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Original article

The role of different organic amendments to improve maize growth in wastewater irrigated soil

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ABSTRACT

Wastewater irrigation in croplands is recognized as one of the major threat, seriously affecting soil health and sustainable agriculture around the globe. Heavy metals presence especially cadmium (Cd) in wastewater irrigated soils is posing serious physiological and morphological disorder in plants due to its highest mobility. Therefore, metals mobility in wastewater irrigated soils can be curtailed through eco-friendly and cost effective organic soil amendments compost (CP), press mud (PM) and moringa leaf extract (ME) at 3% rate that eventually reduces its translocation from polluted soil to plant. This study explored the possible effects of various types of organic soil amendments on Cd phytoavailability in wastewater degraded soil and its subsequent accumulation in maize tissues. Maize plant was grown in Ghazi University as a test plant and Cd accumulation was recorded in its tissues, translocation from root to shoot, chlorophyll contents, plant biomass, yield and soil properties (pH, NPK, OM and Soluble Cd) were also examined. Results revealed that the addition of amendments significantly minimized Cd mobility in soil by 45.8%, 23% and 19.4% when CP, PM and ME were added at 3% over control. Comparing the control soil, Cd uptake effectively reduced via plants shoots by 33.3%, 27.7% and 19.4% when CP, PM and ME. In addition, NPK were significantly increased among all the added treatments in the soil-plant system as well as improved chlorophyll contents relative to non-treated soil. The Current study suggested that among all the amendments, compost at 3% rate performed well and can be considered a suitable approach for maize growth in polluted soil.

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1. Introduction

Cadmium is naturally present in earth crust as a trace element, while its concentration varies because of its solubility and mobility (Shahid et al., 2018). Human beings and animals are greatly exposed to heavy metals because of the contaminated food chain (Xiong et al., 2016). Cd is recognized as a serious global concern and its concentration in industrial and sewage wastewater, and drinking water exceeds the permissible limits (0.003 mg L⁻¹) (Shahid et al., 2018). Wastewater irrigation containing heavy metals especially Cd to the farmlands has become a serious environmental

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threats because of food chain deterioration (Bashir et al., 2020a; Bashir et al., 2020b; Bashir et al., 2020c). Cd is highly reactive and mobile, which has the potential to influence the plants growth.

Accumulation of metals in cultivated soils could lead to deteriorate the soil health and enhances the Cd uptake in plant, which directly effects food safety and quality (Bashir et al., 2020a; Bashir et al., 2020b; Bashir et al., 2020c; Bashir et al., 2019). Nowadays, various soil restoration strategies (physical, chemical and biological) are adopted in order to improve soil health and minimize food security risks (Liu et al., 2018). Additionally, the use of organic materials as a soil amendment could use as a practical and cost effective strategy to restore polluted soils through changing the heavy metals mobility and bioavailability (Bolan et al., 2014; Ueigwe et al., 2011). However, several research studies have shown that the organic based soil amendments (compost, biofertilizers, biochar and manure) are more effective to ameliorate the soil health and minimize the use of chemical fertilizer due to their less production cost (Bashir et al., 2019; Abbas et al., 2020).

Moringa (*Moringa oleifera* L.) that is also known as miraculous tree (evergreen), which is widely grown in tropical areas of Pakistan, having enough tolerance to drought and is easily available at low cost. It contains most important constituents including proteins, carbohydrates, fatty acids, vitamins, flavonoids and phenolic acids. It has a number of applications in the medical field, for example, anti-inflammatory, antihypertensive activity and analgesic, weight losses, etc. It has attained much attention by the researchers because of its environmental friendly usage. To some extent, it acts as a plants growth activator as well as reduces the drought and heavy metals stress on plants (Nouman et al., 2012). Previous study proposed by Ravikumar and Sheeja (2013) studied that Moringa seeds were used for wastewater treatment and effectively removed Cd, Cu, Cr and Pb from drinking water. Similarly, its seed ash was also used in the study conducted by Doobaradaran et al. (2015) for the removal of fluoride from aqueous solutions. Moringa seeds acts as a natural organic biosorbent for the stabilization of heavy metals (Araujo et al., 2013). It can be demonstrated that addition of moringa husks, pods, and seeds showed the noticeable removal of Pb(II) from contaminated water (Tavares et al., 2017).

