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Original article

Comparative role of animal manure and vegetable waste induced compost for polluted soil restoration and maize growth

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ABSTRACT

Soil amendment with two types of composts: animal manure (AC) and vegetable waste (VC) induced composts have potential to alleviate Cd toxicity to maize in contaminated soil. Therefore, Cd mobility in waste water irrigated soil can be addressed through eco-friendly and cost effective organic soil amendments AC and VC that eventually reduces its translocation from polluted soil to maize plant tissues. The comparative effectiveness of AC and VC at 3% rate were evaluated on Cd solubility, its accumulation in maize tissues, translocation from root to shoot, chlorophyll contents, plant biomass, yield and soil properties (pH, NPK, OM). Results revealed that the addition of organic soil amendments significantly minimized Cd mobility and leachability in soil by 58.6% and 47%, respectively in VC-amended soil over control. While, the reduction was observed by 61.7% and 57%, respectively when AC was added at 3% over control. Comparing the control soil, Cd uptake effectively reduced via plants shoots and roots by 50%, 46% respectively when VC was added in polluted soil. However, Cd uptake was decreased in maize shoot and roots by 58% and 52.4% in AC amended soil at 3% rate, respectively. Additionally, NPK contents were significantly improved in polluted soil as well as in plant tissues in both composts amended soil Comparative to control, the addition of composts significantly improved the maize dry biomass and chlorophyll contents at 3% rate. Thus, present study confirmed that the addition of animal manure derived compost (AC) at 3% rate performed well and might be consider the suitable approach relative to vegetable compost for maize growth in polluted soil.

1. Introduction

The lack of good quality water and use of industrial effluents as the irrigation source has become a serious matter of concern for the agricultural land and food security around the globe. Presence of potential toxic elements (PTEs) in polluted water can lead to destroy the physical structure and nutrition values of productive land (Bashir et al., 2020a; 2020b; 2020c; Shahid et al., 2018). The irrigation of sewage wastewater to the farmlands has also become a serious environmental threats because of food chain deterioration (Bashir et al., 2020a; 2020b; 2020c). Contamination of

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farmlands by PETs can widely be exceeded by the excessive mining of mineral resources, industrial products and the use of chemicals as agricultural inputs. Along with the other potential toxic metals, cadmium is considered to be more mobile and neurotoxic, which seriously imposes threats to the soil ecosystem and causes the severe disorder in plants species (Bashir et al., 2019; Xiong et al., 2016).

Nowadays, several soil restoration strategies have been adopted in order to improve the soil health and eliminate the food security risks (Bashir et al., 2019; Liu et al., 2018). Moreover, the use of organic waste materials as a soil conditioner can be used as a practical and suitable approach to restore the contaminated soils via changing the PETs solubility and phytoavailable pool (Bashir et al., 2018; Bolan et al., 2014). Hence, it is an important task to minimize the translocation of phytoavailable metal concentration to edible plant parts using organic based soil amendments. Addition of organic inputs to polluted soils have got much attention because of their several advantages; improving soil fertility, providing essential plant nutrients, which can contribute towards the build–up of soil organic matter (SOM) and its linked benefits (Beesley et al., 2014).

Compost is derived from the agro-industrial by-products such as, garden grasses, vegetables wastes, tree leaves, crop straws and animal manures under the humification and microbiological process. It is an effective way to dispose of organic materials to produce compost as an organic soil amendment and growing media in aerobic condition (Ayilara et al., 2020). As a promising soil amendment, when incorporated into the polluted soil, it could accelerate the soil porosity, nutrient and moister retention and improve the soil fertility status as well as enhance crop growth and yield. Furthermore, it is widely used as a remediation approach for polluted soils restoration (Abbas et al., 2020a; 2020b). Ayilara et al. (2020) confirmed the potential role of composted food by-products for PTEs effected soils health restoration through stimulating the soil microbial communities, which can ensure the food security.

