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THE POTENTIAL OF COMMERCIAL COMPOSTS IN REDUCING HEAVY METALS AND METALLOIDS PHYTOACCUMULATION IN MAIZE

WAQAS AHMED[1], QAMAR UZ ZAMAN[1*], FAISAL MEHMOOD[2], ASIM ABBASI[3], KAMRAN ASHRAF[4], KOMAL FATIMA[1], SABA NAZIR[1], NAYAB KOMAL[1] AND MUHAMMAD WAQAS[1]

[1] Department of Environmental Sciences, The University of Lahore, Pakistan
[2] Department of Chemistry, The University of Lahore, Pakistan
[3] Department of Environmental Sciences, Kohsar University, Murree, Pakistan
[4] Department of Food Sciences, Government College University, Faisalabad, Sahiwal Campus, Sahiwal, Pakistan
[*] Corresponding author's email: qamar.zaman1@envs.uol.edu.pk

Abstract

Plants uptake the heavy metals (HMs) from soil and accumulate in human body and biomagnifications via food chain causes both environment pollution and human health issues. Various amendments of organic and inorganic nature were applied to minimize the metal contamination of soil. Present study investigated the effects of composts for mitigation of metals and metalloids stress in maize. Experimental treatments were comprised of composts (GO-Organic composts and Lahore compost), metals and metalloids (Cd, As and Cr) and their levels (0, 25 and 50 ppm). Results revealed that as HMs and metalloids stress increased in soil, the physiological, growth, quality and yield attributes gradually decreased. Higher levels (50 ppm) of metals stress significantly reduced all attributes as compared to control (0 ppm). The decreasing order of metals and metalloids stress in all parameters was As > Cr > Cd. Maximum reduction in chlorophyll contents (23.1%), cob length (41.3%), cob diameter (32.6%) and grain yield per plant (26.8%) were observed at the 50 ppm of metals and metalloids compared to control. However, an increase of 70.5%, 118.4% and 43.9% in enzymatic activities of SOD, POD and CAT, respectively, was noticed at the same level. Whereas, by using compost, all attributes were significantly improved primarily due to the gradual decrease in accumulation of metals and metalloids in different parts of the plant which ultimately diminishes stress in maize plants with GO-Organic Compost more profound than Lahore Compost. In crux, heavy metals have detrimental effects on the growth, photosynthesis, enzymatic antioxidants, yield and quality of maize. However, compost can be applied safely for maize cultivation in soil spiked with metals and metalloids.

Key words: Maize, Heavy metals, Yield, Physiological, Plant growth and Biochemical.

Introduction

The sustainability of all living organisms including plants and arable lands has been compromised due to unprecedented bio-magnification of heavy metals (HMs) into environment (Minhas *et al*., 2017; Woldetsadik *et al*., 2017; Kweza, 2020). Different anthropogenic activities such as uncontrolled discharge of xenobiotic pollutants in water bodies, urban runoff, mining and burning of liquid and solid fuels are the prime culprits for this rapid bioaccumulation of HMs in our environment (Khan *et al*., 2018; Jurelevicius *et al*., 2021). Moreover, the sustainability of our best suited agro-ecological systems is also at risk due to these eco-destructive activities (Misra, 2018; Martindale, 2019). Optimal concentrations of some essential heavy metals, such as Fe, Co, Zn, Ni, Se and Cu, are required for normal growth and functioning of crop plants. However, when concentrated over supraoptimal level in soil solution or plant tissues, they tend to be toxic in nature (Sun *et al*., 2018; Kosakivska *et al*., 2021; Varshney *et al*., 2021). Conversely, traces of non-essential metals like As, Cs, Pb and Cd can severely effect on plant growth and development (Muszyńska & Labudda, 2019; Shahid *et al*., 2020). Heavy metals normally victimized both aboveground and underground plant surfaces (Sun *et al*., 2018).

Exposure to these heavy metals can inflict score of anomalies in crop plants including inhibition of different physiological functions (Moon *et al*., 2020), alteration in membrane permeability and protein activity (Ajdidi *et al*., 2020; Serreli *et al*., 2020), inactivating photosystems (Gadd, 2007; Lima-Melo *et al*., 2019) and disruption of mineral metabolism (Gadd, 2007). Apart from these, metal pressure also generates excessive ROS which in turn damage plant cellular structures via oxidation of lipids and proteins, chlorosis of shoot cells, and inaction of certain enzyme functioning caused death of plant cells (Onaga & Wydra, 2016; Ahmed *et al*., 2021).

