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CADMIUM AVAILABILITY IN SOIL AND CONSEQUENTIAL IMPACTS ON SUNFLOWER GROWTH IN WASTEWATER IRRIGATED SOIL IN THE PRESENCE OF COMPOST AND MANURE

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ABSTARCT

Background Use of wastewater for farmlands is posing severe threat to food security and safety, particularly in developing countries due to the presence of excessive salts and heavy metals. Possible eco-friendly techniques are urgently required to restore the polluted soil health by using organic amendments such as compost and manure. The prime objective of present study was to evaluate the relative effectiveness of vegetables-waste compost and manure on the cadmium (Cd) solubility and phytoavailable in soil, uptake by plants and consequential impacts on growth and yield attributes of sunflower (*Helianthus annuus* L.).

Methodology Experimental plan consisted of five treatments and three replicates described as follow: i) control (Cd-contaminated soil), ii) Compost 2%, iii) Compost 5%, iv) Manure 2%, v) Manure 5%.

Results It was found that soil pH and bioavailability of Cd was significantly altered after amending the wastewater-induced Cd contaminated soil with compost and manure. The maximum reduction in Cd availability in soil was found 58.2% and 50.0% by compost and manure, respectively when applied at 5% compared to control. In addition, the Cd contents in the sunflower shoots and roots were significantly decreased with the subsequent improvement in sunflower growth and yield attributes.

Conclusion Compost and manure at 5% application rate could be a useful strategy for the restoration wastewater-induced Cd contaminated soil.

INTRODUCTION

Now a days, the release of effluents from industries and urban societies is posing a serious threat to soil health due to the presence of toxic elements in wastewater. The direct irrigation with wastewater of agricultural lands may result in hardening of soil by increasing the accumulation of salts and heavy metals in farmlands (Safdar et al. 2017). Bashir et al. (2019) reported that heavy metals may pose the severe threat to food chain due to their toxic effects, and causing the oxidative deterioration of biological macromolecule. Contaminated soils exert negative impacts on soil biological and physicochemical properties, deteriorating soil health, and have negative impacts on the productivity of various crops (Bashir et al. 2018). Metals contaminated soils are less fertile due to heavy metals effect on nutrients interaction which mainly associated with the crop production. Metals contamination is one of the serious global issue which can be controlled by using some immobilizing agents to metals contaminated soils (Bashir et al. 2018). Accumulation of heavy metals in agricultural soil can retard the plant growth and also affect the physiological, morphological and metabolic activities (Piracha et al. 2016). Moreover, combination of various metals pollution has become more complex issue in the soil. Therefore, remediation of heavy metals contaminated soils attracts more attention all over the world.

Sunflower (*Helianthus annuus* L.) is attaining a great importance as an edible oil seeds crop because of its economic and social significant share in vegetable oil production (Abdou et al. 2011). However, certain

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climatic, edhaphic and managerial factors may affect the growth and yield of sunflower drastically (Ion et al. 2015). To increase the crop productivity, there is an urgent need to address the heavy stress effects on oilseed crops, especially sunflower. Therefore, the selection of alkaline amendments and phosphate fertilizers including fly ash, lime ($CaCO_3$), gypsum ($CaSO_4.2H_2O$), organic wastes (crop residue, compost, and bio-solid compost) and biochar can be considered the efficient soil restoration options (Mahar et al. 2016; Bashir et al. 2018).

Organic inputs have several advantages in soil fertility management. Apart from providing essential plant nutrients, they can contribute directly towards the build–up of soil organic matter (SOM) and its associated benefits (Beesley and Dickinson 2010). In fact, manure is one of the key inputs to smallholder farming systems, especially in the semi–arid environment where the cost and availability limits the use of synthetic fertilizers to address soil fertility problems. Din and Aftab (2017) found that poultry manures markedly improved the growth, yield and plant nutrients concentration in lentil grown in metal contaminated soil. Azeez et al. (2008) demonstrated that addition of manure to soil increased the maize grain yield, while doubling the amount of applied manure did not result in corresponding significant yield increase.

