



**International Journal of Biology, Pharmacy  
and Allied Sciences (IJBPAS)**  
*'A Bridge Between Laboratory and Reader'*

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**ACCUMULATION AND EFFECTS OF Pb, Cr AND Cd ON GROWTH OF ZEA MAYS  
SEEDLINGS**

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Received 8<sup>th</sup> Dec. 2016; Revised 11<sup>th</sup> Feb. 2017; Accepted 14<sup>th</sup> March 2017; Available online 1<sup>st</sup> May

**ABSTRACT**

Heavy metals caused adverse effects on the plant growth and development, microbial growth and survival, productivity of soil and quality of soil. Heavy metal toxicity caused death of plants and soil microbes; therefore the removal of heavy metals from soil is necessary to keep microbes and plant healthy along with clean and pure environment. Prescribed study was conducted at Institute of Agricultural Sciences, University of the Punjab Lahore, Pakistan to assess the ability of maize genotypes (SWL-2002 and Raka-poshi) to grow and survive under heavy metals (chromium, cadmium and lead) in different treatments (control, 0.5mM CrCl<sub>3</sub>, 0.5mM CdCl<sub>2</sub>, 0.5mM Pb(NO<sub>3</sub>)<sub>2</sub>, 0.5mM+0.5mM CrCl<sub>3</sub>+CdCl<sub>2</sub>, 0.5 mM+0.5mM+0.5mM CrCl<sub>3</sub>+CdCl<sub>2</sub>+Pb(NO<sub>3</sub>)<sub>2</sub>). It was found from results that both of the maize genotypes showed almost similar behavior under heavy metals treatments for different morphological studied traits. Strong and positive correlation was reported among the morphological traits and among the uptake of heavy metals by leaves, roots and stem. From principal component analysis it was revealed that most of the variation was due to the uptake of heavy metals by root, leaves and stem. The lowest uptake of chromium, cadmium and lead was reported under control and 0.5 mM+0.5mM+0.5mM CrCl<sub>3</sub>+CdCl<sub>2</sub>+Pb(NO<sub>3</sub>)<sub>2</sub> treatment which indicated the ability of heavy metals to be up taken by roots from root zone area of maize plants. It was concluded from results that the heavy metals caused adverse effects on morphological traits of maize which ultimately reduced production and

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productivity of maize. It was also found beside the adverse effects of heavy metals maize may be used for the removal of heavy metals from soil biosphere.

**Keywords:** *Zea mays*, heavy metals, cadmium, chromium, lead, correlation, principal component analysis

## INTRODUCTION

Maize is the world's largest yielding crop with a lot of uses including industrial material, fodder, as raw source to produce bio energy and most importantly food. Among cereal crops it ranks third in Pakistan after wheat and rice. It occupies 4.8% of cultivated area and adds around 3.5% of productive agricultural supply. In our country, two provinces NWFP and Punjab are the major producers of this crop making 57% and 30% respectively [1]. among this 97% total irrigated maize, 65% has easy excess to irrigation while remaining crop is irrigated under strict conditions of rain [2,3]. The seed used for cultivation of maize has been improved for couple of years and new hybrid varieties has been introduced for elevated growth output. There are certain biotic and abiotic factors that are directly effects the yield of crop. In case of maize, these stresses include drought, moisture, temperature elevation or drop in atmospheric temperature, salinity, heavy metals, water logging *etc.* [4,5].

## EFFECT OF HEAVY METALS ON ZEA MAYS

Heavy metals have strong influence on crop production; they check the rate as well as the pattern of growth in crops. Heavy metals pollution is posing serious issues to crops as the increased industrialization is adding more share of heavy metals to soil and water which directly effects the environment and human health [6]. Heavy metals express themselves by directly affecting the soil biological systems. Heavy metal contamination is detected by different approaches, among those one is microbial biomass carbon [6,7].

## CADMIUM

Cadmium is highly toxic and non-essential component for plants. Presence of cadmium in the soil alarms for its toxicity as cadmium is involved in disturbing homeostasis of plants, inhibiting the growth of roots and shoots and it hinders water uptake of plant [6]. Cd toxicity causes "oxidative cell damage" to corn crop [8]. It causes necrosis, changes morphological traits, wilting of plants, chlorosis and

cellular damage [9]. Cd disturbs the supply of other essential nutrients .i.e. Zn to the plant hindering proper growth and photosynthesis [10] due to degradation of chloroplast structure. Cd enters maize plant through Calcium pathways or through some other carriers and compete with them, depriving corn of its essential required elements [11].