The non-degradable and persistent nature of heavy metals is a major hindrance in remediating contaminated soils (Farooq & Jalees, 2020). Moreover, most of the conventional soil remediation approaches are quite expensive and protracted with little or no field success (Alegbeleye *et al*., 2018). In this regard, usage of organic composts can be a viable option to mitigate the risks associated with heavy metal toxicity (Dancer, 2014). Compost is produced as a result of partially controlled bio-oxidative process known as composting which involves conversion of solid state heterogeneous organic matter (OM) into humified material (Xia *et al*., 2020). Compost is often incorporated in contaminated soils as a remedial material to lessen the toxicity of metals (Beesley *et al*., 2010). Compost is a superior quality organic fertilizer having potential to replenish important soil nutrients, enhance soil microbial activity and improve soil health and structure (Babu *et al*., 2020).

Various physico-chemical approaches, such as chemical precipitation, evaporative recovery, reverse osmosis, flocculation, stabilization, extraction, immobilization and soil washing of landfills. have been deployed in order to make derelict soils cultivable again.

However, most of these techniques are not affordable for the farmers and also cannot be used to treat large land area (Gupta & Diwan, 2017). In recent times, soil remediation has emerged as a viable field-oriented alternative that can successfully convert heavy metal polluted soils into cultivable form again. Generally, soil remediation processes have been divided into two main types, *in situ* bioremediation which involves treatment of xenobiotics at the site of their origin and ex situ bioremediation which involves treatment of contaminated soil at place other than its original site. Of these two strategies *ex situ* remediation is more expensive, labor-intensive and ecologically unsafe (Jurelevicius *et al*., 2021).

In consideration of above facts, the current study was designed to investigate the toxic effect of various levels of metals and metalloids stress on the growth, productivity, enzymatic antioxidants, and metal accumulation in plant organs of maize. Moreover, efficacy of two new commercially available composts was assessed for the mitigation of metals and metalloids toxicity in maize plants. We hypothesized that compost application could be a more effective, easily available and ecofriendly strategy for the improvement in maize productivity under metals and metalloids stress.

Materials and Methods

Experimental site and plant material: A potted maize plant (*Zea mays* L.) trial was conducted in a greenhouse located at Department of Environmental Sciences, The University of Lahore, Lahore, Pakistan. The experimental trial was conducted in completely randomized design (CRD) under factorial arrangement with three replications. Three factors studied in this experiment were composts (GO-Organic and Lahore Compost), metals and metalloids (Cd, Cr and as) and three levels each of Cd, Cr and as (0, 25 and 50 ppm). Ten surface sterilized seeds of putative maize genotype (Kashmir Gold) were sown in 12-kg capacity earthen pots filled with sandy loam soil (EC: 1.78 dS m^{-1} and pH: 7.2) collected from different fields prepared for maize sowing. The collected soil was sieved through 4 mm mesh, sterilized, and homogenized before use. After the emergence of seedling, thinning was performed to ensure a final stand of five healthy vigorous plants per pot. The pots were irrigated twice a week with Peter's Professional fertilizer (Scotts, Marysville, OH), N:P: K 20:20:20. After six weeks of seedling emergence, metal solutions according to treatment plans were prepared in distilled water and applied directly to the soil near the base of the growing plants to induce metals and metalloids toxicity. The pots were amended with composts (layer composting method (1 inch compost layer) with irrigation) two weeks after stress application. Two plants were assessed for the growth and physiological attributes at 60 days after sowing and remaining plants from each replication were used for yield and metal acquisition at the physiological maturity.

Physiochemical analysis of soil and composts: Before the start of experiment, the pH and EC of the soil and compost samples were measured by pH meter (EUTECH pH 700) and conductivity meter (STARTER 3100C), respectively. Nitrogenous contents of both samples were estimated by Kjeldhal method (Putra & Soni, 2018). $K_2Cr_2O_7$ wet oxidation method was used to determine organic matter contents (Bhattacharya & Osburn, 2020). Moreover, potassium and phosphorous contents were detected by standard curve using the flame photometer and Olsen method respectively (do Carmo Horta & Torrent, 2007).

Growth attributes of maize: After 60 days of sowing, the length and width of maize flag leaves were measured, and leaf area was calculated using the equation:

$$\text{Leaf area (LA)} = \text{Leaf length} \times \text{Leaf width} \times 0.75 \text{ (Correction factor)}$$

Plant height and intermodal distance were measured with a measuring tape from two randomly selected plants from each replication.