Composts have also been proved as a growing media and used as a soil conditioner for plants growth (tomato, courgette, and pepper) (Jara-Samaniego et al., 2017). Similarly, the previous study reported by Gupta et al. (2016) confirmed that the composts produced from the cow dung and kitchen waste have the ability to prominently increase the nutrient status of soil especially, N, P, K availability and as well as has the potential to rise the soil organic matter content. It plays a key role as a biosorbent material for the sorption of PTEs. It is recognized as a potential amendment 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; Nurhidayati et al., 2018). Nurhidayati et al. (2018) also found that compost could reduce the toxic elements contents in water by 85–89% through chemical absorption.

Maize (*Zea Mays L.)* is the part of Gramineae family and is considered one of the most nutritious and healthy cereal crop, which has the greater consumptive values as an animal forage (Bashir et al., 2020a; 2020b; 2020c). It is extensively grown around the world and has ability to uptake the PETs. In addition, this crop gains much importance for farmers in Pakistan because of its nutritional uses. There are few scientific studies are present about the composts addition for the restoration of sewage wastewater irrigated polluted soil to tackle the issues of PETs. Therefore, the comparative behavior of vegetable compost and animal manure induced composts were investigated for maize growth in wastewater irrigated polluted soil as well as reduces the Cd uptake by maize tissues under calcareous soil nature. The main objectives of the present study were to explore the influence of vegetable compost and animal manure compost among their application levels on maize growth in polluted soil. Moreover, to examine the effectiveness of both composts on soil and plants nutrients status.

2. Materials and methods

2.1. Soil and amendments collection

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 January 2020. The obtained soil was dried, ground and then shifted to the experimental area of Ghazi University. Some portion of prepared soil about 0.5 kg 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; 2020b; 2020c) explained that the studied soil of this area has more than 4 mg kg^{-1}Cd which is greater than the proposed value of Cd in Agricultural soils by Chinese environmental and quality standard for soils (GB15618-1995).

However, two types of composts (vegetable waste and animal manure waste) were prepared from the raw waste of vegetables and animal manures in Ghazi university and used in current study.

2.2. Pot experiment

The maize growth experiment was performed to examine the influence of various kinds of biochar (compost, press mud and moringa leaf extract) at 3% application rates on sunflower growth and Cd accumulation in its tissues. The pot study was organized with the following treatments (1) Control (CK); (2) Vegetable compost (VC1.5%); (3) Vegetable compost (VC3%); (4) Animal manure compost (AC1.5%); and (5) Animal manure compost (AC3%), each treatment had three replicates. Each pot (16 cm diameter and 18 cm height) contained 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 experimental unit was fertilized with the basal dose of N (180 kg ha^{-1} soil), P (120 kg ha^{-}soil) and K (90 kg ha^{-}soil) in the form of urea, $Ca(H_2PO_4)_2$, and KCl respectively. After seed germination, 3 seedlings in each pot were maintained. After 3 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 (Mettler Toledo Delta 320) and EC meter (DDS-307A) and EC meter according to the described method in our previous study (Bashir et al., 2020a; 2020b; 2020c). Bioavailable Cd contents from each potted soil were estimated using the 1 M NH_4NO_3 extractable technique described in our previous study (Bashir et al., 2018). After extraction and filtration, supernatant was analyzed for Cd concentration through atomic absorption spectroscopy (AAS) (AA-240FS Varian, USA). Soil organic matter contents were calculated by using the wet oxidation method. Similarly, soil available nitrogen, phosphrous and potassium contents were estimated as the method proposed by (Lu et al., 2000).

2.4. Plant analysis

The chlorophyll contents from maize leaves were measured using the SPAD meter at the maturity stage. However, the harvested portion of maize shoots and roots were oven dried and digested with di-acid HNO_3:$HClO_4$ mixture for the estimation of

Table 1
Change in soil and Plant nutrients availability after treated Vegetable waste (VC) and animal manure (AC) induced composts at 3% level. Lettering are given on the basis of means (n = 3) and different letters indicate that values are significantly different p < 0.05.

	Soil (mg kg^{-1})			Plant (g kg^{-1})		
Treatment	N	P	K	N	P	K
CK	18.4D	4.4C	69.0C	11.1D	2.6C	11.5D
VC1.5%	22.3C	5.7BC	73.3BC	13.1C	3.0BC	12.8CD
VC 3%	25.3AB	8.4A	83.7A	14.7B	3.7AB	15.4AB
AMC1.5%	23.6BC	6.4B	76.0B	13.7BC	3.2BC	14.1BC
AMC 3%	27.1A	9.2A	87.0A	16.5A	4.2A	16.1A

Cd contents and nutrients (NPK) as described in our previous study (Bashir et al., 2018; Bashir et al., 2019).