### **CHROMIUM**

Chromium is another non essential and toxic element for the growth of maize. It's toxicity depends on its valency as Cr (III) is comparatively less toxic than Cr(IV) which is highly toxic. Cr causes retardness of growth and growth pattern rendering malfunctioned physiological functions. It not only alters the translocation ability of maize plant but also induces oxidative stress condition [12]. Cr uptake by corn plant causes its leaves dry weight just like the iron deficiency condition [13]. Cr disturbs photosynthetic ability of maize by disrupting the main photosynthetic unit –the chlorophyll. It directs improperly grown lamella having fewer grana and thylakoids spaced at wider distance from each other [14]. Cr compete with essential components for maize due to similarity of structure with them [15].

### **LEAD**

Lead being one of non essential, high toxic heavy metal is profoundly unwanted in food chain. Pb gets accumulated in the corn seedling and cause deleterious effects to the crop. It stops seedling growth of corn, retarded photosynthesis, disrupted growth stages i.e. mitosis, malfunctioned water transportation, in a nut shell Pb adversely effects the maize production [16]. Accumulation of Pb inhibits root growth [17]. Pb effects the enzymatic activity, changes permeability of corn plant membranes, [18] reported inhibition of germination by Pb, disturbed water and nutrients transport , bad photosynthesis, imbalanced hormonal distribution and ultimately cell death following inhibition of cellular activities. It also competes other metals that are good for maize production i.e. magnesium and iron *etc.* [19]. The study was planned to find the effect of heavy metals on growth and the uptake of heavy metals by plant body parts.

### **MATERIALS AND METHODS**

The proposed study was carried out to estimate the toxic effect of cadmium (Cd), lead (Pb) and chromium (Cr) on normal growth and heavy metal uptake of maize plant in earthen pots lined with polyethylene

bags and filled in with eight kg sterilized sand, in the green house in the Institute of Agricultural Sciences, University of the Punjab Lahore Pakistan, located at  $74.34^{\circ}$  East longitude and  $31.55^{\circ}$  North latitude, at an altitude of 224 meter from sea level, where the climate is semi arid and subtropical.

### SEED MATERIAL

Seeds of Maize variety SWL-2002 and Raka-poshi were used in this study, obtained from Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan.

### SEED GERMINATION

Seeds were surface sterilized with 10% v/v hydrogen peroxide [20] before sowing making 2cm deep holes with the help of a wooden stick (1.5 cm diameter) sowed eight seeds in each pot. Afterwards, each seed was covered with a small amount of soil for proper supplement of germination factors. By thinning we maintained only six seedlings in each pot in order to avoid imbalanced uptake of heavy metals by plants. Water added and mixes thoroughly in order to maintain field capacity of soil. Fertilizer added to increase the growth rate.

### EXPERIMENTATION

The experiment comprised three replicates and was laid out in a RCBD (randomized

complete block design). Chromium used as a source ( $\text{CrCl}_3$ ), lead as ( $\text{Pb}(\text{NO}_3)_2$ ) and cadmium as ( $\text{CdCl}_2$ ). After Twenty days of germination, maize plants were treated with following four treatments for about 20 days on alternative days.

$T_0$ = Untreated control condition

$T_1$ = 0.5 mM/500ml of chromium as  $\text{CrCl}_3$

$T_2$ = 0.5 mM/500ml of cadmium as  $\text{CdCl}_2$

$T_3$ = 0.5 mM+0.5mM combined cadmium and chromium

$T_4$  = 0.5 mM+0.5mM  $\text{Pb}(\text{NO}_3)_2$

$T_5$ = 0.5 mM+0.5mM+0.5mM combined cadmium, lead and chromium

The plants were harvested after the treatment and their roots, stems and leaves separated according to their treatment. Plants washed with tap water and then rinsed in distilled water. Following morphological investigation carried out before and at harvesting the plant: dry leaf weight (g), dry root weight (g), fresh root weight (g), leaf area ( $\text{cm}^2$ ), fresh leaf weight (g), laves per plant, root diameter (cm), root length (cm), stem diameter (cm), stem dry weight (g) and stem fresh weight (g).