Enzymatic attributes of maize: After 60 days of sowing of compost application, chlorophyll contents of leaf were measured with Chlorophyll Meter (SPAD 502 Plus) (Minolta, Ramsey, NJ). For enzymatic activities such as POD, SOD and CAT various protocols were followed. Inhibition in photo-reduction of NBT (nitro blue tetrazolium) was used to find SOD activity. The reaction mixture (1mL) [phosphate buffer 500 µL (pH 7.8), 100 µL methionine, 0.5 mL distilled H_2O, 50 µL NBT and 50 µL sample extract] taken in cuvettes and were kept for 20 min under light. The OD of the irradiated aliquot was read at 560nm. The method of (Giannopolitis & Ries, 1977), enzyme activity of SOD per unit depends on the amount of enzyme that inhibited 50% of NBT photoreduction. The method of (Chance & Maehly, 1955) was used to find catalase (CAT) and peroxidase (POD) activities.

Yield attributes of maize: At the physiological maturity, three plants from each replicate were randomly selected and tagged from every pot and data regarding cob length and cob diameter was measured with measuring tape. Similarly, number of grains in each row, number of rows in each cob and number of grains in each cob were counted and grain yield per plant was assessed using electric balance.

Metal quantification: For quantification of Cd, Cr, and As contents in grains, leaf and roots of maize plants, a mixture of di-acid (HNO_3:$HClO_4$ 2:1) was used following the standard protocols devised by (Dancer, 2014).

Statistical analysis

The collected data regarding all attributes were subjected to Fisher's ANOVA for analyses and treatments means with significant differences were separated by LSD test at $p \leq 0.05$. All statistical analyses were carried out using Statistix 8.1 package (Analytical Software, Tallahassee, FL).

Results

Physiochemical analysis of soil and composts: The summary of physiochemical properties of soil and composts are shown in (Table 1). The pH was observed as 8.3, 7.5 and 6.7 and EC as 411, 320 and 360 µS/cm for soil, Lahore compost and GO-Organic compost respectively. For mineral contents the observed value for the phosphorus content as 350, 1123 and 1322 mg kg^{-1}, potassium content as 200, 1356 and 1711 mg kg^{-1} and nitrogen content as 210, 1560 and 2011 mg/kg^{-1} were noticed in soil, Lahore compost and GO-Organic compost respectively. However, the organic matter percentage was 1.76, 16.5 and 18.07% for soil, Lahore composts and GO-organic composts respectively.

Growth parameters: Applications of compost (C) at the various levels (L) of metals and metalloids stress (M) in maize showed a significant impact on height of plant, leaf area and internodal length of maize plants as compared to sole application of compost treatments (control). While the interactive effects showed significant results for all the growth attributes except C × M for internodal length and C × M × L for plant height and internodal length (Table 2). For different compost maximum plant height (187 cm), leaf area (225 cm^2) and internodal length (13.6cm) was recorded where GO-Organic compost was applied in metals and metalloids spiked soil. For metals and metalloids stress highest plant height (189 cm), leaf area (228 cm^2) and internodal length (13.8 cm) was noted in Cd followed by Cr while lowest of the growth paraments was noticed in the As contaminated soil. All the attributes showed variation where different levels of metals and metalloids were used. The maximum reduction was noticed at 50 ppm dose in all the growth attributes compared to control.

Table 1. Physiochemical analysis of soil and composts (Means ± SE).

Attributes	Soil	Lahore composts	GO-Organic composts
pH	8.3 ± 0.07	7.5 ± 0.09	6.7 ± 0.08
EC (µS/cm)	411 ± 0.11	320 ± 0.15	360 ± 0.23
Phosphorus (mg kg^{-1})	350 ± 0.21	1123 ± 0.75	1322 ± 0.82
Potassium (mg kg^{-1})	200 ± 0.55	1356 ± 0.89	1711 ± 0.91
Nitrogen (mg kg^{-1})	210 ± 0.44	1560 ± 0.95	2011 ± 0.88
Organic matter (%)	1.76 ± 0.09	16.5 ± 0.05	18.07 ± 0.09

Table 2. Combinatorial effect of commercial composts, metals and metalloids stress at various rates on the growth attributes of maize.