Compost is organic carbon and nutrient rich organic material that can be used as a soil amendment to substitute the chemical fertilizers in agricultural production. The incorporation of compost prominently improves the physical structure and fertility status, microbial communities in degraded soils, improves crop biomass and promote crop growth (Calleja-Cervantes et al., 2015; Abbas et al., 2020). In a similar manner, it has the ability to act as biosorbent for the sorption of heavy metals from polluted soils and water (Anastopoulos et al., 2013). It has been demonstrated that the compost is a suitable candidate to minimize the risk of crop growth, yield and economic losses through ameliorating the soil properties and thereby, ensure the human health. (Bolan et al., 2014). Simantiraki and Gidarakos (2015) found that incorporation of compost effectively reduced the toxic elements from polluted water by 85–89% through chemical absorption.

Press mud is the by-product of sugarcane obtained from the sugar industry after the clarification process of sugarcane juice. Press mud is a dark brown, spongy and amorphous material containing sugar, fiber and coagulated colloids including soil particles, and mainly comprises of CaO, organic matter, nitrogen, phosphorus, potassium, calcium, sulphur in varying amounts (Khan et al., 2019). Chiu et al. (2009) demonstrated that addition of soil amendments such as press mud, poultry manure farmyard manure (FYM) and fish manure to Cr polluted soil. Results revealed that these amendments have potential to stabilize Cr in soil. It can be demonstrated that press mud had been recognized as the filter cake which can contribute to enhance the soil fertility status and can

create extra binding sites for the toxic metals adsorption and complexation (Khan et al., 2019). Press mud has the ability to buffer the soil pH and reduces the uptake of heavy metals. It contains functional groups like hydroxyl ions that play an important role in the adsorption of heavy metals (Lee et al., 2004; Mahmood, 2010), and is also considered a key source of NPK and carbon contents. Press mud is considered a key source of NPK and carbon contents (Khan et al., 2019). Sabir et al. (2013) confirmed that press mud incorporation as a soil amendment could help to improve soil health, structure and thereby, reduces the metals accumulation in plant tissues.

Maize (*Zea Mays* L.) belongs to Gramineae family and is recognized as one of the most important nutritious cereal crop that is also consumed by animals as a forage (Bashir et al., 2020a; Bashir et al., 2020b; Bashir et al., 2020c). It is widely grown all around the globe and has greater potential to uptake heavy metals. Particularly, this crop being the highest yielding cereal crop in the world has a significant importance in Pakistan. There is only little scientific knowledge is present about the effect of ME as a biofertilizer, compost and press mud on the growth, metabolic and antioxidant enzymes of plants. Thus, the comparative efficiency of compost, press mud and *M. oleifera* leaf extract was assessed for wastewater irrigated soil restoration as well as reducing the Cd stress on maize plant in calcareous soil condition. The prime objectives of the current study were: i) to evaluate the effect of compost, press mud and *M. oleifera* leaf extract on Cd solubility and maize growth in polluted soil and ii) to examine the efficacy of these soil amendments on soil and plant nutrients status.

2. Materials and methods

2.1. Soil and amendments

Soil samples were taken from productive land in the suburbs of Dera Ghazi Khan City, Pakistan that was irrigated with the wastewater of Manka canal. The polluted soil samples were gathered from the upper layer at 0–30 cm depth in 2019. The obtained soil was then shifted to green house for air drying about three days. After drying, soil samples were ground, stones and pebbles were removed and then the soil passed through a 2-mm sieve for pot study. Approximately 0.5 kg of the prepared soil was further ground and passed through 0.25-mm sieve for the basic physico-chemical characteristics of the studied soil (Table 1). In our previous study (Bashir et al., 2020a; Bashir et al., 2020b; Bashir et al., 2020c) explained that the studied soil of this area has more than 5 mg kg⁻¹ Cd which is greater than the proposed value of Cd (0.2 mg kg⁻¹) in Agricultural soils by Chinese environmental and quality standard for soils (GB15618-1995). Similarly, press mud was purchased from Fatima sugar mill for the current study. While the vegetables waste product derived compost was prepared in Ghazi university and used in current study (Table 1).