### DETERMINATION OF UPTAKE OF CR, PB AND CD BY ROOT, STEM AND LEAVES

For this purpose dried material of plants i.e. root, stem and leaves of each treatment was ground separately with the help of grinder than dried ground material of root, stem and leaves was digested by sulfuric acid and hydrogen peroxide in the digestion flasks and incubated it at room temperature for 24 hours. Spectrometric techniques were used to determination of uptake of Cr, Pb and Cd by root, stem and leaves.

### STATISTICAL ANALYSIS

All values reported in this study were mean of at least three replicates. The data analyzed using a SPSS version 16.0 (SPSS, Chicago, IL). One-way analysis of variance (ANOVA) will be carried out, followed by the Duncan's multiple range test to determine the significant difference between means of treatments [21].

### RESULTS AND DISCUSSIONS

It was revealed from results (Table 1, 1a) that significant differences were reported for genotypes and treatments while for some of interactions among the genotypes and treatments for dry leaf weight, fresh root weight, leaf area, root length, fresh leaf weight, leaves per plant, root diameter, root length and stem diameter. The table 2 showed significant differences among the studied morphological traits SWL-2002 and

Raka-poshi showed higher root length under 0.5 mM/500ml CrCl<sub>3</sub> (12.892cm, 12.982cm) while lowest with combine treatment of 0.5 mM+0.5mM CrCl<sub>3</sub>+ CdCl<sub>2</sub> (7.536cm, 7.626cm) respectively. The higher root length indicated that the genotypes have resistance against the application of Cr, Cd and Pb treated environmental conditions. The heavy metals caused adverse effects on the plant growth and development stages, the resistant plants showed better performance under such conditions. The accumulation of heavy metals in plant body caused damage in physiological functioning of various body tissues. The plant tried to adjust under such stress environmental conditions. The heavy metal stress resistant plant remains its survival as compared with sensitive plants. Most of the metabolic pathways blocked due to heavy metals effects [22-24]. Leaf per plant were found higher for both of genotypes under 0.5 mM/500ml of cadmium as CdCl<sub>2</sub> while lowest under 0.5mM/500ml Pb(NO<sub>3</sub>)<sub>2</sub>. Stem and stem diameter was higher under treatment of 0.5 mM/500ml CrCl<sub>3</sub>, while lowest under treatment of 0.5mM/500ml Pb(NO<sub>3</sub>)<sub>2</sub>. Fresh and dry root weight was higher for treatment 0.5 mM+0.5mM CrCl<sub>3</sub>+ CdCl<sub>2</sub> for both of genotypes, lowest was

under treatment of 0.5 mM/500ml of cadmium as CdCl<sub>2</sub>. Dry and fresh leaf weight and leaf area was under treatment 0.5 mM/500ml CrCl<sub>3</sub> while lowest was for treatment of 0.5mM/500ml Pb(NO<sub>3</sub>)<sub>2</sub> for both of the genotypes. Stem dry weight was higher under treatment of 0.5 mM/500ml CrCl<sub>3</sub> while lowest for treatment of 0.5 mM+0.5mM CrCl<sub>3</sub>+ CdCl<sub>2</sub> for both of the genotypes. Fresh stem weight was higher under treatment of 0.5 mM/500ml CrCl<sub>3</sub> while lowest for treatment of 0.5mM/500ml Pb(NO<sub>3</sub>)<sub>2</sub> for both of the genotypes. The treats which showed higher performance under the applications of heavy metals showed that the genotypes of maize have ability to withstand under heavy metal environmental conditions [25-27].

It was revealed from results shown in table 2a that higher uptake of cadmium by roots was under the treatment of 0.5 mM+0.5mM CrCl<sub>3</sub>+ CdCl<sub>2</sub>, while lowest was under the treatment of 0.5mM/500ml Pb(NO<sub>3</sub>)<sub>2</sub> for both of the genotypes.

