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ALONE AND COMBINED APPLICATION OF PRESS MUD COMPOST AND FULLER EARTH FOR ABATING Pb AND Cd AND ENHANCE SORGHUM GROWTH IN POLLUTED SOILS

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The aim present work was to examined the alone and combined impact of press mud compost and fuller earth at 0.5 and 1 % dosage on immobilization of Pb and Cd in Sharafi Goth and Malir polluted soils and reduce their uptake by sorghum plant. The results revealed that sorghum dry biomass yield was observed by 41.47 and 58.8 % with press mud compost (PMC) 1 % + fuller earth (FE) 1 % in Sharafi Goth soil and in Malir polluted soils than control. The immobilization of Pb was observed by 88.0 and 93.52 % with PMC 1 % + FE 1 %, and Cd was immobilized by 90.36 with PMC 1 % + FE 1 % and 78.0 % with PMC 0.5 % + FE 0.5 % in Sharafi Goth and Malir polluted soils than control. The uptake of Pb and Cd in shoot and root by sorghum was reduced in both soils with application additives. The studied amendments increased the soil chemical properties such as electrical conductivity (EC), pH, cation exchange capacity (CEC), organic matter (O.M) and $CaCO_3$ than control soil. The results of redundancy analysis showed that soil O.M had positive correlation with plant dry biomass, whereas EC, pH, CEC, O.M and $CaCO_3$ showed negative correlation with Pb and Cd in soil and Pb and Cd in plant soot and root biomass. The results of present study indicated that press mud compost alone and in combined form shown positive impact on plant growth, immobilize Pb and Cd in both soils and reduced their uptake by sorghum plant. Future long-term field experiments must be carried out in multi-metals polluted soils and cultivate different genotypes.

Keywords: press mud; fuller earth; pollution control; sorghum production; soil health.

INTRODUCTION

Soil contamination with toxic metals (TMs) has raised concern since recent decades, due to its negative impacts on soil health, environment and bioaccumulation in the food chain (Kumar et al., 2019; Yadav et al., 2023). TMs contamination of soil is a result of both anthropogenic and natural activities (Khan et al., 2010). Soil is the primary source of TMs from various sources, the main source of food contamination is human activities. Human health is exposed to direct or indirect risks through the food chain (Zayna et al., 2022).

Lead (Pb) is a quite immobile in the soil system, and non-essential for living beings (Collin et al., 2022). The contamination of Pb in soil can consequence from several anthropogenic activities, such as Pb-based paint, gasoline with tetraethyl Pb, pesticides, firing ranges, coal burning, mining, waste incineration, smelting untreated industrial/domestic effluent (Kumar et al., 2022). Burki, (2020) reported that approximately 815 million children globally have high blood lead levels >5 μg/dL according to current Centre for Disease Control and Prevention (CDC) standard values. It shares nearly 10 % of total pollution produced by TMs. Plants have been found to have an impact on their metabolic functions, growth, and photosynthetic activity. The excess accumulation Pb in the plant roots can lead to a 42 % reduction; especially root vegetables such as carrots and sweet potatoes may contain the maximum Pb contents (Shahid et al., 2015). The adsorption of Pb in the roots is detected in several species of plants. The absorbed Pb is stored in the roots, and only a small portion is transported to the aerial parts of the plant (Kumar et al., 2017). Cadmium (Cd) is a highly mobile and non-essential metal for living organisms, due to continuous application of P-rich fertilizer, industrial activities, dyes, Cd containing batteries, electroplating, combustion of crude oil, paints, untreated waste water and agricultural practices are the main sourced of releasing Cd in the agriculture soil-plant system (Yang et al., 2023). Chaney, (2010) reported that the high content of Cd in the soil poor organic matter can enhance Cd uptake by plants. They decrease the growth and development of plants even at low concentrations of Pb and Cd (Muhammad et al., 2009; John et al., 2009). Therefore, restoration is necessary to improve the negative influences caused by the TMs in the soil and reduce their accumulation of plant with the application of low cost and environmental friendly additives under in-situ condition (Saini et al., 2021).

In recent years, many restoration approaches have been applied to address the issue of soil contamination, such as physical remediation, chemical remediation, bioremediation, nano-bioremediation and phytoremediation (Mukhopadhyay et al., 2022). At present, in-situ stabilization approaches are much preferred, because of their economical, feasible, easily applicable and less energy requirements (Lwin et al., 2018). This technology relies application additives either organic and/or inorganic solid form to convert a soluble form of TMs in less or insoluble form in soil-plant system (Pi et al., 2017). In this technology, the TMs are not removed from the site, but rather transformed into forms less biologically accessible (Pi et al., 2017). Al Jabri et al. (2022) reported that heavy metal toxicity can be diminished by decreasing their solubility using organic and inorganic amendments. Plant uptake of the TMs can be decreased by several low-cost inorganic and organic matter-rich

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soil amendments (Bolan & Duraisamy, 2003), although increasing soil fertility (Głąb et al., 2018).