Additionally, Moringa leaf extract was prepared according to the method proposed by Valdez-Solana et al. (2015). For this purpose, moringa (*Moringa oleifera* L.) tree leaves were obtained from the local area of Dera Ghazi Khan, Pakistan. Then the collected leaves were rinsed with tap water to remove dust particles from leaves and dried under shade. After drying plant samples were preserved in freezer, then plant leaves were ground and the collected was filtered through Whatman filter paper. After filtration, the extract was stored at 4 °C for further chemical analysis. There are the followings selected properties were measured: moisture (82 mg); Protein (5.82 mg); Vitamin C (906 mg) and others were presented in (Table 1).

Table 1
Selected properties of soil, press mud (PM); Compost (CP) and Moringa leaf extract (ME).

Properties	Soil	Press mud	Compost	Properties	Moringa Leaf extract
pH	7.8	8.4	7.3	pH	6.8
EC	0.6	2.7	2.4	EC	0.2
OM (g kg ⁻¹)	0.08	0.3	14	Ca (mg/100 g)	5.32
Texture	silty clay			Mg (mg/100 g)	0.75
Total N (g kg ⁻¹)	0.2	3.6	9.4	P (mg/100 g)	0.84
Avail. P (g kg ⁻¹)	0.005	0.74	3.2	Na (mg/100 g)	0.21
Extractable K (g kg ⁻¹)	0.07	1.8	11.5	K (mg/100 g)	0.32
				Fe (mg/100 g)	0.03

2.2. Pot experiment

The maize growth experiment was performed to examine the influence of various kinds of organic soil amendments (compost, press mud and moringa leaf extract) at 3% application rates on maize growth and Cd accumulation in its tissues. The pot study was organized with the complete randomized design with their three replicates. The studied soil was amended with the following treatments; (1) Control (CK); (2) Compost (CP); (3) Press mud (PM); (4) Moringa leaf extract (ME) and each treatment had three replicates. Each pot (16 cm diameter and 18 cm height) had 4 kg soil and homogeneously mixed with their respective treatments. All the experimental units were irrigated with distilled water and kept their water contents at 70% water holding capacity and left them for 2 weeks for equilibrium. After 15 days, the sterilized Pioneer-1543 seeds were placed in each experimental unit. Each pot was fertilized with the basal dose of N (180 kg ha⁻¹ soil), P (120 kg ha⁻¹ soil) and K (90 kg ha⁻¹ soil) in the form of urea, Ca (H₂PO₄)₂, and KCl respectively. After seed germination, 3 seedlings in each pot were maintained. After 4 months, the mature maize plants were harvested and the further plants and soil analysis were performed.

2.3. Soil analysis

After the crop harvest, soil samples were taken from each unit and measured soil pH and EC using pH and EC meter according to the described method in our previous study (Bashir et al., 2020a; Bashir et al., 2020b; Bashir et al., 2020c). Bioavailable Cd contents from each potted soil were estimated using the CaCl₂ extractable technique described by Houben et al. (2013). Soil organic matter contents were calculated by using the wet oxidation method. Similarly, soil available nitrogen, phosphorus and potassium contents were estimated by (Lu et al., 2000).

2.4. Plant analysis

Chlorophyll contents were measured using the SPAD meter. However, the harvested portion of maize shoots and roots were oven dried and digested with di-acid HNO₃:HClO₄ mixture for the estimation of Cd contents and nutrients (NPK) as described in our previous study (Bashir et al., 2018; Bashir et al., 2019).

