soil Science Laboratory-1, Department of soil science, HSTU
AEZ	Old Himalayan Piedmont plain (AEZ-1)
General soil type	Non- calcareous brown floodplain soil
Drainage	Well drained
Topography	Medium high land

Table 2. Physical characteristics of Basic soil

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

Table 3. Chemical characteristics of Basic soil

Characteristics	Analytical Data
pH	4.7
Organic Matter (OM) %	0.55
Electrical Conductivity (EC) ms	0.02
Cation Exchange Capacity (CEC) cmolkg-1	5.07
Ca (meq 100g^{-1})	4.27
Mg (meq 100g^{-1})	3.9
Na (meq 100g^{-1})	0.32
K (meq 100g^{-1})	0.12

Table 4. Chemical composition of organic amendments

Sample	Physical condition	Colour	pH	EC	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Na (%)
Compost	Dust	Gray	8.64	1.46	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-compost 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 = Phosphorous
K = Potassium

S = Sulfur
Na = Sodium
Ca = Calcium
Mg = Magnesium

3.4 Setting of pots for the experiment

The pots were set out in the designated open area in 6 rows and 3 columns.

3.5 Treatments

The experiment's treatment combinations were as follows:

T_1 = Control soil (750 g) + 200 mg Pb

T_2 = 750 g soil + 200 mg pb + 10% Compost

T_3 = 750 g soil + 200 mg pb + 10% Ash

T_4 = 750 g soil + 200 mg pb + 10% Biochar

T_5 = 750 g soil + 200 mg pb + 10% Poultry Litter

T_6 = 750 g soil + 200 mg pb + 10% Co-Compost Biochar

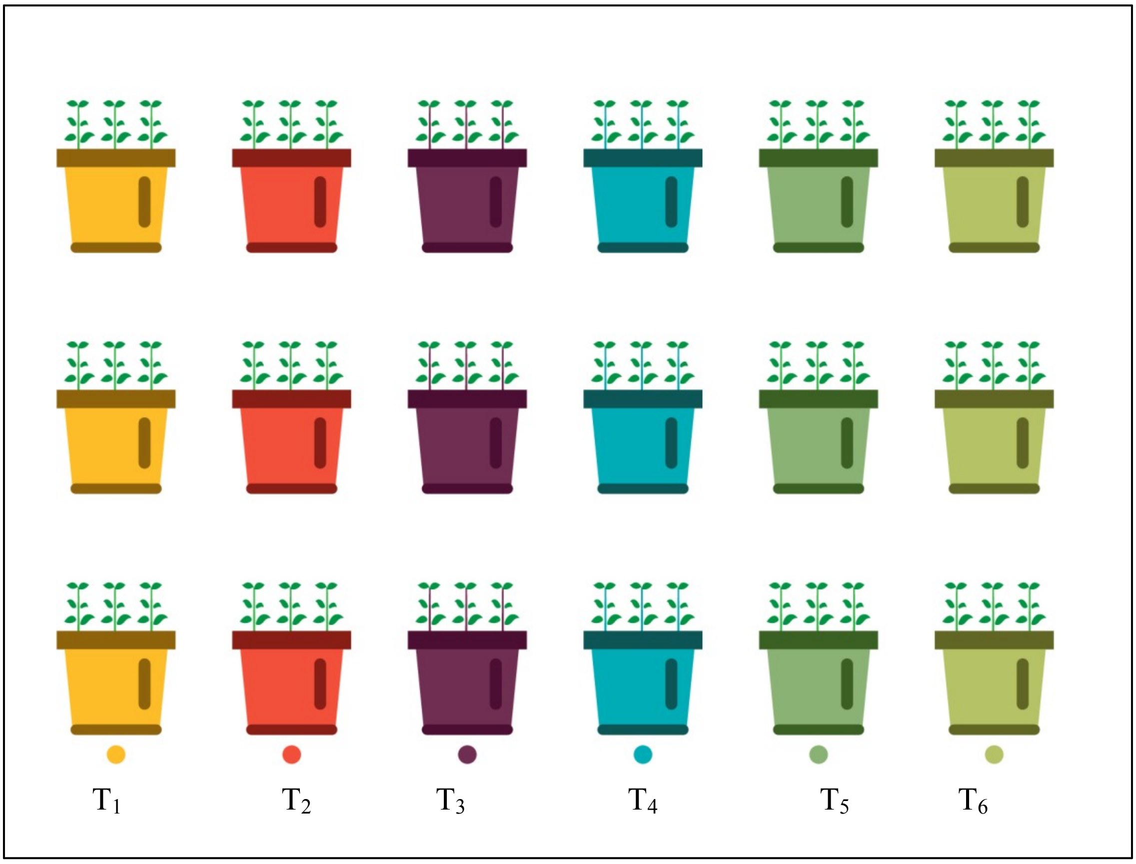

Fig. 1. Graphical representation of different treatments

3.6 Experimental design

The treatments were arranged in a Completely Randomized Design (CRD) with 7 treatments and 3 replications for the pot study. The total pot number was $6\times3 = 18$. The distance maintained between two pots was 15 cm.

3.7 Pot preparation

Each 1.0 kg of air-dried soil sample treatments were placed in plastic pot. The required amount of compost and biochar added 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. BARI Sarisha-18 (Canola type) was used as the test crop.

3.7.1 Sowing of seed

The seeds were primmed with 10% H_2O_2 and allowed for germination in an incubator at 25^0C. After that, eight uniform germinated seeds transferred to a plastic pot having 1.0 kg soil. After one week, four seedlings removed to confirmed the uniformity among the plants in each treatment.

3.7.2 Weeding and thinning

The experimental pots were kept free of weeds by regular weeding.

3.7.3 Irrigation

Sufficient water was given regularly to maintain the 70% of the field water holding capacity during the growing period.