Press mud is a residue organic waste material manufactured from of sugarcane industries that creates the problem of contamination in the surrounding of sugar mills on its accumulation (Bhosale et al., 2012). It is a soft, porous, spongy, blackish in colour has great potential to improve soil properties due to rich in nutrients and organic matter, organic fertilizer and restoration of organic/inorganic pollutants and mitigates the carbon emissions (Eid et al., 2021). Press mud includes hormones, enzymes, auxins, incorporating plant growth regulators, and vitamins, which improves growth of a plant by enhancing soil aeration, robust root development. It enhances soil aeration, porosity, organic matter content, water retention capacity, and the overall nutrient status of the soil (Barry et al., 2001).

Fuller earth is a hydrated solid material that has potential to adsorb pollutants in the soil medium due to greater pore space and high cation exchange capacity and huge surface area of particles (Bahadur et al., 2022). It is a sedimentary clay, which is rich in magnesium oxide, having bleaching and clarifying petroleum applications along with abilities to refine edible oils. It is a natural absorbent, which makes it valuable for heavy metal removal from wastewater to inhibit TMs toxicity to humans if released untreated (Oubagaranadin et al., 2007). In the former study, Oubagaranadin et al. (2007) applied fuller's earth as adsorbent for removal of mercury from aqueous solutions. Beltran-Perez et al. (2020) assessed the toxicity of fuller earth contaminated with dielectric oil is evaluated before and after treatment. Mise et al. (2020) evaluated that impact of fuller's earth on removal of Zn from laterite soil and black cotton soil. Bahadur et al. (2022) assessed that impact of fuller earth, rock phosphate, and biochar on remediation of Cu, Zn, Fe, and Cd in heavy and less polluted soil and reduce their uptake by maize plant. Kandil et al. (2023) studied the efficacy of hybrid composite of fuller's earth, aluminium silicate and chitosan on removal of Pb(II) and Cu(II) in aqueous solution.

Akhtar et al. (2019) assessed that impact of press mud compost (2 %) along with rock phosphate 1 and 2 % for stabilization of Cd in Sandy polluted soil. Mushtaq et al., (2021) evaluated that potential of plant growth promoting rhizobacteria (PGPR) and press mud 2 % on the bioavailability of Cr in soil reduce their uptake by okra plant. Hussain et al. (2022) revealed that the potential of press mud, poultry waste, and farmyard manure for remediation of Cd, Co, Cr, Cu, Pb, Zn, Fe and Mn in acidic polluted soil. Dotaniya et al., (2023) applied press mud 0, 2.5, 5 and 10 g/kg and Pb 0, 100, 150, 300 mg/kg for remediation of Zn, Cu Mn and Fe in polluted soil. Up-to-date no any research work was performed to assess the impact of press mud compost (PMC) alone and combined with fuller earth (FE) on stabilization of Pb and Cd in polluted soil and reduces their uptake by sorghum plant.

The main objective of the present study was to assess the efficacy of press mud compost and fuller earth alone and mixed at 0.5 and 1 % on the stabilization of Pb and Cd in Sharafi Goth and Malir polluted soils, and reduce the uptake of Pb and Cd in the root and shoot by sorghum plant. It was hypothesized that alone and combined impact of press mud compost and fuller earth may be remediated the Pb and Cd in polluted soils.

MATERIALS AND METHODS

Study area and soil collection

In the present work, Sharafi Goth and Malir polluted soils were used in this investigation, aiming to remediate pollution for safe crop production (Figure 1).

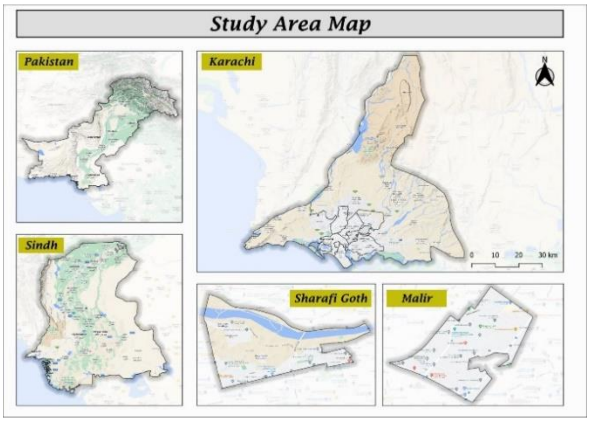

Figure 1. GPS Map of Jos metropolis

These soils are polluted with metals, due to discharge of untreated industrial and city effluent. Due to lack knowledge and proper awareness to remediate these risky areas with application of low cost and environment friendly additives. Soil samples were collected from (0 – 15 cm depth) from top layer of contaminated cultivated field. All the soil sample in bulk condition were air dried and sieved through 2 mm for soil texture, electrical conductivity (EC), pH, soil organic matter (O.M), cation exchange capacity (CEC) and $CaCO_3$, whereas 0.15 mm nylon sieve was used for test the Pb and Cd in soil. The polluted soils samples were well mixed and homogenized before filling the pots. The basic properties of soils and press mud compost and fuller earth are indicated in Table 1.