2.5. Statistical analysis

Collected data of growth, yield and quality parameters were analyzed using statistical package "Statistic 8.1". Fisher's analysis of variance (ANOVA) technique was used to test the significance in the data. Microsoft Excel was used for calculation of standard errors of means and graphical presentation. The differences among treatment means were assessed using LSD post-hoc test at 5% probability.

3. Results

3.1. Effect of amendments on soil pH and Cd bioavailability

The incorporation of various kinds of soil amendments showed the significant alteration in soil pH and soil bioavailable Cd, relative to without soil amendments. The greater increase in soil pH was observed in press mud by 0.4 units relative to control. However, the addition of compost at 3% rate showed the prominent decline in soil pH by 0.2 units, relative to control soil (Fig. 1).

While, the mixing of soil amendments in sewage wastewater irrigated polluted soil showed the significant decline in the soil bioavailable Cd contents against without treated soil (Fig. 2). The maximum reduction was recorded in compost by 49%. Compared to the control soil, the addition of PM and ME at 3% rate also showed the prominent reduction by 28% and 25.3% respectively.

3.2. Effect of amendments on soil organic matter and nutrients availability

The addition of soil amendments in polluted soil led to enhance soil organic carbon contents, over without treated soil. The significant improvement in soil carbon was recorded by 42.7%, 20.2% and 4.5%, when compost, press mud and moringa leaf extract were incorporated at 3% rate relative to non-amended soil. Similarly, the bioavailable status of NPK nutrients efficiently improved in the treated soil relative to non-amended soil (control). The prominent increase in available-N was recorded by 26.7 mg kg⁻¹ when compost was amended in polluted soil at 3% rate. Whereas, the addition of press mud and moringa leaf extract at 3% dose level also showed the prominent increment in soil available-N by 24.2 and 23.2 mg kg⁻¹ relative to non-amended soil (21.8 mg kg⁻¹) (control), respectively. Likewise, addition of compost, press mud and moringa leaf extract into wastewater polluted soil efficiently improved soil available-P by 9.5, 6.7 and 6.6 mg kg⁻¹ respectively,

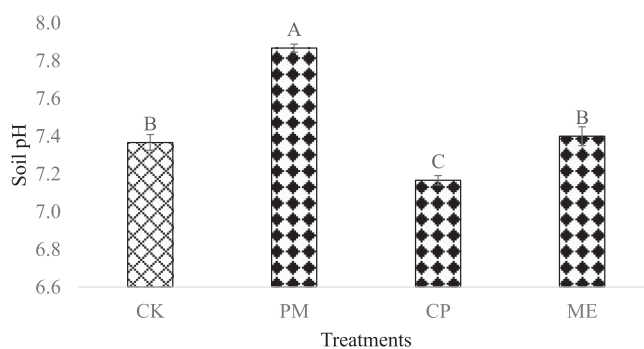


Fig. 1. Change in soil pH after treated with control (CK), Press mud (PM), Compost (CP) and Moringa Leaf Extract (ME) at 3% application level Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different p < 0.05.

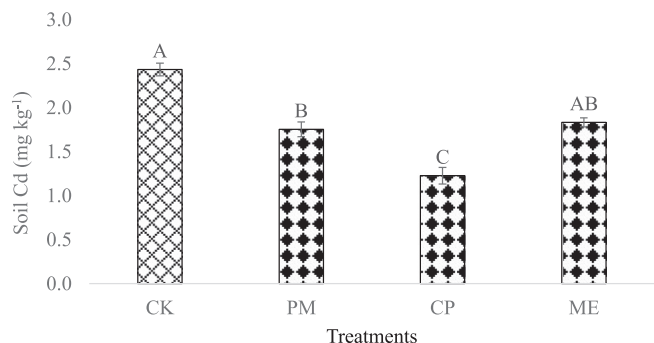


Fig. 2. Change in soil Cd bioavailability after treated with control (CK), Press mud (PM), Compost (CP) and Moringa leaf extract (ME) at 3% application level Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different p < 0.05.

over control soil (5.7 mg kg⁻¹). Available-K contents in wastewater irrigated polluted soils were prominently improved when compost, press mud and moringa leaf extract at 3% rate by 90.7, 81.7 and 73.3 mg kg⁻¹ respectively, over control (72.3 mg kg⁻¹).