3.7.4 Crop protection

Throughout the trial time, there were no pests or diseases, hence no control measures were implemented.

3.7.5 Harvesting

The plants were harvested after 30 days of seedling emergence. The height of the plants was measured for each corresponding treatment. The mustard shoots and roots were harvested separately. Shoots and roots washed with distilled water, oven-dried at 105 ^0C for 30 minutes, and later at 80 ^0C to the constant weight.

3.8 Analyses of plant samples

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

3.8.1 Plant height

Plant height was measured in centimeters at intervals of 25 days after sowing. Plant height was measured using a scale that considered the distance between the soil's surface and the tips of 8 randomly chosen plants. A mean value was computed for each treatment.

3.8.2 Plant dry weight

Dry weight of plants was measured by using electric precision balance. The plants were dried in an oven set to low heat 68 ^{0}F for 2 days.

3.8.3 Total N and P (%)

Total N and P content were determined by Kjeldahl method in the laboratory by Bremner (1879).

3.9 Analyses of soil samples

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), available K^+, Na^+, $Ca^{2+,}$ and Mg^{2+} contents.

3.9.1 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 Marshell's Triangular co-ordinate as designated by USDA.

3.9.2 Organic carbon (%)

Soil organic carbon was estimated by Walkley and Black's wet oxidation method as outlined by Jackson (1973).

3.9.3 Soil organic matter

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N FeSO4. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage.

Soil organic matter content was calculated by multiplying the percent value of organic carbon with the Van Bemmelen factor, 1.724.

% organic matter = % organic carbon × 1.724

3.9.4 Soil pH

The pH was determined by glass-electrode pH meter in a Soil: water ratio 1:2.5 (Jackson, 1973). 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). Soil organic matter was measured by the dichromate method and cation exchange capacity was determined using the ammonium acetate method at pH 7.0. The CEC was measured by the ammonium acetate method at pH 7.0 (Pansu and Gautheyrou, 2006).

3.9.5 CEC (cmolkg^{-1})

Soil exchangeable base cations were extracted with 1.0 ammonium acetate at PH 7.0 (Pansu and Gautheyrou, 2006).

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

The Ca^{2+} and Mg^{2+} were measured by using atomic absorption spectrophotometer.