Table 1. Basic characteristics of soils, press mud compost and fuller earth

Characteristics	Sharafi Goth soil	Malir soil	Press mud compost (PMC)	Fuller earth (FE)
Sand, %	65.45	60.20	-	-
Silt, %	16.32	10.19	-	-
Clay	18.23	29.61	-	-
Textural class	Sandy loam	Sandy clay loam	-	-
EC, dS m^{-1}	0.91 ± 3	1.17 ± 0.1	4.32 ± 0.8	1.69 ± 0.2
pH	8.9 ± 0.6	7.83 ± 0.3	7.4 ± 0.5	6.92 ± 0.4
O.M, %	0.87 ± 0.1	0.89 ± 0.8	41.2 ± 0.1	-
CEC	12.1 ± 0.9	16.9 ± 0.4	84.2 ± 0.2	113.4 ± 0.4
Lime $CaCO_3$, %	7.9 ± 0.3	10.79 ± 0.5	-	-
Pb, mg/kg	107.4 ± 0.6	122.14 ± 0.7	0.001 ± 0.2	0.006 ± 0.4
Cd, mg/kg	0.82 ± 0.2	0.89 ± 0.1	0.02 ± 0.3	0.004 ± 0.2

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Pot experiment

A pot experiment was performed to investigate the impact of press mud compost and filler earth alone and in combined form to stabilize that Pb and Cd in Sharafi Goth and Malir polluted soils and reduce their accumulation by sorghum as test plant. Because, sorghum plant has potential to grow very fast, enough biomass for testing metals and, also having long root to accumulate elements by root hairs. Approximately, 1 kg in both polluted was placed in each plastic pot. According to study plan 0.5 to 1 % dose (w/w) of press mud compost and filler earth at < 1 mm sieve size was amended polluted soils except control treatment. Furthermore, the detail of experimental treatments and dose are indicated in Table 2.

Table 2. Treatment code and dose

Treatments	Code	Dose
TI	Ck	Soil 1 kg
T2	Press mud compost	0.5 %
T3	Press mud compost	1 %
T4	Fuller earth	0.5 %
T5	Fuller earth	1 %
T6	Press mud compost + Fuller earth	0.5 % + 0.5 %
T7	Press mud compost + Fuller earth	1 % + 1 %

The pots were irrigated with distilled water, and the field capacity was adjusted 65 % and all the pots were incubated for 15 days aiming to chemical reaction between metals and additives. About 8 healthy seeds of sorghum were sown in the each pot, and the moisture was kept about 80 % during the germination time. All the plants were thinned and left 3 healthy plants in each pot for assessing the potential of additives on plant growth and metals in soil-plant system. All the sorghum plants were harvested after 45 days of sowing. Plants were uprooted from each pot and carefully washed with distilled water and cleaned with soft tissue papers. The roots were separated from shoot biomass and dried in the oven for 3 days at 65 °C. After drying all the plants were ground in the small electric mill and dry biomass of root and shoot was noted, furthermore all the dried plant sampled were stored in polyethylene bags for analysis of Pb and Cd in the shoot and root by plants.

Soil and material analysis

The soil texture was determined by using the Mastersizer 2000E (Malvern, UK) laser diffractometer Sochan et al. (2012). The textural class of both soils was indicated in (Figure 2). The pH and EC were determined in a 1 : 2 (w/v) suspension by a digital pH meter for both soils, press mud compost and fuller earth (Kwon et al., 2012). CEC soils and amendments were tested according to USEPA Method 9080 (2019). Soil organic matter (O.M) was tested by an oil bath heated $K_2Cr_2O_7$ volumetric method (Bao, 2000). Lime $CaCO_3$ was analysis by the calcimeter method (Burt 2004). The total concentration of Pb and Cd in both soils and fuller earth were measured by digesting with aqua regia and analysed by Perkin Elmer Atomic Adsorption Spectrophotometer (Pin AAcle 900F, China) according to (Ure, 1990).

Plant analysis

Approximately 0.5 g of dried sorghum root and shoot biomass and 0.2 g of press mud compost was digested on a hot plate by adding a mixture of acids (HNO_3 : $HClO_4$ at ratio 2 : 1), after digestion, Pb and Cd content in plant biomasses was tested by using atomic absorption spectrometry (AAS, PerkinElmer Analyst™ 800) according to (Jones and Case 1990; Zhu et al., 2018).

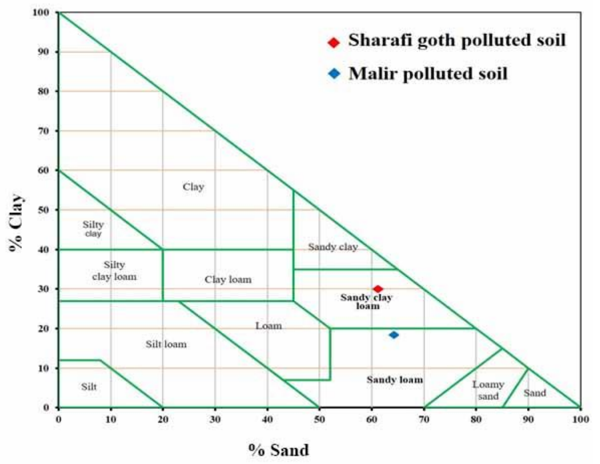

Figure 2. Textural class of studied soils

Statistical analysis

The data was statistical analysed by using Statistics 8.1 version. The data of 3 replicated was analysed by one-way analysis of variance (ANOVA) at significance level of $p < 0.05$ to assess the difference between three replications of treated samples. All the data graphs were made by using Origin Pro 8.1 version. Redundancy analysis was used to assess the relationship between studied parameters via CANOCO-5 version.