3.3. Effect of amendments on Cd uptake and chlorophyll contents

The results revealed that Cd accumulation in maize shoots and roots tissues were increased in the wastewater polluted soil relative to soil treated with organic amendments (Figs. 4 and 5). However, addition of various kind of amendments has ability to reduce Cd accumulation in plant tissues. The greater reduction in Cd accumulation in plant shoots was recorded by 50%, 36.8% and 23.7% when compost (CP), press mud (PM) and moringa leaf extract (ME) were added at 3% rate into wastewater polluted soil respectively, over control. Likewise, incorporation of CP, PM and ME also significantly reduced the Cd accumulation in maize roots. The highest reduction was recorded by 39%, 25% and 17.2% after CP, PM and ME were incorporated at 3% application level.

Our current study results revealed that the addition of soil amendments showed a significant decline in Cd translocation from root to shoot. The maximum reduction was recorded by 30.3% when soil was treated compost. Similarly, the addition of press mud and moringa leaf extract showed the prominent reduction in Cd translocation from root to shoot by 22.7% and 16.6% respectively at 3% application rate, relative to control. Results showed that the addition of soil amendments in waste water irrigated soil improved the soil health and plant growth. The chlorophyll con-

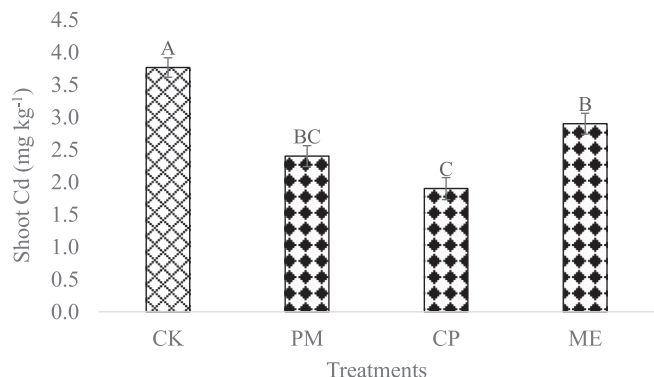


Fig. 4. Change in Cd contents in maize shoot after treated with control (CK), Press mud (PM), Compost (CP) and Moringa leaf extract (ME) at 3% application level Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different p < 0.05.

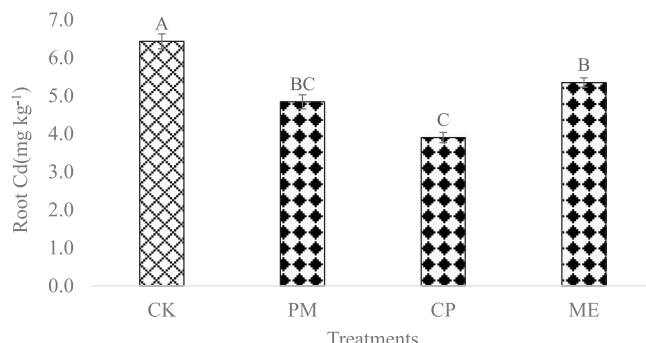


Fig. 5. Change in Cd contents in maize root after treated with control (CK), Press mud (PM), Compost (CP) and Moringa leaf extract (ME) at 3% application level Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different p < 0.05.

tents prominently improved in treated soil relative to control soil (Fig. 3). The maximum increment in chlorophyll contents was recorded in CP, PM and ME amended soils by 27.7%, 16.3% and 13.3% at 3% application rate, respectively over control.

3.4. Effect of amendments on maize biomass and nutrients accumulation

Maize fresh and dry shoot root biomass was also improved after the addition of compost (CP), press mud (PM) and moringa leaf extract (ME) at 3% dose level. The maximum fresh shoot and root biomass was recorded when soil was amended with soil amendments relative to control (Table 2). While, the maximum dry biomass was recorded in CP amended soil. Likewise, all other growth and yield parameters were improved among all the incorporated treatments (Table 2). Similarly, nutrients contents in maize shoots were improved when CP, PM and ME were added at 3% application rate. Among all the soil amendments, CP showed the greater NPK contents in plant shoot tissues relative to other treatments indeed control (Table 3).