2.5. Statistical analysis

One–way analysis of variance (ANOVA) followed by the LSD test were postulated at ($P < 0.05$) to analyze the data using Statistic 8.1 (Analytical software, USA). In addition, the means and standard deviations (SD) clearly indicated the statistically significant differences among all the treatments for each examined parameters.

3. Results

3.1. Effect of amendments on soil pH and Cd bioavailability

The incorporation of two types of compost: vegetable waste and animal manure derived composts significantly altered the soil pH (Fig. 1), and soil the soil bioavailable fraction of Cd against the soil which was not treated with compost. The greater reduction in soil pH was observed in vegetable waste induced compost at 3% application rate by 0.8 units relative to control. However, the addition of animal compost at 3% rate showed the decline in soil pH by 0.7 units, relative to control soil.

While, the prominent reduction was observed in soil bioavailable Cd fraction when treated with the both types of compost at 3% application rate over without treated soil (Fig. 2). The maximum reduction was recorded in animal manure derived compost (AC) by 61.7%. while the reduction was also observed when vegetable derived compost (VC) was added at 3% by 58.6% over without treated soil, respectively.

The TCLP extractable-Cd was significantly declined with the mixing of vegetable compost (VC) and animal manure compost (AC) in waste water irrigated soil (Fig. 3). The greater reduction in TCLP Cd was recorded by 46.6% and 56.6% when VC and AC were added at 3% rate respectively over without treated soil.

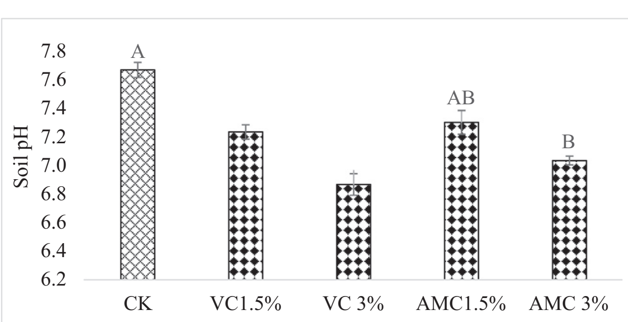

Fig. 1. Change in soil pH after treated with vegetable waste (VC) and animal manure (AC) induced composts at 3% level. Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different p < 0.05.

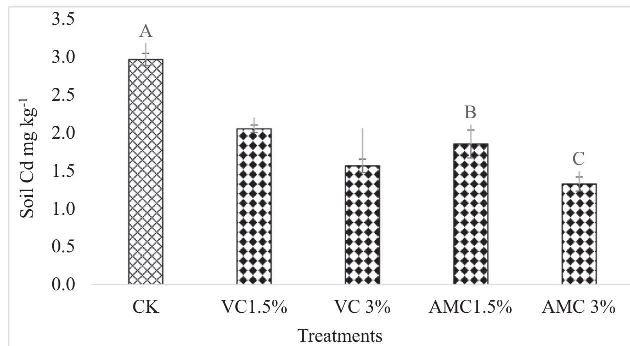

Fig. 2. Change in soil Cd after treated with vegetable waste (VC) and animal manure (AC) induced composts at 3% level. Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different p < 0.05.

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

The addition of vegetable (VC) and animal manure (AC) derived compost in polluted soil led to enhance soil organic carbon contents over without compost amended soil (Fig. 4). The significant improvement in soil carbon was recorded, when vegetable and manure derived compost application rate was increased from 1.5% to 3%. The highest increase in carbon contents were recorded in VC and AC compost by 36.5% and 46.6% at 3%, respectively, relative to non-amended soil.

Similarly, the bioavailable status of NPK nutrients efficiently improved in the VC and AC treated soil relative to non-amended soil (control) (Table 1). The prominent increase in available-N was recorded by 27.3% and 32.1% when VC and AC was mixed in polluted soil at 3% rate. Whereas, addition of VC and AC at 3% dose level showed the prominent increment in soil available-P by 47.6% and 52.2% relative to non-amended soil (control), respectively. Comparative to control, incorporation of VC and AC significantly enhanced soil available-K by 16.9% and 20.6% at 3% rate, respectively.