RESULTS AND DISCUSSION

Effect of amendments on plant growth and soil chemical properties

The application of press mud compost and fuller earth alone and in combined showed positive impact on sorghum growth. The highest dry biomass of sorghum (root and shoot) was noted in 41.47 and 58.8 % with PMC 1 % + FE 1 % in Sharafi Goth soil and in Malir polluted soils than control. It could might be due to an increase of O.M from press mud compost which was responsible for an increase of plant biomass (Figure 3 a, b). Sarangi et al., (2008) stated that press mud has potential to promote plant growth and restore the degraded polluted soils. Sabir et al. (2013) revealed that maize growth was increased by application of press mud. Bahadur et al. (2022) reported that the maize growth was increased in heavily polluted soil with the application of fuller earth. It was observed that the soil EC was increasing application of amendments, whereas the maximum soil EC was observed ranging from 0.94 to 1.46 EC dS m^{-1} with the application of PMC 1 % + FE 1 % in Sharafi Goth polluted soil, and 1.16 to 1.77 EC dS m^{-1} with the addition of PMC 1 % + FE 1 % in Malir polluted soil (Figure 3 c, d). The soil pH was increased from 8.10 and 8.18 with the addition of PMC 1 % + FE 1 %, whereas PMC 1 % as amendment reduced the pH values from 8.10 to 7.41 in Sharafi Goth polluted soil. Similarly, the pH value was increased from 7.85 to 8.18 with incorporation FE 1 %, but the application of PMC 1 % reduced the pH values ranging from 7.85 to 7.24 in Malir polluted soil (Figure 3 e, f).

The CEC content was increased by 70.7 % and 79.9 % with the application of PMC 1 % + FE 1 % in Sharafi Goth and Malir polluted soils (Figure 4 a, b). The concentration of O.M was increased up to 47.02 and 36.6 % by application of PMC 1 % + FE 1 % in Sharafi Goth and Malir polluted soil (Figure 4 c, d). The concentration $CaCO_3$ was increased up to 3.55 and 22.58 %

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with PMC 1 % + FE 1 % as amendment in the Sharafi Goth and Malir polluted soils (Figure 4 e, f). Bahadur et al. (2022) stated that EC, pH and O.M were enhanced with the addition of fuller earth in contaminated soils from Korangi industrial area. James and Pandian (2016) examined that 0.25 % press mud was ideal in augmenting the strength of the lime-stabilized soil at the initial consumption of lime (ICL). Asghar and Afzal (2020) found that application of press mud compost at 25 t ha^{-1} increased the O.M content in the soil. Brady (1990) reported that soil O.M boosts granulation, rises cation exchange capacity (CEC) as a result that can increases adsorbing capacity about 90 % of cations such as Ca^{2+}, Mg^{2+} and K^{+} during the decomposition. Azhar et al. (2019) stated that application press mud at 2 % dose significantly increased the CEC proportion in soil.