Compost is one of the valuable soil amendment which improves the quality of soil and enhances the plant growth (Rouse et al. 2008). Compost consist of stabilized decomposed organic matters that are resulted from biological decomposition of organic matter in controlled aerobic environment (Paulin and O'Malley 2008). Plant waste composts such as garden grasses, tree leaves, and tree barks can make ideal amendments because of high carbon and nitrogen while low heavy metals contents. It is reported that the compost addition increased the cation exchange capacity of soil (Hseu et al. 2013) which is most important for heavy metals immobilization in contaminated soils.

Several types of organic and inorganic amendments have been studied for Cd immobilization in contaminated soils (Bashir et al. 2018; Bashir et al. 2019). However, a limited information has been reported regarding the incorporation of compost and animal manure in wastewater irrigated agricultural soils for controlling Cd immobilization and phytoavailability to sunflower in contaminated soil. Thus, the primary objective of the current study was to assess the comparative effectiveness of compost and animal manure to control Cd availability in soil, and consequential impacts on sunflower productivity under wastewater induced Cd contaminated soil.

MATERIAL AND METHODS

Soil characterization

The experimental soil was collected from 0-15 cm from wastewater irrigated agricultural fields of Dera Ghazi Khan, Punjab, Pakistan. Soil samples were air dried under shed. The dried samples were ground and sieved through 2 mm sieve before pot study. The soil was analyzed for pH and electrical conductivity (EC) with soil to water ratio of 1:2.5 and 1:5 (w/v). EC was found 3.85 dS m^{-1} and pH 8.1. Pipette method was used for soil textural analysis, and soil textural class was found clay loamy. Total nitrogen (N) and available phosphorous (P) contents of soil were measured according to the methods proposed by Lu (1999), and N was found 0.19%, available P 7.9 mg kg^{-1}. Cation exchange capacity (CEC) of soil was measured in accordance with ammonium acetate method, and found 18.3 meq 100 g^{-1}. The determination of soil Cd was done by the tri-acid mixture (HCl-HNO-$HClO_4$) and the readings were recorded using atomic absorption spectrophotometer (AAS) which was found 5.22 mg kg^{-1}.

Pot experiment

A pot study was conducted to estimate the effect of compost and manure on Cd availability in polluted soil. The study was systematically arranged with five treatments and three replicates described as follow: i) control, Cd-contaminated soil (CK), ii) Compost 2%, iii) Compost 5%, iv) Manure 2%, v) Manure 5%. Pots were filled with 2 kg of air dried Cd-contaminated soil. The experimental soil was homogenously amended with compost and manure with the respective application rates. The experimental pots were irrigated with distilled water at 65% moisture holding capacity and left for 2 weeks. Two healthy sunflower seeds were sown in each experimental pot at 3–5 cm depth. After a period of 2 months, one sunflower plant from each pot was harvested for further analysis, while second plant was grown up to maturity. Sunflower shoots and roots were thoroughly washed with tap water and rinsed one time in deionized water to remove the dust particles. The plant samples were dried in an oven at 75 ºC in paper bags for 2 days. The stainless steel mill was used to grind the sunflower shoots and roots tissues for Cd analysis. After plant harvesting at maturity, the soil samples were collected from each pot and left for drying for 3 days and then ground and pass through 2 mm sieve for the determination of Cd in soil.