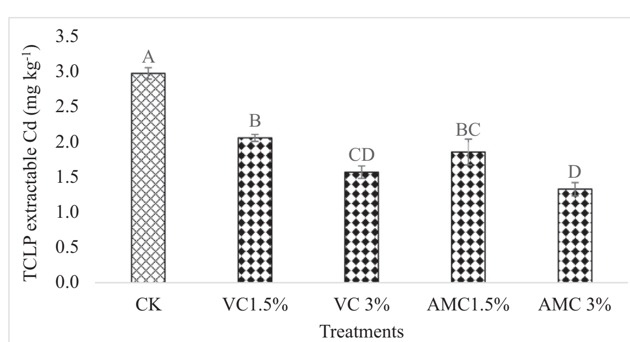

Fig. 3. Change in soil TCLP- extractable Cd after treated with vegetable waste (VC) and animal manure (AC) induced composts at 3% level. Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different p < 0.05.

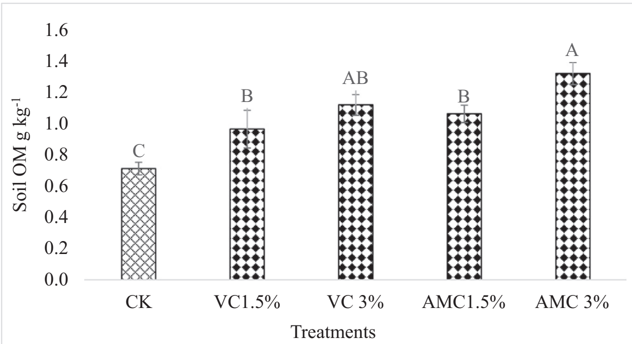

Fig. 4. Change in soil Organic matter (OM) after treated with vegetable waste (VC) and animal manure (AC) induced composts at 3% level. Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different $p < 0.05$.

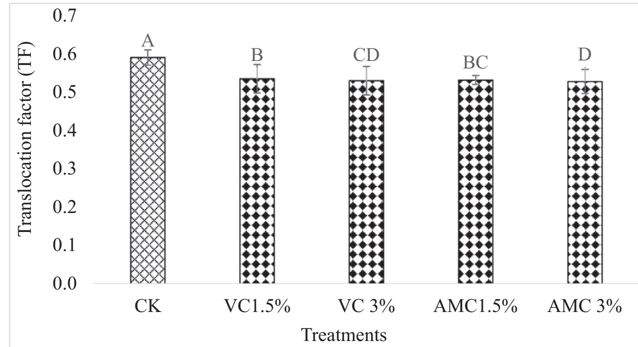

Fig. 6. Change in Cd translocation factor after treated Vegetable waste (VC) and animal manure (AC) induced composts at 3% level. Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different $p < 0.05$.

4.1. Effect of biochars on Cd uptake and chlorophyll contents

The results revealed that Cd accumulation in maize shoots and roots tissues was increased in wastewater polluted soil relative to soil treated with composts. However, addition of both kind of composts have the ability to reduce Cd uptake by maize tissues (Fig. 5). The greater reduction in Cd accumulation in plant shoots was recorded by 30.6% and 50% when VC was added at 1.5% and 3% rate respectively. Likewise, addition of animal manure induced compost also showed the significant reduction in Cd uptake. The maximum reduction was recorded by 38.8% and 58.3% when AC compost was incorporated at 1.5% and 3% dose level respectively over control. Similarly, the addition of organic soil amendments significantly reduced translocation of Cd from root to plant shoot (Fig. 6).

Results showed that the addition of various kinds of soil amendments in sewage wastewater irrigated soil efficiently improved the soil health and plant growth. The chlorophyll contents prominently improved in treated soil relative to control soil. The maximum increment in chlorophyll contents was recorded in VC and AC added soil by 28% and 31.5% 16.3% and 13.3% at 3% application rate, respectively over control (Table 2).