3.9.7 Available Na and Mg (cmolkg^{-1})

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

3.10 Statistical analyses

All the statistical analyses were performed with SPSS (version 22.0, USA), and the graphs were drawn with Origin (version Origin Pro 2018, USA). The mean of three replicates along with the standard deviation were used to present all the data. An analysis of variance (ANOVA) was performed using a multivariate general linear model to determine the differences and interactions between the treatments.

CHAPTER 4
RESULTS AND DISCUSSION

The current experiment was plotted to investigate the effect of compost and biochar on Pb contaminated soil phytoremediation. Tables, graphs, and figures that display the statistical analysis of data on various parameters are provided. The following headings provide examples and a discussion of the study's findings along with potential interpretations.

4.1 Effects of organic amendments on plant height

According to the study's findings, the height of rapeseed plants was significantly impacted by compost and poultry litter (Fig. 2). Applying compost and poultry litter has a substantial impact on the plant height of mustard cv. BARI Sarisha-18 (Canola type). It was observed that in case of plant height significant difference was found at compost, biochar, ash, poultry litter and co-compost biochar. A substantial impact on the height of the mustard plant at 25 days after sowing (Fig. 2). The tallest plant measured on compost and poultry litter.

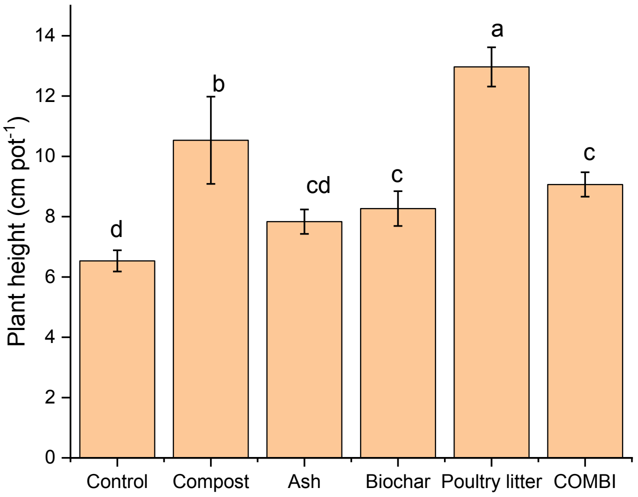

Fig 2. Effect of organic amendments on plant height of *Brassica napus* in Pb contaminated soil

4.2 Effects of organic amendments on plant shoot dry weight

According to the study's findings, the shoot dry weight of rapeseed plants was significantly impacted by compost and poultry litter (Fig. 3). Applying compost and poultry litter has a substantial impact on the shoot dry weight of mustard cv. BARI Sarisha-18 (Canola type). It was observed that in case of shoot dry weight significant difference was found at compost and poultry litter.

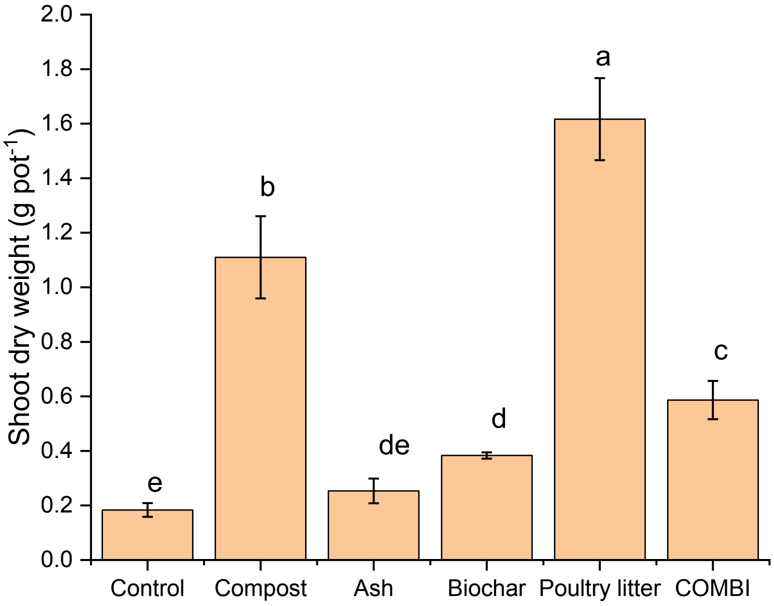

Fig 3. Effect of organic amendments on plant shoot dry weight of *Brassica napus* in Pb contaminated soil

4.3 Effect of organic amendments on plant available P

The impact of modified organic amendments on plant available P presented in (Fig. 4). The results indicated that the plant available phosphorous significantly increased in application of compost treatment compared to control. The impact of biochar and poultry litter on plant available P also comparable.