4. Discussion

Restoration of wastewater polluted soil and wastewater treatment is an emerging challenge for all around the globe and scientist to protect food chain. Recently, use of various organic amendments, especially compost (CP), press mud (PM) and moringa leaf extract (ME) is suitable approach for polluted soil

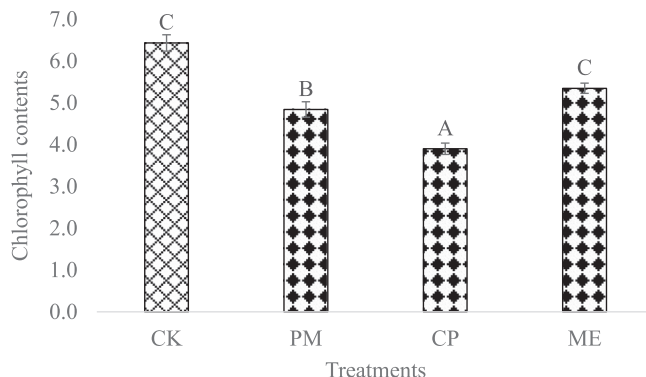


Fig. 3. Change in Chlorophyll contents after treated with control (CK), Press mud (PM), Compost (CP) and Moringa leaf extract (ME) at 3% application level Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different p < 0.05.

Table 2

Change in plant growth parameters after treated with control (CK), Press mud (PM), Compost (CP) and Moringa Leaf Extract (ME) at 3% application level Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different p < 0.05. Plant height (PH); Shoot length (SL); Root length (RL); Fresh shoot biomass (FS); Dry shoot biomass (DS); Fresh root biomass (FR); Dry root biomass (DR); Number of leaves (NL).

Treatment	PH	SL	RL	FS	DS	FR	DR	NL
CK	55.3c	45.3c	8.5c	15.4c	6.5c	5.5c	3.1c	14.0c
PM	60.7bc	50.0bc	9.5b	17.8b	8.4b	7.3b	4.1b	16.7b
CP	75.3a	63.0a	12.5a	22.3a	10.3bc	9.5a	4.8a	19.0a
ME	64.3b	52.7b	9.1b	18.4b	7.0a	7.9b	3.5bc	15.3bc

Table 3

Change in soil and plant nutrients after treated with control (CK), Press mud (PM), Compost (CP) and Moringa Leaf Extract (ME) at 3% application level. Different letters indicate that values are significantly different p < 0.05.

Treatment	Soil (mg kg ⁻¹)				Plant (g kg ⁻¹)		
	N	P	K	N	P	K	OM (g kg ⁻¹)
CK	21.8c	5.0c	72.3c	11.8c	1.5c	12.7c	0.63c
PM	24.2b	7.0b	81.7b	13.9ab	2.1b	15.5b	0.79b
CP	26.7a	9.5a	90.7a	14.7a	3.9a	17.7a	1.10a
ME	23.2bc	6.0bc	73.3c	13.4b	1.9b	14.8b	0.66c