Treatments	Plant height (cm)	Leaf area (cm^2)	Internodal length (cm)
Compost (C)			
C$_1$ = GO-Organic Compost	186.8 A	224.58 A	13.61 A
C$_2$ = Lahore Compost	183.2 B	221.91 B	13.31 B
Metals and metalloids (M)			
M$_1$ = Cadmium (Cd)	189.2 A	227.58 A	13.77 A
M$_2$ = Chromium (Cr)	185.4 B	225.41 B	13.51 B
M$_3$ = Arsenic (As)	180.4 C	216.75 C	13.10 C
Levels (L)			
L$_1$ = 0 ppm	205.4 A	245.12 A	16.29 A
L$_2$ = 25 ppm	181.9 B	217.00 B	12.87 B
L$_3$ = 50 ppm	167.6 C	207.62 C	11.23 C
HSD (C) ($p \leq 0.05$)	0.97	0.98	0.08
HSD (M) ($p \leq 0.05$)	1.44	1.44	0.11
HSD (L) ($p \leq 0.05$)	1.44	1.44	0.11
HSD C × M ($p \leq 0.05$)	2.50	2.51	0.19
HSD C × L ($p \leq 0.05$)	2.50	2.51	0.19
HSD M × L ($p \leq 0.05$)	3.36	3.37	0.26
HSD C × M × L ($p \leq 0.05$)	5.40	5.41	0.42
F-value (C)	54.93**	30.89**	65.61**
F-value (M)	113.11**	188.90**	111.63**
F-value (L)	2108.31**	2192.64**	6482.01**
F-value C × M	3.66*	17.63**	0.21^{NS}
F-value C × L	5.67*	3.46*	9.39**
F-value M × L	19.17**	28.43**	35.92**
F-value C × M × L	1.09^{NS}	5.09*	2.17^{NS}

Different letters indicate significant difference between the treatments ($p \leq 0.01$ HSD test)

Table 3. Combinatorial effect of commercial composts, metals and metalloids stress at various rates on the biochemical attributes of maize.

Treatments	Chlorophyll contents (mg/L)	SOD (mg protein^{-1})	CAT (mg protein^{-1})	POD (mg protein^{-1})
Compost (C)				
C_1 = GO-Organic Compost	3.68 A	99.41 B	2.11 B	34.03 B
C_2 = Lahore Compost	3.64 B	104.03 A	2.15A	35.03 A
Metals and metalloids (M)				
M_1 = Cadmium (Cd)	3.74 A	96.41 C	2.06 C	31.96 C
M_2 = Chromium (Cr)	3.66 B	101.02 B	2.13 B	34.55B
M_3 = Arsenic (As)	3.58 C	107.72 A	2.21 A	37.10 A
Levels (L)				
L_1 = 0 ppm	4.24 A	77.99 C	1.36 C	31.96 C
L_2 = 25 ppm	3.48B	94.18 B	2.07 B	34.65 B
L_3 = 50 ppm	3.26 C	132.98 A	2.97 A	45.99 A
HSD (C) ($p\leq0.05$)	0.01	1.39	0.02	0.31
HSD (M) ($p\leq0.05$)	0.02	2.05	0.03	0.45
HSD (L) ($p\leq0.05$)	0.02	2.05	0.03	0.45
HSD C × M ($p\leq0.05$)	0.04	3.57	0.04	0.79
HSD C × L ($p\leq0.05$)	0.04	3.57	0.04	0.79
HSD M × L ($p\leq0.05$)	0.05	4.79	0.06	1.06
HSD C × M × L ($p\leq0.05$)	0.08	7.70	1.71	1.71
F-value (C)	36.82**	45.56**	26.48**	43.71**
F-value (M)	168.14**	92.12**	12129.3**	381.66**
F-value (L)	7393.40**	2273.52**	95.40**	7685.17**
F-value C × M	1.95^{NS}	0.35^{NS}	4.74*	7.15*
F-value C × L	5.97*	16.02*	0.99**	32.30**
F-value M × L	33.77**	28.58**	32.66**	131.14**
F-value C × M × L	1.80^{NS}	1.67^{NS}	0.41^{NS}	1.68^{NS}

Different letters indicate significant difference between the treatments ($p\leq0.01$ HSD test)

Chlorophyll contents and enzymatic antioxidants: Application of compost significantly affected chlorophyll contents and enzymatic antioxidants in maize plants grown in metals and metalloids spiked soil. Except C × M for chlorophyll contents and SOD and C × M × L, for all the interactive effects depicted significant outcomes (Table 3). Maximum improvement in chlorophyll contents was noticed where C_1 was applied as compared to C_2. However, opposite response for the enzymatic antioxidants was observed where Lahore compost showed maximum values. Maximum reduction in chlorophyll contents (23.11%) were observed where 50 ppm of metals and metalloids and increase in SOD (70.50%), POD (118.38%) and CAT (43.89%) was noticed. However, for metals and metalloids stress highest reduction was noticed in the As spiked soil. Similarly, for SOD, CAT and POD highest activity was noticed in As followed by Cr while lowest of enzymatic antioxidants were noticed in the Cd contaminated soil.