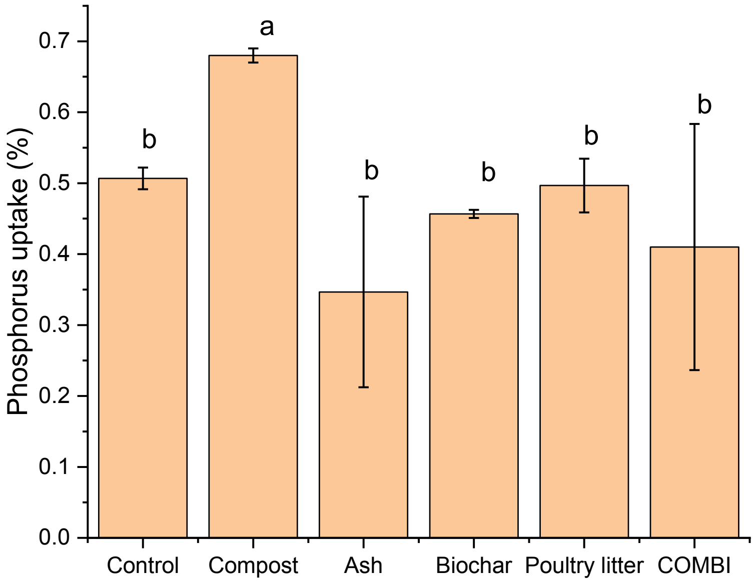

Fig 4. Effect of organic amendments on plant available P of *Brassica napus* in Pb contaminated soil

4.4 Effect of organic amendments on plant available N

The impact of modified organic amendments on plant available Nitrogen presented in (Fig.5). The results indicated that the plant available phosphorous significantly increased in application of compost, ash, and co-compost biochar compared to control. The application of biochar and poultry litter also enhanced plant available nitrogen compared to control.

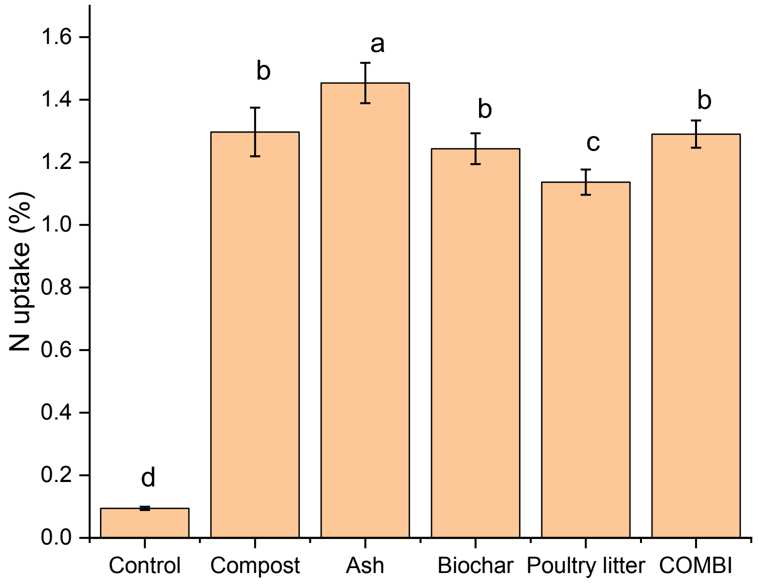

Fig 5. Effect of organic amendments on plant available N of *Brassica napus* in Pb contaminated soil

4.5 Effect of organic amendments on plant uptake Pb

The impact of modified organic amendments significantly influenced plant Pb uptake in *B. napus* (Fig.6). The results indicated that the plant uptake Pb significantly increased in application of compost and poultry litter compared to control. The application of ash, biochar and co-compost also enhanced plant uptake Pb compared to control.