restoration. The current investigation confirmed that the incorporation of various organic materials has exhibited their potential to alleviate Cd mobility and phytoavailability to maize in wastewater irrigated farmlands (Ali et al., 2020). As described in Table 1, all materials have sufficient amount of C, H, N and O. The greater amount of carbon contents and C:N in compost and press mud attributed the presence of highest amount of lignin and cellulose. Incorporation of organic amendments has the ability to improve soil organic carbon and nutrients status which ultimately promote crop growth. The addition of compost significantly ameliorates the soil alkalinity and reduced soil pH because of sufficient amount of humic acid in compost, which is helpful for the mobility of soil nutrients in calcareous soil. Similar findings were reported in the recent study described by Li et al. (2019) indicated that the addition of compost could reduce the soil pH due to the humification nature of studied compost. Zhou et al. (2017) described that the vegetable derived compost significantly reduced the soil pH, which might be due to the abundance of humic acid and organic compounds in the compost. Similar findings were reported by Tang et al. (2020) confirmed that organic soil amendments especially compost could release humic substances which could contribute to lessen soil pH. Recent study reported by Bashir et al. (2021a) confirmed that incorporation of vegetable and animal manure induced composts showed the significantly decline in soil pH that have contribution to improve the nutrients availability in alkaline contaminated soil. Another possible reason was that the richness of compost with essential nutrients and the possible decomposition of organic matter. The organic carbon in organic amendments treated soil significantly increased the soil fertility status, water contents and reduced the metals mobility in polluted soils (Bashir et al. 2021b).

The recent studies reported by Kizito et al. (2019) and Yuan et al. (2017) suggested that the incorporation of soil organic amendments (biochar, compost, and biogas slurry) prominently influenced the soil pH, EC and CEC as well as provided the essential nutrients (C, N, P, K, and S) to plant. This enhancement in soil fertility leads to an improvement in plant growth through the uptake of essential elements provided by the organic soils amendments (Abbas et al., 2020). However, the use of press mud significantly enhances the soil pH relative to without treated soil (control) Borcard et al. (2014). Present study confirmed that the significant increase in soil pH and essential soil nutrients (NPK) might be due to the presence of base cations and CaO in press mud. Due to the alkalinity of press mud, OH⁻ ions released in soil solution and

prominently increase soil pH, which could create the bindings sites for heavy metals complexation and adsorption (Karwal and Kaushik, 2020). It can be demonstrated that the increase in soil pH could enhance the sorption cavities and bindings sites on soil collides and as well as increased the net electronegative charges on soil constituents, which are thus responsible for the Cd immobilization through adsorption and precipitation (Bashir et al., 2018).

The findings of current study confirmed that the addition of organic soil amendments (compost, press mud and moringa leaf extract) effectively minimized Cd mobility in polluted soil, which might be possible due to the presence of organic substance and functional groups that have great contribution to stabilize Cd through complexation. In the similar manner, Liu et al. (2019) examined that municipal solid waste compost has the potential to remediate Cu polluted soil by reducing the exchangeable portion of Cu. Addition of compost in degraded soil significantly improve soil health by reducing the metals mobility because of minerals, organic acids and microbes that have much contribution to promote the metals stabilization Awasthi et al. 2015; Białobrzewski et al., 2015). Anastopoulos et al. (2013) and Soares et al. (2016) found that compost has a potential role as a biosorbent for adsorbing heavy metals. It can be recognized that the prominent decline in Cd mobility might be ensured because of all the applied soil amendments properties such as physical (porous structure) and chemical (high pH, greater CEC and surface functional groups) properties could cause the greatest reduction in the solubility of Cd through complexation and adsorption on soil surface. Another possibility was that the addition of press mud would be able to release the greater amount of carbonates, oxides and hydroxides into the soil solution, which increase soil pH that would be able to enhance Cd precipitation as Cd(OH)₂ and CdCO₃. (Bashir et al., 2019; Bashir et al., 2020a; Bashir et al., 2020b; Bashir et al., 2020c). This could influence the reduction of Cd contents in maize tissues. It can be attributed that press mud contains functional groups like hydroxyl ions that play an important role in adsorption of heavy metals (Mahmood, 2010). Press mud reverse the toxic effect of heavy metals. Sabir et al. (2013) demonstrated that the addition of press mud significantly decreased the Cr (VI) accumulation in root and shoot by 33% and 20%, respectively relative to untreated soil.

Present study confirmed that the addition of green waste derived organic compost has the ability to overcome the Cd solubility and mobility issue in polluted soil due to its organic nature.