Yield parameters: Commercial composts applications in maize showed a significant impact on yield attributes of maize (Table 4). All the interactive effects were significant results for all the yield attributes except for C × M and C × M × L for all yield attributes. Maximum cob length (18.9 cm), cob diameter (3.7 cm), number of rows per cob (16.30), number of grains per row (41.04), number of grains per cob (650.56) and grain yield per plant (166.59 g) were observed where C_1 was applied as compared to C_2 in metals and metalloids contaminated soil. For metals and metalloids rates, highest decrease in cob length (41.32%), cob diameter (32.60%), number of rows per cob (47.27%), number of grains per row (22.68%), number of grains per cob (15.62%) and grain yield per plant (26.80%) was noticed at the highest level (L_3) of metals and metalloids in the soil compared to control (0 ppm). Highest reduction in the yield attributes was noticed in case of As spiking followed by in Cr while minimum was noticed in Cd contaminated soil.

Cd, As and Cr accumulations: Significant differences in Cd, Cr and As contents in root, leaves and grain of maize were observed (Tables 5-7). While, for interactive effects all the interactions showed non-significant results for the As contents in plant organs of maize except C × L for grains (Table 5), for Cd stress the interactive effect for Cd and levels showed significant results except C × L for leaves (Table 6) for the Cr stress interactive effect for Cr and its levels showed significant results except C × L for leaves (Table 7). For commercial composts maximum reduction in As contents in grains (17.07%), leaves (10.11%) and roots (60.55%), cadmium contents in grains (21.42%), leaves (10.16%) and roots (6.79%) and chromium contents in grains (13.72%), leaves (8.00%) and roots (1.16%) was observed where C_1 was applied as compared with C_2 in metals and metalloids spiked soil. Metals and metalloids stress at 50 ppm increased accumulation in grains, roots and leaves as compared to no stress (0 ppm). The highest accumulation of metals and metalloids in stress spiked soil for C × L showed that roots are more accumulator as compared to grains (Figs. 1-3).

Table 4. Combinatorial effect of commercial composts, metals and metalloids stress at various rates on the yield attributes of maize

Treatments	Cob length (cm)	Cob diameter (cm)	No. of rows per cob	No. of grains per rows	No. of grains per cob	Grains yield per plant (g)
Compost (C)						
C_1 = GO-Organic Compost	18.9 A	3.7 A	16.30 A	41.04 A	650.56 A	166.59 A
C_2 = Lahore Compost	18.2 B	3.6 B	14.44 B	39.52 B	641.11 B	161.96 B
Metals and metalloids (M)						
M_1 = Cadmium (Cd)	19.1 A	3.8 A	17.33 A	42.89 A	659.56 A	169.67 A
M_2 = Chromium (Cr)	18.5 B	3.7 B	15.00 B	39.83 B	647.00 B	163.78 B
M_3 = Arsenic (As)	17.9 C	3.6 C	13.78 C	38.11 C	630.94 C	159.39 C
Levels (L)						
L_1 = 0 ppm	24.2 A	4.6 A	21.28 A	46.56 A	712.00 A	193.56 A
L_2 = 25 ppm	16.6B	3.3 B	13.61B	38.28 B	624.72 B	157.61 B
L_3 = 50 ppm	14.2 C	3.1 C	11.22 C	36.00 C	600.78 C	141.67 C
HSD (C) ($p \leq 0.05$)	0.10	0.02	0.60	0.75	2.92	1.58
HSD (M) ($p \leq 0.05$)	0.15	0.03	0.89	1.10	4.31	2.33
HSD (L) ($p \leq 0.05$)	0.15	0.03	0.89	1.10	4.31	2.33
HSD C × M ($p \leq 0.05$)	0.27	0.05	1.54	1.92	7.50	4.06
HSD C × L ($p \leq 0.05$)	0.27	0.05	1.54	1.92	7.50	4.06
HSD M × L ($p \leq 0.05$)	0.36	0.06	2.07	2.58	10.07	5.45
HSD C × M × L ($p \leq 0.05$)	0.58	0.10	3.33	4.14	16.19	8.77
F-value (C)	204.57**	43.66**	39.06**	16.98**	43.03**	35.27**
F-value (M)	170.88**	170.88**	49.568**	57.48**	132.30**	58.35**
F-value (L)	12686.00**	12686.00**	419.17**	302.94**	2204.44**	1550.04**
F-value C × M	1.80^{NS}	1.80^{NS}	0.81^{NS}	0.07^{NS}	0.45^{NS}	0.04^{NS}
F-value C × L	52.94**	52.94**	4.89*	8.01*	10.48**	5.84*
F-value M × L	42.84**	42.84**	3.41**	9.97**	36.04**	21.42**
F-value C × M × L	1.96^{NS}	1.96^{NS}	0.18^{NS}	0.19^{NS}	0.39^{NS}	0.28^{NS}

Different letters indicate significant difference between the treatments ($p \leq 0.01$ HSD test)

Table 5. Combinatorial effect of compost and As stress on the As accumulation (mg kg^{-1}) in maize.