4.2. Effect of amendments on maize biomass and nutrients accumulation

The prominent increase in maize fresh and dry shoot root biomass was recorded when vegetable waste (VC) derived and animal manure (AC) derived compost was mixed with polluted soil at 3% dose level. The maximum fresh shoot and root biomass was recorded with the increase in the VC and AC application rate from 1.5% to 3% relative to control (Table 2). While, the maximum dry biomass was also increased among all the added soil amendments soils. Likewise, all other growth and yield parameters were improved among all the incorporated treatments (Table 2). Similarly, nutrients contents were also prominently enhanced in maize shoot parts after the mixing of treatments in polluted soils. The plants grown in treated soil showed the significant increase in N (19.7% and 32.7%), P (29.7 and 38%) and K (25.3% and 26.6%) after CV and AC addition at 3% rate, receptively over non-treated soil (Table 2).

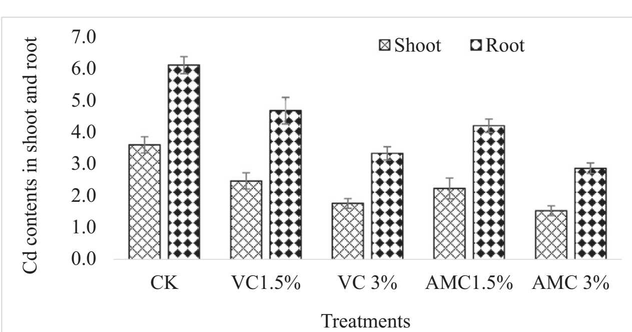

Fig. 5. Change in Cd accumulation in maize shoot and root after treated Vegetable waste (VC) and animal manure (AC) induced composts at 3% level. Error bars are the SD of the means (n = 3) and different letters indicate that values are significantly different $p < 0.05$.

5. Discussion

In current study, soil contamination caused by the frequent use of sewage wastewater as an irrigation source. Thus, the restoration of soil health using organic soil amendments (composts) is deliberated an appropriate candidate. Recently, excessive quantity of organic waste material was discarded and discharged around the globe and much of them were processed and recycled for agricultural inputs. The present results revealed that both composts: vegetable compost (VC) and animal manure derived compost (AC) have the ability to influence soil chemical properties (pH, EC, OM, AN, AP and AK) and soluble portion of Cd which could reduce the maize growth in wastewater irrigated polluted soil.

Firstly, the addition of both composts (VC and AC) significantly declined the soil pH and improved the nutrients availability in alkaline contaminated soil (Table 1 and Fig. 1), because of the richness of compost with essential nutrients and the possible decomposition of organic matter. The organic carbon (OC) contents in VC and AC treated soil significantly increased which could improve the soil fertility status, water contents and metals mobility in polluted medium (Ondrasek et al., 2019). Soil available nutrients were prominently increased among both the composts amended soils. Similar findings were explained by the recent studies Song et al. (2020) and Grigatti et al. (2017) indicated that potassium and phosphrous are the key nutrients which could directly release from compost and contribute for crop growth. It can be demonstrated that the addition of both composts could improve soil available nutrient status and improved their uptake by plants tissues.

Previous studies described by Congreves et al. (2015) and Lemaire et al. (2019) suggested that soil pH, EC, available nutrients and OM were considered the key factors that directly influence the soil health. The studied soil showed the remarkable decline trend in soil pH after the addition of VC and AC which might be the release of humic and organic substances from composts. Similar findings were reported by Tang et al. (2020) confirmed that organic

Table 2
Change in plant height (PH), Shoot fresh biomass (SF); Dry shoot biomass (DS); Fresh root biomass (FR); Dry root biomass (DR) and Chlorophyll contents after treated Vegetable waste (VC) and animal manure (AC) induced composts at 3% level. Lettering are given on the basis of means (n = 3) and different letters indicate that values are significantly different $p < 0.05$.