Heavy metal determination

After harvesting of sunflower plants, the Cd bioavailability in soil was determined according to the procedure of Houben et al. (2013). Samples containing

Table 1 Effect of compost and manure on plant growth parameters of sunflower in Cd-contaminated soil

Treatments	Chlorophyll content (mg g^{-1} FW)	Number of leaves $plant^{-1}$	Shoot length (cm)	Root length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)
Control	3.9 d	12.0 c	41.0c	8.3 c	25.0 b	10.5 c	2.3 c	1.3 d
Compost 2%	5.7 b	19.3 a	63.0 a	12.3 ab	34.7 a	13.6 b	4.7 b	2.9 bc
Compost 5%	6.7 a	21.7 a	67.7 a	15.3 a	38.3 a	15.9 a	6.2 a	4.5 a
Manure 2%	4.4 c	14.7 b	48.0 b	11.3 bc	27.0 b	11.6 c	3.4 bc	2.4 c
Manure 5%	5.6 b	16.7 b	50.7 b	12.3 ab	33.3 a	14.3 ab	4.4 b	3.2 b

2.0 g of soil was shaken with 25 ml of 0.01M $CaCl_2$ for 2 h at 3500 rpm for 20 min. For determining Cd in plant tissues, sunflower roots and shoots were ground to powder with the help of electric mill. The roots and shoots samples (0.2 g) were digested using the mixture of H_2SO_4: $HClO_4$ in the ratio of 3:1 (v/v) for the determination of Cd contents in plant tissues.

Plant growth parameters

At maturity, sunflower growth and yield parameters including, plant height (cm), number of leaves, plant root and shoot fresh and dry biomass were measured. The plant chlorophyll content was determined by using chlorophyll meter.

Statistical analysis

The data were subjected to Analysis of Variance (ANOVA) using Statistic 8.1 and LSD test ($p < 0.05$) were used to test the mean significance of all treatments. Statistical variations of the data were expressed as standard deviation and significance of the data was calculated at $p < 0.05$.

RESULTS AND DISCUSSION

Effect of amendments on soil pH and Cd immobilization

Application of compost and manure at two application rates significantly altered the soil pH (Figure 1). The application of compost at 2 and 5% showed the prominent reduction in soil pH with its increasing rate. Relative to control, the decrease in soil pH was recorded from 0.5 units at 5% application rate. Mainly, compost being organic rich material released organic acid, particularly humic acid into soil that might contribute to a decrease in soil pH. Similar findings were observed by Borchard et al. (2014) that the addition of organic materials such as compost into soil released sufficient amount of humic acid which might have ability to decrease soil pH. Another previous study reported by Zeng et al. (2015) suggested that incorporation of compost into polluted soils showed the prominent reduction in soil pH due to the release of organic substance and organic acids in soil. Furthermore, the addition of compost could also lower the soil pH due to a marked increase in CO_2 level after the decomposition and mineralization of the organic matter.

In contrast, an increase in pH was observed in manure amended soil by 0.4 units over control at 5% manure application rate. The increase in soil pH by manure addition could be because of its alkalinity and presence of several basic cations. The increasing trend in soil pH was due to the increasing rate of its addition in polluted soil. These results were in line with the previous studies reported by Liao et al. (2016); Xiao et al. (2017). Wan et al. (2019) also described that farm yard manure and poultry manure contained sufficient amount of alkaline substances such as hydroxyl and carbonates which played significant role to increase soil pH. As soil pH increased after manure addition, the surface electro-negative charges on soil collides led to increase the formation of iron (Fe) and manganese (Mn) oxides and enhanced sorption capacity of soil for Cd. The maximum decrease of Cd availability (58.2%) was occurred in soil by adding compost at 5% while, amending soil with manure at 5% application rate decreased Cd availability by 50% compared to control (Figure 2). The phytoavailability of heavy metals such as arsenic (As) and cupper (Cu) decreased as these heavy metals/ metalloids bound strongly with organic matter applied to the soil (Perez de Mora et al. 2006).