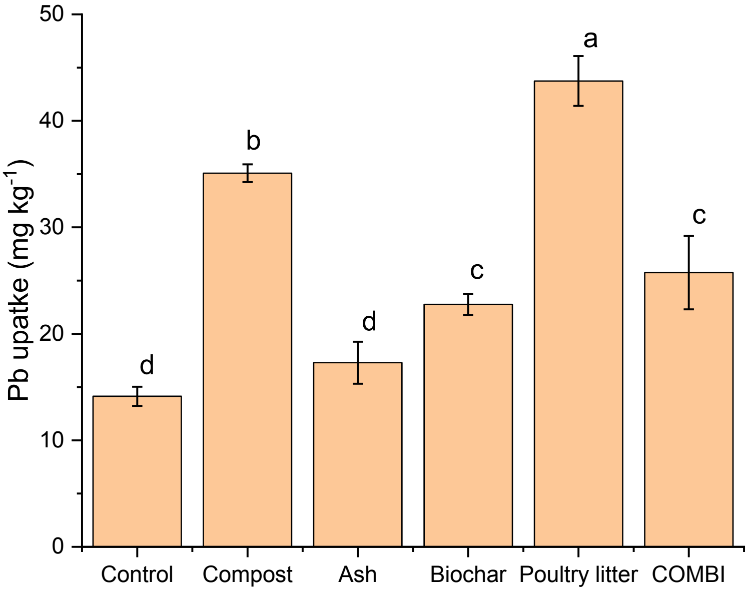

Fig 6. Effect of organic amendments on plant uptake Pb of *Brassica napus* in Pb contaminated soil

4.6 Effect of organic amendments on soil base cation

The impact of modified organic amendments significantly enhanced soil base cation in B. *napus* (Fig.7). The results indicated that soil base cation significantly increased in application of compost, poultry litter and co-compost biochar compared to control. The application of ash and biochar also enhanced soil base cation compared to control.

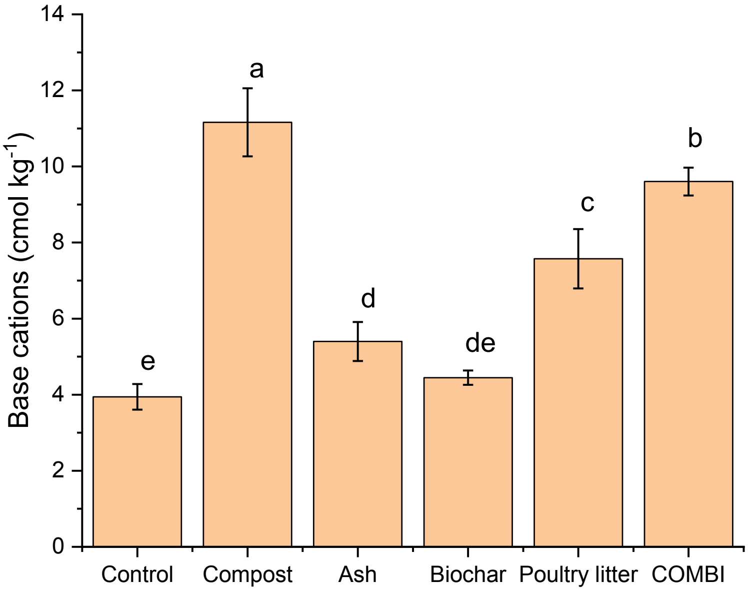

Fig 7. Effect of organic amendments on soil base cation of *Brassica napus* in Pb contaminated soil

4.7 Effect of organic amendments on soil pH

There is observed a significant difference in soil pH when modified organic amendments is applied (Fig 8). The results of this study showed that the highest value observed where compost, poultry litter and co-compost biochar was applied. The highest value was also found in ash and biochar application compared to control.