Treatments	Grains	Leaves	Root
Compost (C)			
C_1 = GO-Organic Compost	0.34 B	0.89 B	1.09 B
C_2 = Lahore Compost	0.41 A	0.98 A	1.75 A
Levels (L)			
L_1 = 0 ppm	0.10 C	0.65 C	1.26 C
L_2 = 25 ppm	0.35 B	0.94 B	1.48 B
L_3 = 50 ppm	0.69 A	1.21 A	1.62 A
HSD (C) ($p \leq 0.05$)	0.04	0.05	0.15
HSD (L) ($p \leq 0.05$)	0.06	0.08	0.22
HSD C × L ($p \leq 0.05$)	0.10	0.14	0.39
F-value (C)	14.40*	12.70*	344.96**
F-value (L)	372.85**	190.04**	46109.80**
F-value C × L	5.63*	2.57^{NS}	2.57^{NS}

Different letters indicate significant difference between the treatments ($p \leq 0.01$ HSD test)

Discussion

The accumulation of toxic elements, e.g., Cd, As and Cr in agricultural lands is of great concern due to its adverse impact on crop productivity and quality, health of soil organisms and ultimately food safety (Chen *et al.*, 2017). Among the heavy metals that are affecting soil and water quality, Cd, Zn, As, Cu, Pb, and Cd are the most dangerous elements in the ecosystem due to their high mobility in soil, plant, and water systems (Qin *et al.*, 2020). Crop production on the contaminated soils using the organic amendments is a sustainable way for achieving the better quality of produce and environmental sustainability. The present study revealed that the growth, productivity and quality of maize was variably affected by the heavy metal (Cr, As and Cd) stress. Higher levels of these metals reduced the growth and development of plants as described in earlier research work (Rout & Das, 2009; Alaboudi *et al.*, 2018). However, addition of organic amendments exerts a significant effect on morphological, physiological and biochemical process during the plant growth, germination of seeds, ion uptake and cell development in metal contained soils (Canellas & Olivares, 2014). In the current research, the improved growth, productivity and reduced metals accumulation in the maize plant was noticed by using the organic amendments in the metal spiked soils, same as previous findings (Beesley *et al*., 2010; Bassu *et al*., 2014). According to Wu *et al*., (2014) a significant reduction was noticed with the high level of heavy metals. These reductions become more prominent by increasing the metal and metalloids levels. Heavy metals and metalloids are considered as chief source for the cell membrane injury in the plants that ultimately results in changes in the morphological and physiological attributes of plant (Zaman *et al*., 2021). Maximum internodal length results in more photosynthetic area that ultimately results in better growth and biomass production (Karami *et al*., 2011). It is commonly known that organic amendments provide the essential nutrients to soil and binds the metals and metalloids and positively influenced the plant biomass and chlorophyll contents compared to the plants grown on the metals and metalloids spiked soil and enhanced enzymatic activities either directly or indirectly by changing soil nutrient level under metals and metalloids stress (Park *et al*., 2011; Lwin *et al*., 2018).

The current findings revealed that the higher levels of metal stress decreased the chlorophyll content in the leaves. It showed that higher levels of metals caused the chloroplast degradation and this is the main reason of reduction of chlorophyll content (Abbas *et al*., 2018). Photosynthetic pigments also reduced by high metal levels (Azevedo *et al*., 2005). It has already been described that when leaf begins old, even low contents of metals affected the chloroplast which is the first site of cell, fluorescence and chlorophyll content reduced by the cadmium stress led to reduction in photosynthetic efficiency of plants (Orr *et al*., 2016). While, the usage of organic composts has been proved more beneficent for the photosynthesis process (Scotti *et al*., 2015; Iqbal *et al.,* 2022). Metals and metalloids stress increased the enzymatic antioxidants (SOD, POD and CAT) in maize and considered as indicators of more reactive oxygen species generation. Application of compost showed the main mechanisms for detoxification of metals in plants and considered as an effective approach to strengthen cell organelles and to minimize the risk associated with oxidative stress indicators by metals and metalloids (Shakir *et al*., 2018). Previously, it was noticed that metal stress in the rhizosphere increased the activities of enzymatic antioxidants in leaves of sunflower (Gopal & Nautiyal, 2011). The performance physiologically active antioxidants enzymes are affected by increasing the metals and metalloids rates in the soil plant ecosystem (Gadd, 2007).