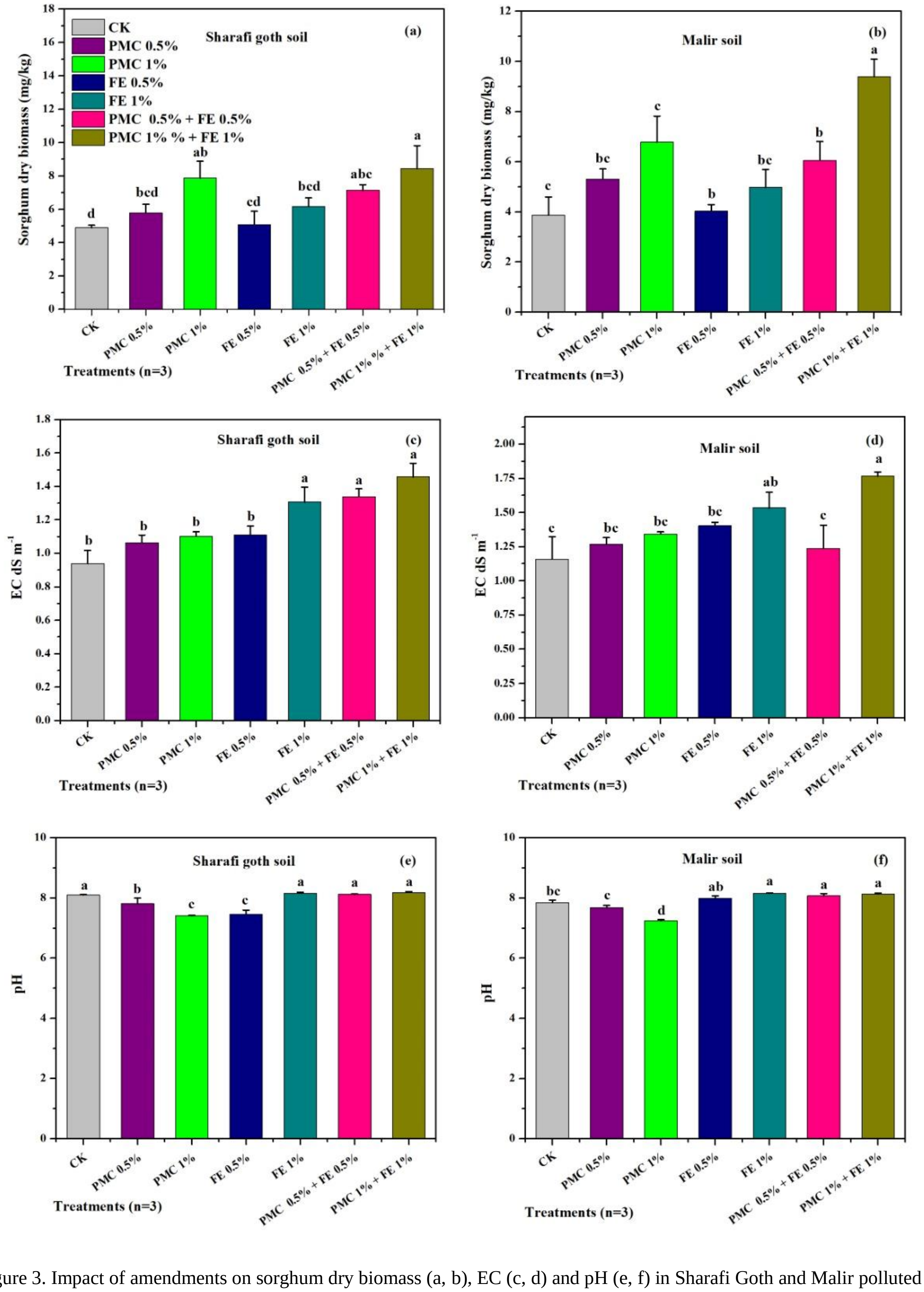

Figure 3. Impact of amendments on sorghum dry biomass (a, b), EC (c, d) and pH (e, f) in Sharafi Goth and Malir polluted soils

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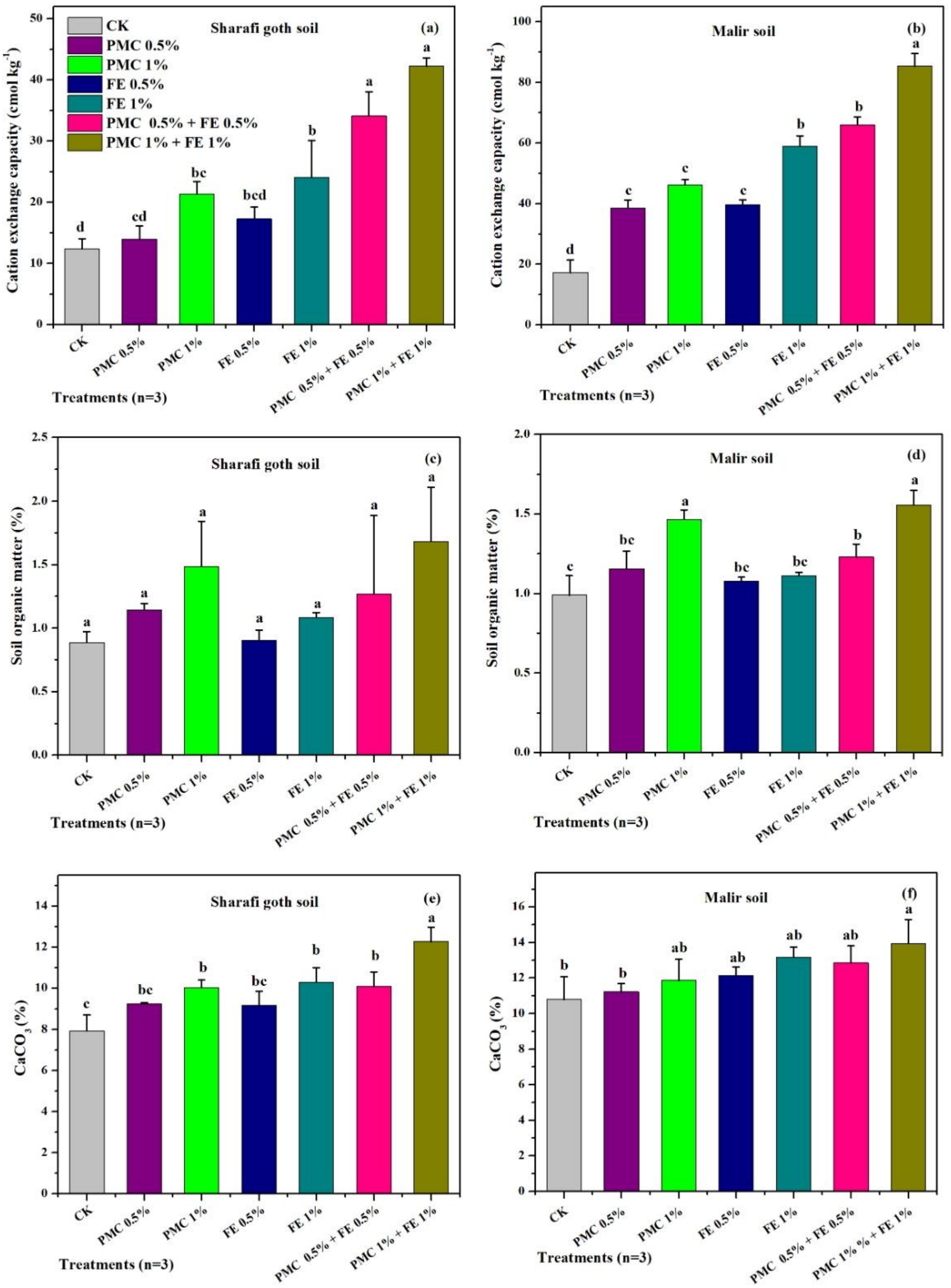