Plant Cadmium accumulation

In present study, compost and manure amended soil showed the significant decrease in Cd accumulation by sunflower shoots and roots relative to control (Figure 3). The greater reduction in Cd accumulation was occurred with the increasing rates of amending materials from 2 to 5%. The maximum reduction was recorded in sunflower shoots by 55.7 and 47% at 5%

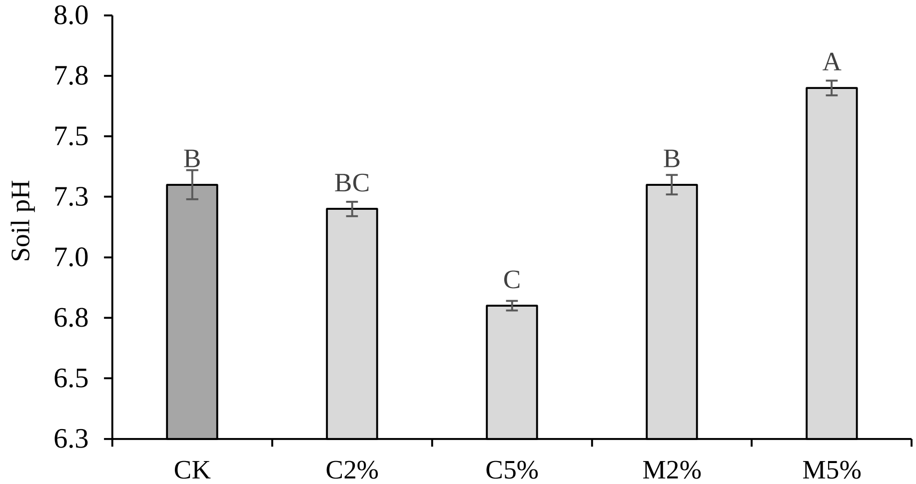

Figure 1 Effect of compost (C) and manure (M) on the pH of wastewater-induced Cd contaminated soil. Control (CK), compost 2% (C2%), compost 5% (C5%), manure 2% (M2%), and manure 5% (M5%)

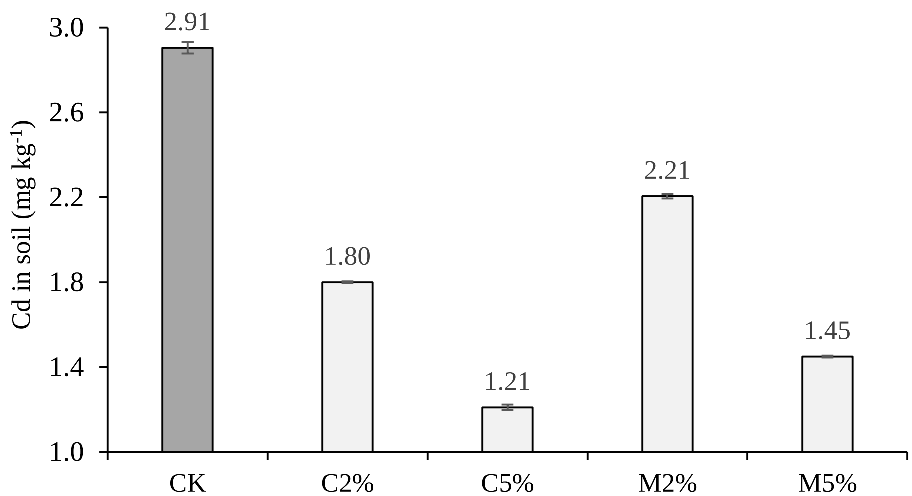

Figure 2 Effect of compost (C) and manure (M) on bioavailable Cd in wastewater-induced Cd contaminated soil. Control (CK), compost 2% (C2%), compost 5% (C5%), manure 2% (M2%), and manure 5% (M5%)

compost and manure, respectively compared to control. Likewise, Cd was reduced in plants roots by 54 and 44% when compost and manure were applied at 5%, respectively over control. It was found that organic nature of both amendments effectively stabilized Cd in soil and, thereby minimized its uptake by plants. Karami et al. (2011) examined the efficacy of amendments like green waste compost and biochar for the bioavailability of heavy metals such as Cu and lead (Pb) in plants. The application of biochar and compost significantly decreased the Cu and Pb toxicity by inhibiting their accumulation in plant tissues. It is important to note that the incorporation of compost and manure efficiently improved the soil properties, in addition to improving fertility and carbon contents (Weber et al. 2014; Papafilippaki et al. 2015). Because of these beneficial role, Cd stabilization in the polluted soil can be achieved, particularly due to the presence of electronegative charges on the surface of organic and humic substance in compost and manure (Paradelo and Barral, 2012). Similar findings were observed by Zhou et al. (2014) indicating that greater percentage of organic matter and presence of microorganism in compost amended soil could be favorable to metal fixation.