Table 6. Combinatorial effect of composts and Cd stress on the Cd accumulation (mg kg^{-1}) in maize

Treatments	**Grains**	**Leaves**	**Root**
Compost (C)			
C_1 = GO-Organic Compost	0.14 B	0.59 B	1.62 B
C_2 = Lahore Compost	0.17 A	0.65 A	1.73 A
Levels (L)			
L_1 = 0 ppm	0.05 C	0.25 C	1.25 C
L_2 = 25 ppm	0.15 B	0.68 B	1.72 B
L_3 = 50 ppm	0.27 A	0.95 A	2.07 A
HSD (C) ($p \leq 0.05$)	0.02	0.03	0.05
HSD (L) ($p \leq 0.05$)	0.03	0.05	0.07
HSD C × L ($p \leq 0.05$)	0.05	0.08	0.12
F-value (C)	12.06*	17.36*	25.89**
F-value (L)	201.29**	803.58**	519.36**
F-value C × L	4.49*	3.88^{NS}	9.97*

Different letters indicate significant difference between the treatments ($p \leq 0.01$ HSD test)

Table 7. Combinatorial effect of composts and Cr stress on the Cr accumulation (mg kg^{-1}) in maize.

Treatments	**Grains**	**Leaves**	**Root**
Compost (C)			
C_1 = GO-Organic Compost	0.51 B	2.00 B	5.99 B
C_2 = Lahore Compost	0.58 A	2.16 A	6.06 A
Levels (L)			
L_1 = 0 ppm	0.11 C	1.12 C	3.02 C
L_2 = 25 ppm	0.50 B	2.10 B	6.01 B
L_3 = 50 ppm	1.02 A	3.03 A	9.05 A
HSD (C) ($p \leq 0.05$)	0.06	0.07	0.03
HSD (L) ($p \leq 0.05$)	0.08	0.11	0.05
HSD C × L ($p \leq 0.05$)	0.15	0.19	0.09
F-value (C)	8.33*	22.04*	20.90*
F-value (L)	420.98**	1086.56**	55156.40**
F-value C × L	4.40*	1.42^{NS}	7.83*

Different letters indicate significant difference between the treatments ($p \leq 0.01$ HSD test)

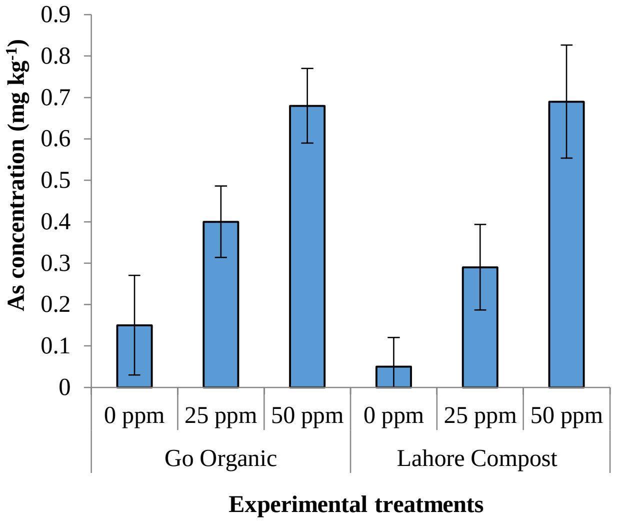

Fig. 1. Combinatorial effect of compost and various As rates on the As accumulation in grains of maize.

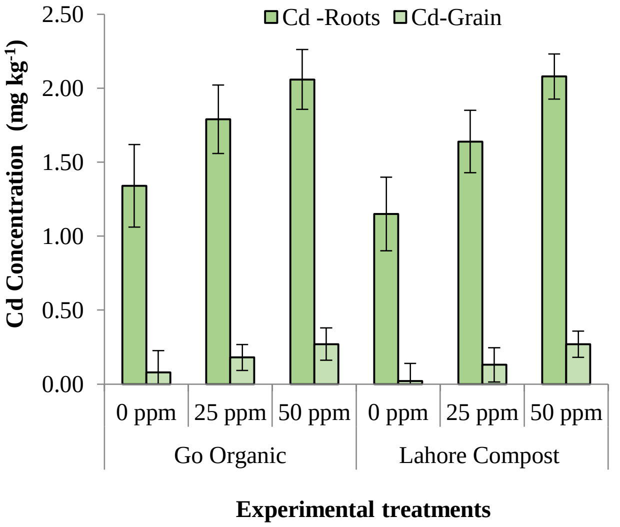

Fig. 2. Combinatorial effect of compost and various Cd rates on the Cd accumulation in grains of maize.