Figure 4. Impact of amendments on CEC (a, b), O.M (c, d) and $CaCO_3$ (e, f) in Sharafi Goth and Malir polluted soils

Effect of amendments on Pb and Cd in soil

Compared with the control treatment, the application of soil amendments significantly immobilized the Pb and Cd in Sharafi Goth and Malir polluted soil. The maximum immobilization of Pb was observed by 88.0 and 93.52 % with PMC 1 % + FE 1 % in Sharafi Goth and Malir polluted soil than control (Figure 5 a, b). The stabilization of Cd was noted by 90.36 with PMC 1 % + FE 1 % in Sharafi Goth polluted soil, and 78.0 % with PMC 0.5 % + FE 0.5 % in the Malir polluted soil than control. It was observed that the combined application of press mud compost and fuller earth was found to be highly effective for immobilization of Pb and Cd in both soils than control soil (Figure 5 c, d). Azhar et al. (2019) observed that the immobilization of ABDTPA-Cd in soil was observed with application press mud at 2 % dosage than control. Raza Altaf et al. (2021) reported that application of press mud 2 % dose enhanced immobilization of Pb in soil and promote sunflower growth. Bahadur et al. (2022) found that the immobilization of Cd in heavily and less polluted soils with application of fuller earth.

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Effect of amendments on Pb accumulation in the shoot and root by sorghum

The uptake of Pb in the sorghum shoot was reduced up to 89.6 and 81.5 % with application of PMC 1 % + FE 1 % in Sharafi Goth and Malir pollutes soils (Figure 5 e, f). The accumulation of Pb in sorghum root was decreased by 83.6 % with PMC 1 % + FE 1 % in Sharafi Goth polluted soil, and 74.9 % with FE 1 % in Malir polluted soil Figure 6 a, b. It was noted that combined application of PMC 1 % + FE 1 % had shown highly effective for reducing Pb in the shoot and root by sorghum plant. Haider et al. (2023) noted that application of press mud at 10 g/kg significant reduced the uptake of Pb by wheat plants.

Effect of amendments on Cd in the shoot and root by sorghum

The absorption of Cd in soot by sorghum was reduced by 80.48 and 96.22 % with addition of PMC 1 % + FE 1 % in Sharafi Goth and Malir polluted soils as compared with control treatment (Figure 6 c, d). The accumulation of Cd in the root by sorghum was decreased by 90.0 and 89.8 % amended with PMC 1 % + FE 1 % in Sharafi Goth and Malir polluted soils as compared with control Figure 6 e, f).