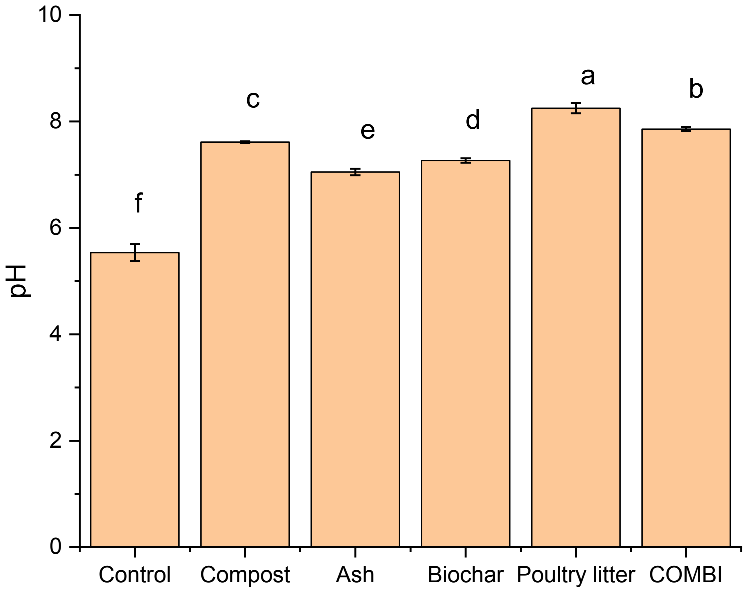

Fig 8. Effect of organic amendments on soil pH of *Brassica napus* in Pb contaminated soil

4.8 Effect of organic amendments on soil Organic Matter (OM)

The application of modified organic amendments resulted in a notable alteration in the amount of OM (Fig 9). The results of this study showed that the highest value observed where compost, poultry litter and co-compost biochar was applied. The application of ash and biochar significantly contributes to changes in soil organic OM compared to control.

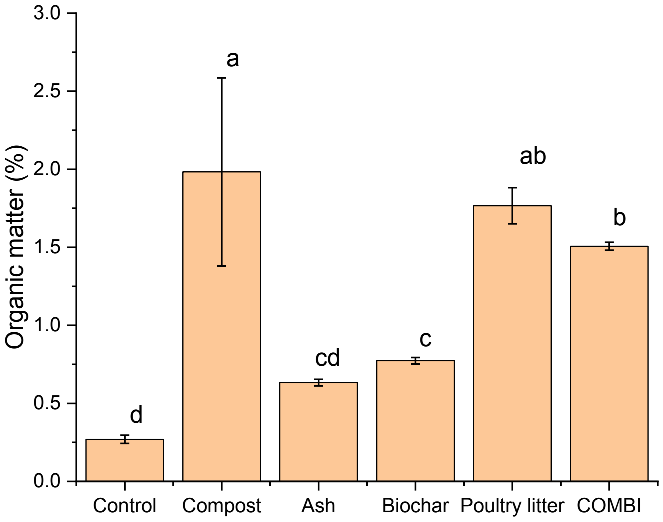

Fig 9. Effect of organic amendments on soil OM of *Brassica napus* in Pb contaminated soil

4.9 Effect of organic amendments on soil CEC

It measures the number of cations that can be held on the surfaces of soil particles, generally. Positively charged atoms or molecules can interact with other positively charged particles in the soil by way of the negative charges on their surfaces. The soil's water surrounding it. Therefore, a plant's benefit increases with its CEC. So, the higher the CEC, the more the plant benefited. According to this theory, the application of organic amendments produced CEC that was more beneficial.