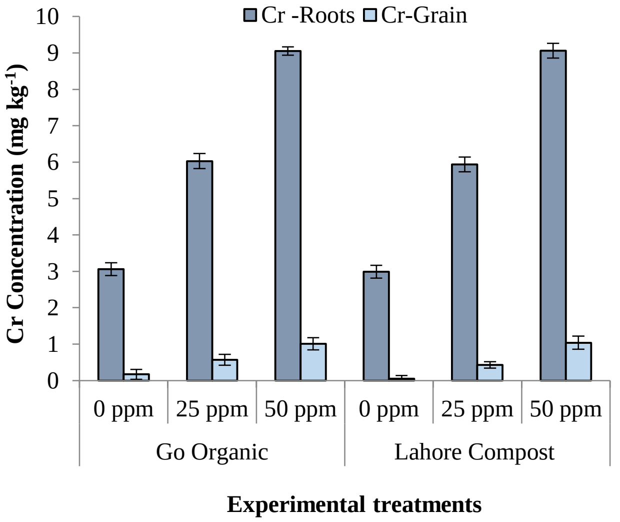

Fig. 3. Combinatorial effect of compost and various Cr rates on the Cr accumulation in grains of maize.

All the yield parameters of maize such as grain yield plant^{-1}, grains cob^{-1}, grains per row, number of rows, diameter of cob and length of cob were decreased significantly by increasing the metal levels in the growing medium. Significant decrease in plant yield and growth occurred due to metal supplements from 0-50 ppm in the rhizosphere of soil (Piracha *et al.*, 2019). In this research an adverse effect was observed significantly by the stress of heavy metals on the yield attributes of maize crops. Similar findings such as reduction in per plant yield and other biochemical activities was due to higher contents of metals (Tang *et al.*, 2020). According to previous studies the usage of organic composts frequently increases the yield of crops and improve the soil properties as compared to unused composts soil (Courtney & Mullen, 2008; Cherif *et al.*, 2009). Plants uptake the metal contents from the heavy metal accumulated soil (Zwolak *et al.*, 2019). So, various factors like transpiration, root exudation, mycorrhiza ion and surface area of roots affect bioavailability and absorption of metal contents (Soudek *et al.*, 2014). The Ca^{2+}permeable channels and apoplastic pathway were used by the plants for the absorption of metals. These are primarily stored in root cells after the up taken due to endodermis blockage via casparion strips (Pourrut *et al.*, 2011). Lead is fully trapped in roots through negative charges (Schwab *et al.*, 2016). Many toxic effects were occurred by accumulation of lead on biochemical, physiological and morphological functions of plants (Abdelkrim *et al.*, 2018). The entered metals cause toxicity by permeability of cell membrane, complex formation with ATP and ADP, essential ion replacement and metabolic enzyme activity (Bai *et al.*, 2018). Enzyme activity inhibition was caused by toxicity of metals, production of ATP forbidden, hormonal disturbance, water imbalance, mineral nutrition and detrimental to plant DNA by the overproduction of reactive oxygen species (Sharma & Dubey, 2005; Sethy & Ghosh, 2013). However, the balanced application of composts has ability to bind the metals and metalloids and hinders their uptake in plant organs (Emamverdian *et al.*, 2015; Aslam *et al.,* 2022).

Conclusion

This study showed that high levels of metal and metalloids contents in the soil reduced growth and biomass, photosynthetic and antioxidative machinery, yield and metal uptakes in maize plants compared to those of the control, respectively. More reduction in the growth and yield attributes was noticed at maximum levels (50 ppm) of metals and metalloids stress as compared to control. Furthermore, metals and metalloids stress at higher level increased antioxidative stress indicators SOD (70.51%), POD (43.90%), CAT (58.38%) and metals acquisition in plant organs [As in grains (90%), As in leaves (86.15%), As in roots (28.57%), Cd in grains (40%), Cd in leaves (80%), Cd in roots (65.60%), Cr in grains (87.27%), Cr in leaves (70.54%), Cr in roots (79.67%)] as compared to control. Application of compost confers the normal plant growth even under metals and metalloids stress. Therefore, in future research, more lowcost, eco-friendly soil remediation field studies should be conducted to draw parallels in maize crop using combination of organic and inorganic amendments in order to gain insights into underlying mechanism for better soil health and plant productivity.

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