Plant growth characteristics

The data regarding the effect of compost and manure on sunflower growth in Cd contaminated soil is illustrated in Table 1. The addition of compost at 2 and

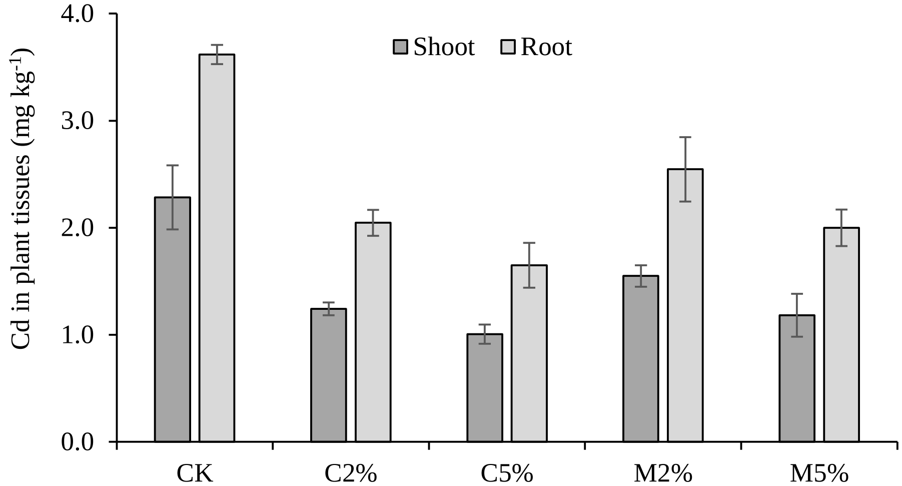

Figure 3 Effect of compost (C) and manure (M) on Cd accumulation in shoots and roots of sunflower grown in wastewater-induced Cd contaminated soil. Control (CK), compost 2% (C2%), compost 5% (C5%), manure 2% (M2%), and manure 5 % (M5%).

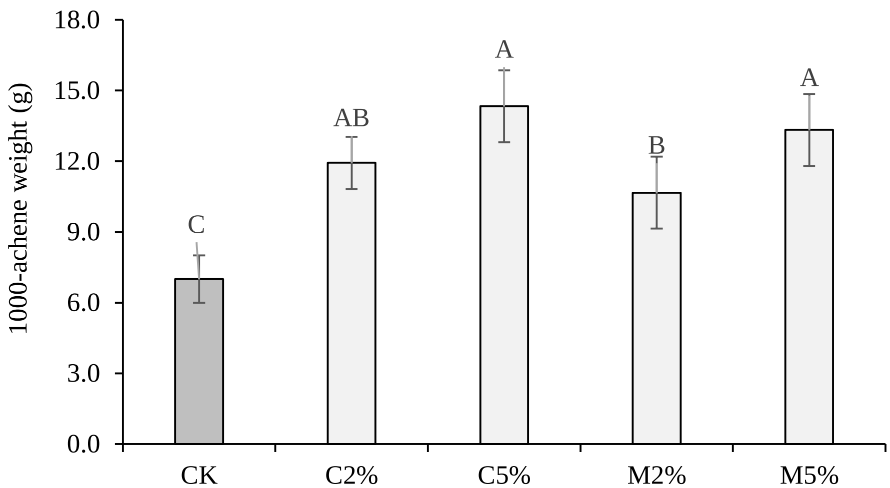

Figure 4 Effect of compost (C) and manure (M) on 1000-achene weight of sunflower grown in wastewater-induced Cd contaminated soil. Control (CK), compost 2% (C2%), compost 5% (C5%), manure 2% (M2%), and manure 5 % (M5%).