Additionally, compost incorporation improved the contents of soil carbon by 6–7 times relative to the untreated soil. It has sufficient quantity of humic substances, which held various kinds of functional groups e.g., carboxyl and hydroxyls. Some of these functional groups could contribute to bind the heavy metals with their organic complexes and chelates (Chang-Chien et al., 2006). Previous study explained by Song et al. (2010) suggested that the compost addition could transform soluble portion of Cd by 47.8%–69.8% to the most stable form, and therefore, reduced Cd accumulation in Pakchoi tissue by 56.2%–62.5% relative to un-amended soil. The mitigation of Cd solubility by compost was recognized primarily to complexation of Cd by organic substance that was present in compost (Song et al., 2010). Karami et al. (2011) confirmed the effectiveness of green waste induced compost on the phytoavailability of metals such as Cu and lead Pb in plants tissues. Moreover, the incorporation of compost expressively reduced the Cu and Pb toxicity by hindering their uptake in plant tissues. Several recent studies Bashir et al. (2021a) and Bashir et al. (2021b) suggested that Cd accumulation plant tissues prominently decreased with the increasing rates of organic amendments relative to untreated soil. This significant decline could be because of Cd binding with the organic substance that were present in the organic amendments.

Our results revealed that moringa leaf extract prominently reduced Cd mobility and enhanced maize growth. The reduction in Cd accumulation in maize plants is might be due to the hormonal behavior of moringa that lead to mitigate the toxicity of Cd in plants parts. Similarly, the study conducted by Shinomol et al. (2016) suggested that the use of moringa parts such as seeds, leaf and bark have the potential to hinder the heavy metals mobility and retain them in their surface through surface functional groups present on moringa parts. Current findings demonstrated that ME has ability to alter bioavailable pool of Cd to most stable residual form, which could contribute to reduce the stress on maize plant in polluted soil. Another previous study discussed by Reddy et al. (2011) indicated that addition of *Moringa Oleifera* parts including seeds, leaves and fruits are useful for polluted water purification and improvement of water quality that make it possible for the drinking purpose. The modification of the moringa as a biosorbent was used to enhance the adsorption of Ni from aqueous solution. It can be demonstrated that *M. Oleifera* seed were used as a good approach for the removal of Co, Cu, Pb and Cd (Maina et al., 2016). In addition, they studied that Cd has greater ability to adsorb on the moringa bark and leaf as well as enhance crop growth.

After the treatment of polluted soil with organic amendments the maize biomass significantly improved compared to control. This improvement might be attributed to the nutritious significance of compost, press mud and moringa leaf extract that improves the soil productivity. Other possible reason might be considered because of their potential to boost the organic matter mineralization and enhanced crop yield and growth (Shinomol et al., 2016; Abbas et al., 2020; Ali et al., 2020). It is important to discuss that compost and press mud acts as buffer and contains sufficient quantity of vital plant nutrients which pointedly rise crop yield (Ali et al., 2020). The establishment of these results might occurred due to the obvious reduction in the phytoavailable Cd in treated soil, thus alleviating Cd uptake by maize. From the findings of current study, it has been established that use of organic materials as a soil amendment has capability to ameliorate soil alkalinity. In addition, they could release basic nutrients and exchange metals from soil solution, which might be able to tackle metals mobility in polluted soils and improved crop growth (Abbas et al., 2020).

5. Conclusion

This study established the efficiency of compost (CP), press mud (PM) and moringa leaf extract (ME) as a soil amendment to sorb Cd and its translocation from soil to plant tissues and nutrients status that was investigated in pot study. The findings revealed that CP, PM and ME addition at 3% rate significantly altered soil pH, nutrients availability in soil–plant system, reduced the mobility and uptake of Cd in maize plant as well as minimize its toxicological and physiological stress in polluted soil relative to control. Hence, it has been established that the use of organic waste induced materials to remediate the Cd-polluted soil is considered an emerging approach to restore the polluted soil health and improve the better crop growth. Additionally, the findings of current study need to be further confirmed on large scale field experiments under the presence of multiple potential toxic elements. Organic materials production from different feedstock's could be systematically arranged on their comprehensive soil restoration performance in the following order CP > PM > ME.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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