Treatment	PH	SF	DS	FR	DR	Chl
CK	62.3D	17.7C	7.9C	7.3C	3.6C	18.5C
VC1.5%	66.3CD	20.4B	9.2BC	8.2BC	4.3BC	22.3B
VC 3%	74.7AB	22.3B	10.6AB	10.1AB	5.3AB	25.7A
AMC1.5%	69.0BC	21.2B	11.4A	9.4BC	4.5BC	23.2B
AMC 3%	79.3A	25.3A	12.3A	12.4A	6.4A	27.0A

soil amendments especially compost could release humic substances from which could contribute to lessen soil pH. These findings were in line with the previous study discussed by Borchard et al. (2014) investigated that the incorporation of compost into soil could discharge the sufficient amount of humic acid which has ability to decline the soil pH. Zeng et al. confirmed the efficiency of compost for the prominent reduction in soil pH because of the organic substance and organic acids presence in it, which could decompose and mineralized.

Comparing to the control soil, the compost amended soil showed the significant reduction in Cd solubility and leachability at 3% application rate. The reduction of Cd in both extractable techniques were maximum in animal manure derived compost (AC) treated soil because of its alkaline and organic nature relative to vegetable waste compost (VC). Presence of humic substance and sufficient amount of carbon contents could ameliorate the toxicity of Cd in polluted soil and reduce the uptake of Cd in maize tissues. In the similar manner, Liu et al. 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 PTEs mobility because of minerals, organic acids and microbes which could contribute to influence the metals stabilization Awasthi et al. 2015; Bialobrzewski et al., 2015). Cd stabilization in wastewater irrigated soil might be due the involvement of the following chemical reactions including: sorption, complexation, precipitation, and redox reactions (Lagomarsino et al., 2011; Park et al., 2011). Pardo et al. (2011) established that the incorporation of composts induced from animal manure significantly improved the stabilization process of Zn and Pb and altered the speciation of these metals.

In current study, accumulation of Cd in maize tissues effectively decreased with the increasing rates of both animal manure and vegetable waste derived composts from 1.5% to 3% application dose relative to untreated soil. This reduction might be because of Cd binding with the organic substance that were present in the compost. These results were in the line of previous study reported by Pérez-de-Mora et al. (2006) investigated that the addition of organic matter based soil amendments could significantly reduce the phytoavailable pool of Cu and As in polluted soil by reducing their mobility. Vodounnou et al. (2016) investigated the efficiency of animal wastes (cow, sheep, pig, rabbit and poultry) and vegetable produced compost can enhance the earthworm in soil as a substrates and improve the availability nutritive element.

Karami et al. (2011) confirmed the effectiveness of soil amendments e.g., green waste compost and biochar for the phytoavailability of metals such as copper (Cu) and lead (Pb) in plants tissues. Moreover, the incorporation of biochar and compost expressively reduced the Cu and Pb toxicity by hindering their uptake in plant tissues. Present study suggested that the vegetable and animal manure derived composts prominently improved maize biomass and enhanced the chlorophyll contents. These findings assumed that the addition of compost effectively reduced soil pH that might contributed to improve nutrient solubility in alkaline soil. Recently, Adejumo et al. (2018) suggested that the mixing of compost in metal effected soils significantly improved the maize growth because of the sufficient amount of nutrients in soil which might have great contribution to enhance soil health and crop growth. Abbas et al. (2020a; 2020b) suggested that the addition of various amendments compost and biogas slurry with and without biochar mixings has the prominent influence on the soil nutrient status and maize growth.

6. Conclusion

In support of our hypothesis, this study confirmed the comparative efficiency of animal manure derived compost (AC) and vegetable waste induced compost (VC) at 3% application rate for maize growth in sewage wastewater soil. In addition, lessening the detrimental effects of Cd could ameliorate the soil pollution and hinder the Cd contamination in the food chain among both composts. The present findings reveled that all soil amendments have the ability to alter soil pH, nutrients availability in soil–plant system, reduces the mobility and uptake of Cd in maize plant as well as minimize its toxicological and physiological stress in polluted soil. Plant biomass and chlorophyll contents in maize leafs were also increased especially in compost. Therefore, it can be concluded that the addition of composts prepared from animal and vegetables wastes is a cost effective remediation method, and promising strategy to restore the wastewater contaminated soil by reducing the Cd availability and improving microbiological and biochemical conditions. Additionally, the findings of current study need to be further confirmed on large scale field experiments under the presence of multiple potential toxic elements

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