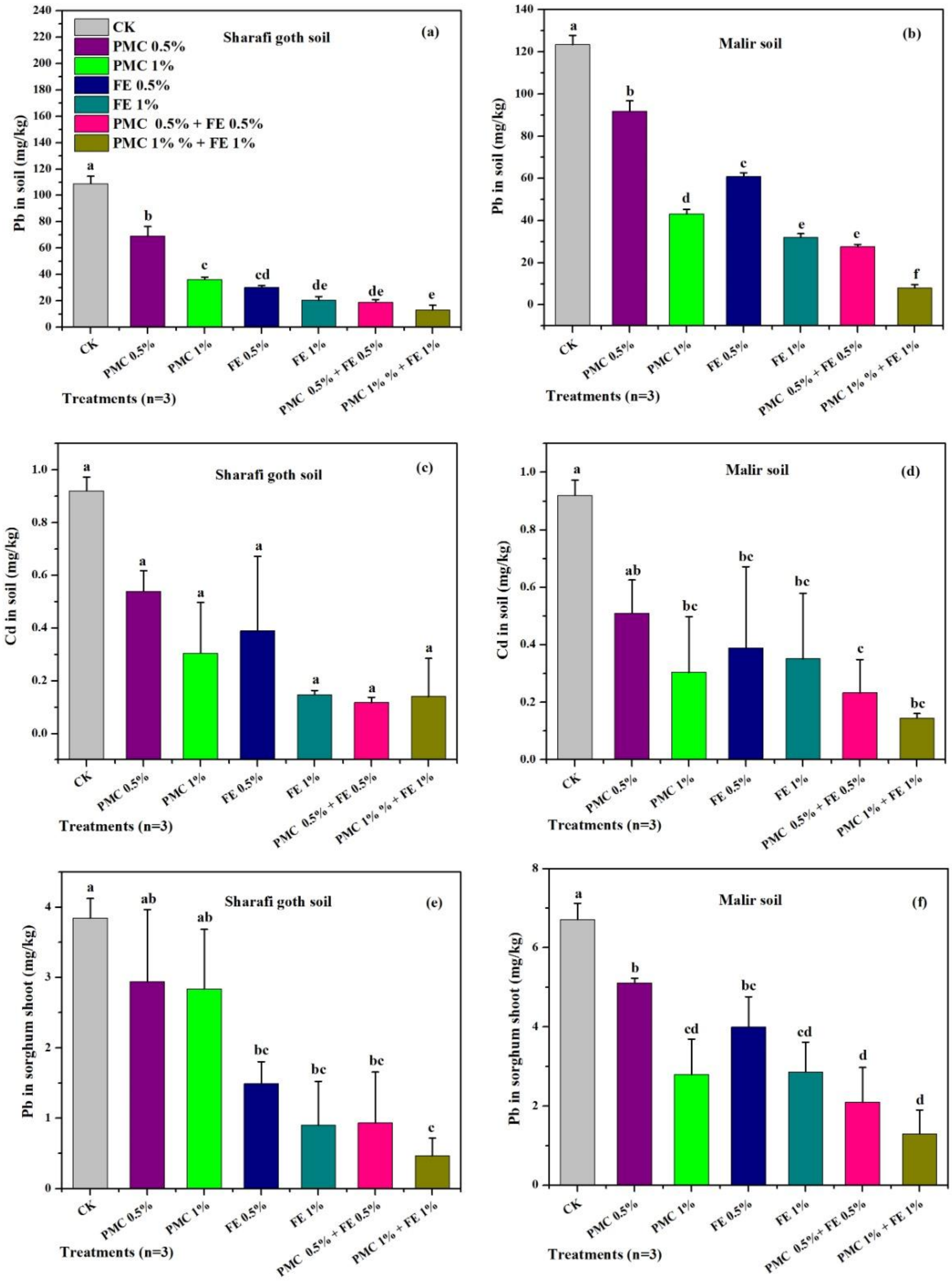

Figure 5. Impact of amendments on Pb in soil (a, b), Cd in soil (c, d) and Pb in sorghum shoot (e, f) in Sharafi Goth and Malir polluted soils

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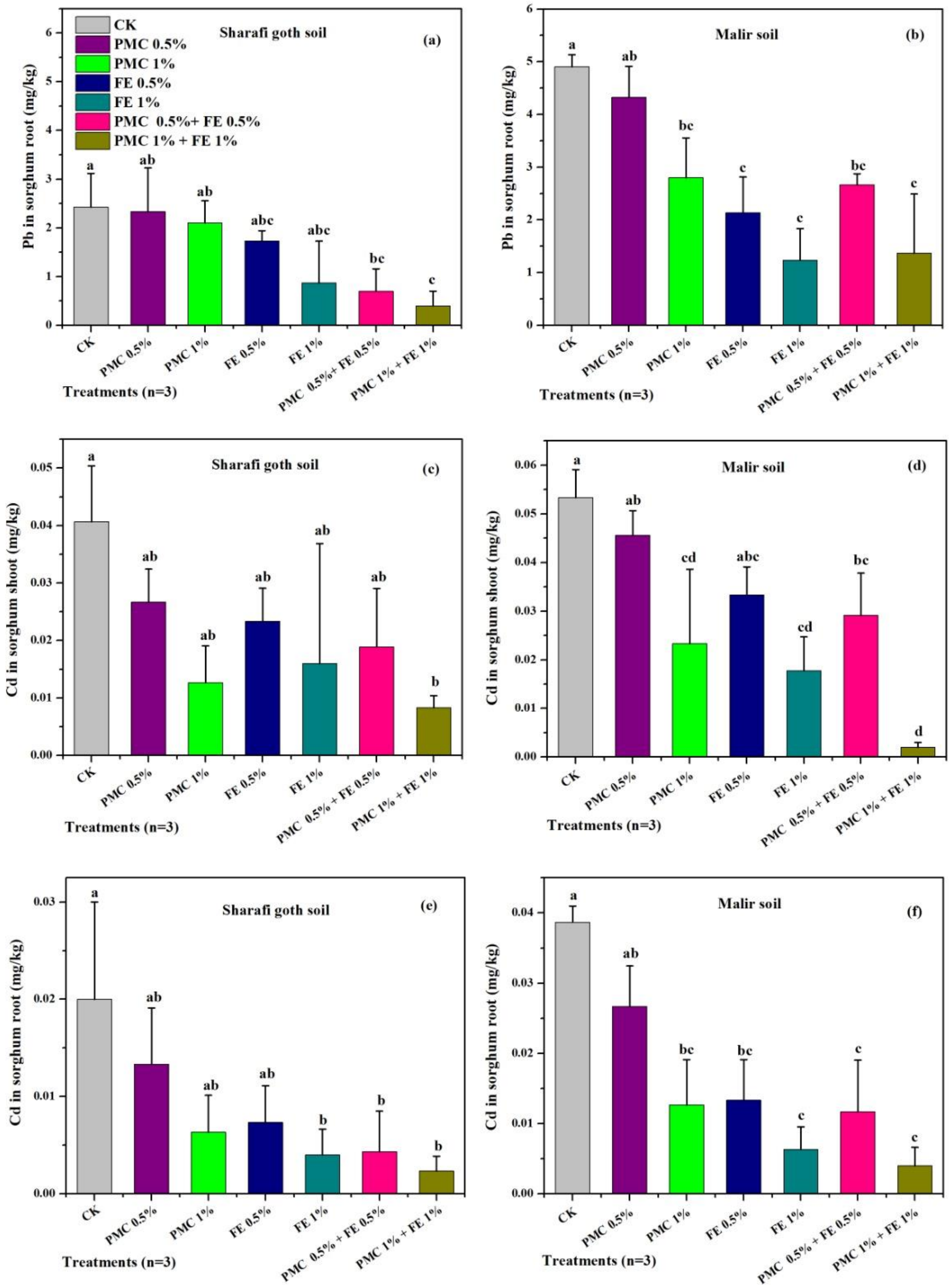