5% rate increased the number of leaves by 44.7 and 28%, respectively relative to control. Likewise, shoot and root dry biomass increased by 33.9 and 76%, respectively when compost was applied at 5%. The addition of manure at 5% application rate also showed the significant increment in shoot and root dry biomass (Table 1). Similarly, the chlorophyll contents increased with the incorporation of compost and manure by 41.5 and 30%, respectively at 5% application rate over the control. It could be described that organic material such as compost and manure contained sufficient amount of carbon contents and nutrients which were released from these materials during their decomposition and plants could easily absorb them. Adejumo et al. (2018) reported that compost application significantly enhanced the maize growth because of the greater availability of plant nutrients in soil. In addition, the compost has sufficient amount of humic acid and organic carbon to reduce soil pH which subsequently increased available nutrients in alkaline polluted soils. The present result showed that the addition of compost and manure to wastewater-induced Cd polluted agricultural soil significantly increased the yield of sunflower. The achene weight of 1000 seeds increased by 51 and 47% after the incorporation of compost and manure at 5% application rate, respectively (Figure 4).The number of achenes plant^{-1} increased with the increasing rate of compost and manure from 2 and 5% relative to control. The highest increase in achene count of 18 and 11%

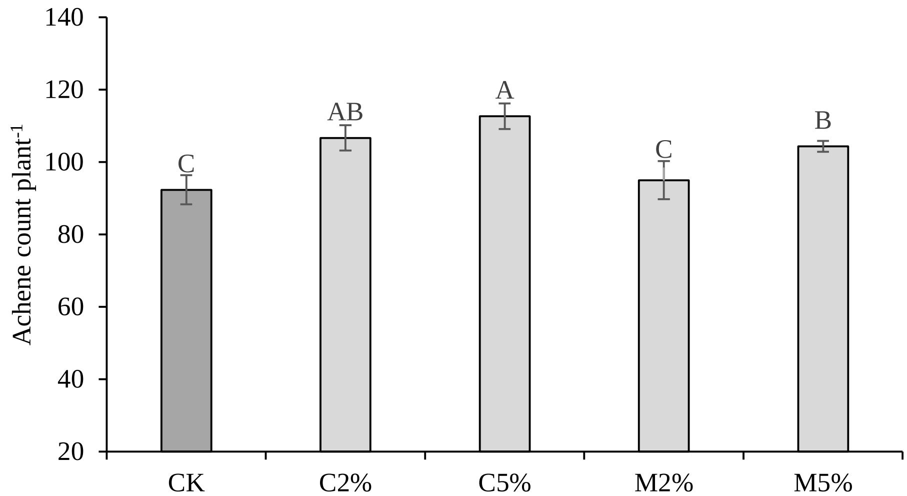

Figure 5 Effect of compost (C) and manure (M) on achene count plant^{-1} of sunflower grown in wastewater-induced Cd contaminated soil. Control (CK), compost 2% (C2%), compost 5% (C5%), manure 2% (M2%), and manure 5% (M5%)

was found when compost and manure were added at 5%, respectively over control (Figure 5).

CONCLUSIONS

Vegetable waste derived compost performed better to adsorb Cd by changing its behavior in soil which reduced Cd availability in soil. Among different application levels of compost and manure, 5% application rate of both amendments more markedly reduced Cd availability in soil, uptake by plants, and subsequently improved sunflower growth and yield attributes. When comparing the efficiency of both amendments, compost performed better than manure in mitigating wastewater-induced Cd toxicity. Application of manure, particularly at higher application rate (5%) could be a promising option for improving sunflower growth and yield in Cd-polluted soils.

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