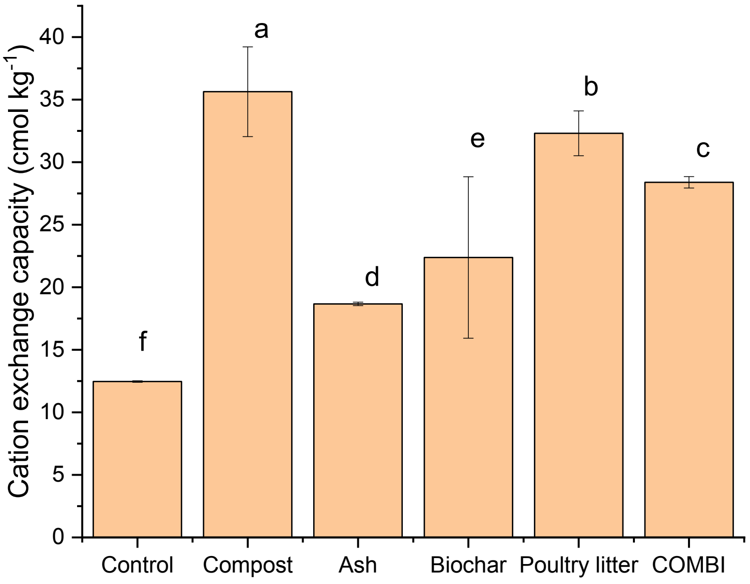

Fig 10. Effect of organic amendments on soil CEC of *Brassica napus* in Pb contaminated soil

The results of this study showed that the highest value observed where compost, poultry litter and co-compost biochar was applied (Fig 10). The highest value was also found in ash and biochar application compared to control.

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was carried out in Research Field 1 of the Department of Soil Science at Hajee Mohammad Danesh Science and Technology University, Dinajpur. Lead is one of the most toxic metals found in the environment. Plants have been shown to exhibit a variety of hazardous symptoms when exposed to excessive lead in the soil. Phytoremediation is the extraction or stabilization of heavy metals in soil using plants. Phytoremediation is a low-cost, environmentally acceptable substitute for traditional physical and chemical remediation techniques. The purpose of this study was to investigate the altered soil chemical properties (soil pH, OM, cation exchange capacity, Electrical conductivity, Base cation Ca, Mg, N, P, k) due to application of compost, biochar, ash, poultry litter and co-compost biochar influence phytoremediation of Pb contaminated soil. The treatments were a) control with 200mg Pb, b) Pb contaminated soil with compost (10%), c) Pb contaminated soil with ash (10%), d) Pb contaminated soil with biochar (10%), e) Pb contaminated soil with poultry litter (10%), f) Pb contaminated soil with co-compost (10%) and replicate three times in a completely randomized design.

The present investigation is designed to evaluated the potentials of Pb phytoextraction from artificially polluted soil by *B. napus* and investigated the influence of organic amendments on enhanced Pb accumulation. In a Pb-contaminated environment, *Brassica napus* grows and survives better with the addition of compost and poultry litter. Both the total amount of P accessible in the plant and the plant height of *B. napus* were greatly boosted by compost and poultry litter. The overall quantity of N available in the soil was increased by the application of compost, ash, and co-compost biochar. Compost, poultry litter, and co-compost biochar treatment had the highest Pb uptake. Applying compost, poultry litter, and co-compost biochar resulted in the highest activity of soil nutritional element supplies (base cations Ca, K, Na, and Mg). The pH of the soil was greatly raised by applying compost, co-compost charcoal, ash, and chicken litter. Additions of compost and hen manure improved soil organic matter (OM). The cation exchange capacity (CEC) of soil was improved considerably by compost, poultry litter, and co-compost biochar.

Consequently, the obtained result showed that the most beneficial option for the treatment of Pb contaminated soil phytoremediation was the application of organic amendments poultry litter > compost > co-compost biochar (COMBI) > biochar > ash.

This study demonstrates that the synergistic technique of applying organic amendments with accumulators to repair Pb-contaminated environments is both feasible and promising.

Recommendation

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. To examine the findings and determine the effects of compost and biochar on Pb contaminated soil phytoremediation, more pot and field-level research will be required.
2. For further research work, other species can be used instead of mustard to determine the effects of compost and biochar influence phytoremediation on Pb contaminated soil.

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APPENDIX

Appendix I: Experimental Photo

Fig. Pot set up

Fig. Seed sowing

Fig. Seedling stage

Fig. Thinning

Fig. Harvesting

Fig. Chemical Analysis