Figure 6. Impact of amendments on Pb in sorghum root (a, b), Cd in sorghum shoot (c, d) and Cd in sorghum root (e, f) in Sharafi Goth and Malir polluted soils

The above results clearly indicated that the application of PMC 1 % + FE 1 % was found to be highly effective for reducing Cd accumulation in the shoot and root by sorghum as compared with other treatments. Azhar et al. (2019) observed the reduction of Cd in soil reduce their accumulation in the root and shoot by rice and wheat plants with application of press mud. Bahadur et al. (2022) applied fuller earth in the polluted soil and found the reduction of Cd by maize plants.

Redundancy analysis

The redundancy analysis was used between dry shoot and root biomass of sorghum, EC, pH, CEC, O.M, $CaCO_3$, Pb and Cd in shoot and root by sorghum, and Pb and Cd in Sharafi Goth and Malir polluted soils (Figure 7). The data revealed studied parameters can explained 91.69 %, which indicated that sorghum dry biomass has positive correlation with soil O.M. In addition, soil chemical properties EC, pH, O.M, CEC and

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$CaCO_3$ were negatively correlated with Pb and Cd in shoot and root by sorghum, and total Pb and Cd in Sharafi Goth polluted soil. It was observed that the studied parameters can explained 95.9 % total variability of Malir polluted soil. The O.M had shown positive correlation with sorghum dry biomass, but the negative correlation of EC, pH, CEC, O.M, and $CaCO_3$ was found with Pb and Cd in shoot and root by sorghum, and total Pb and Cd in Malir polluted soil.

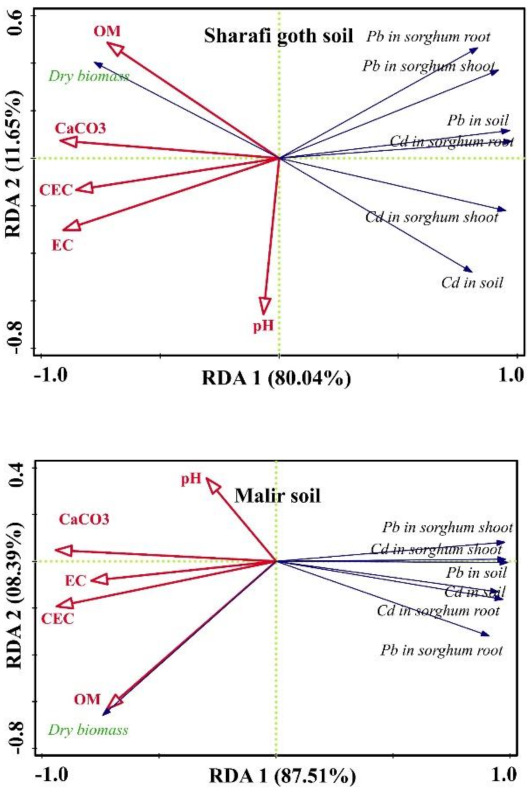

Figure 7. Redundancy analysis of studied parameters in Sharafi Goth and Malir polluted soils

CONCLUSION

It was concluded that the sorghum dry biomass was increased in combined application of PMC 1 % + FE 1 % in Sharafi Goth and Malir polluted soils. The application of press mud and fuller earth alone and combined significantly increased the soil chemical properties such as EC, pH, O.M, CEC and $CaCO_3$ Sharafi Goth and Malir polluted soils. The maximum immobilization of Pb and Cd observed with combined application of press mud compost and fuller earth in Sharafi Goth and Malir polluted soils and reduced that uptake of Pb and Cd in the shoot and root by sorghum plant. The finding of present study suggested that combined application of press mud compost and fuller earth to be highly effective for enhance plant growth, Pb and Cd in soil and reduce their uptake by plant. Future studies must be focus on impact of these studied amendments on microbial community, plant physiology, enzymatic activities in soil and plant, metal fractions, mechanism and different plant genotypes under long-term field conditions.

Declaration of conflicting interest

The authors declare no competing interests.

Contributions

Conceptualization: A.H.L.; Data curation: A.H.L.; Formal Analysis: S.R.A.; Funding: M.M-H.; Acquisition: A.A.; Investigation: M.M-H.; Methodology: I.S.; Project: A.H.L.; Administration: A.H.L.; Resources: M.T.M.; Administration: A.H.L.; Software: A.H.L., S.B.; Supervision: A.H.L.; Validation: W.A.S.; Visualization: M.T.M.; Writing – original draft: A.H.L.; Writing – review & editing: A.H.L., S.R.A.

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Additional information

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