Table 1: Analysis of Variance for morphological traits of maize

Source	DF	DLW	DRW	FRW	LA	FLW	LPP	RD	RL	SD	SDW	SFW
Replication	2	0.022ns	0.369ns	0.008ns	3.198ns	0.022ns	2.137ns	0.0001ns	0.027ns	0.002ns	0.052ns	0.021ns
Treatments	4	58.029*	0.101*	22.644*	25208.60*	343.735*	24.398*	0.003*	105.062*	0.057*	92.385*	1187.91*
Genotypes	1	0.060*	0.435*	0.898*	115.448*	0.060*	15.196*	0.0202*	0.060*	0.040*	0.060*	0.060*
treatment*genotypes	4	0.0001ns	0.134*	0.0001ns	0.0001ns	0.0003ns	0.0002ns	0.0003ns	0.0001ns	0.0002ns	0.0004*	0.025*
Error	18	0.00002	0.0063	0.000001	0.000003	0.00002	0.00005	0.00001	0.00002	0.00001	0.00002	0.00004
Grand Mean	Σ	5.394	15.740	6.246	784.710	13.981	12.133	0.074	11.224	0.465	9.281	24.866

Table 1a: Analysis of Variance for uptake of heavy metals by morphological traits of maize

Source	DF	cdupleaves	cduproot	cdupstem	crupleaves	cruproot	crupstem	pbupleaves	pbuproot	pbupstem
Replication	2	0.036ns	0.034ns	0.028ns	0.022ns	0.021ns	0.082ns	0.072ns	0.023ns	0.052sn
Treatments	4	254.789*	605.261*	599.077*	481.711*	4226.49*	1866.75*	638.509*	182.478*	695.091*
Genotypes	1	0.0530*	0.091*	0.049*	0.060*	0.0634*	0.0490*	0.087*	0.0823*	0.096*
treatment*genotypes	4	0.0004*	0.0006*	0.0023*	0.0054*	0.054*	0.0089*	0.0056*	0.087*	0.0782*
Error	18	0.000001	0.00003	0.0000002	0.000003	0.000005	0.000001	0.000002	0.000006	0.000001
Grand Mean	Σ	3.858	7.492	6.436	6.759	19.313	12.226	5.079	2.765	5.075

\*=Significant at 5% level of probability level, DLW = Dry leaf weight, DRW = Dry root weight, FRW = Fresh root weight, LA = Leaf area, FLW = Fresh leaf weight, LPP = Leaves per plant, RD = Root diameter, RL = Root length, SD = Stem diameter, SDW = Stem dry weight, SFW = Stem fresh weight, cduproot = Cd uptake by roots, cdupleaves = Cd uptake by leaves, cdupstem = Cd uptake by stem, cruproot = Cr uptake by roots, crupleaves = Cr uptake by leaves, crupstem = Cr uptake by stem, pbuproot = Pb uptake by roots, pbupleaves = Pb uptake by leaves, pbupstem = Pb uptake by stem

Table 2: Mean performance of maize genotypes for morphological traits under different treatments of heavy metals

Genotypes	Treatments	RL	LPP	SD	RD	FRW	DRW	DLW	LA	SDW	LFW	SFW
SWL-2002	Control	17.673a	13.232a	0.424b	0.087b	4.234de	1.231d	10.520a	846.634a	15.661a	26.324a	44.231a
	0.5 mM/500ml CrCl <sub>3</sub>	12.892b	11.431c	0.562a	0.096a	5.974c	1.424c	5.472b	845.324a	9.564b	15.246b	31.872b
	0.5 mM/500ml of cadmium as CdCl <sub>2</sub>	9.245c	12.432b	0.436b	0.075c	4.099d	0.965e	3.755d	802.365b	7.246d	11.573c	24.671c
	0.5 mM+0.5mM CrCl <sub>3</sub> + CdCl <sub>2</sub>	7.536e	9.087d	0.342c	0.063d	8.562a	1.563b	2.446e	723.546c	5.348e	7.174e	14.245d
	0.5mM/500ml Pb(NO <sub>3</sub> ) <sub>2</sub>	8.363d	8.678e	0.312c	0.035e	7.345b	1.732a	4.364c	712.233cd	8.172c	9.174d	8.896e
	0.5 mM+0.5mM+0.5mM CrCl <sub>3</sub> +CdCl <sub>2</sub> +Pb(NO <sub>3</sub> ) <sub>2</sub>	8.312d	9.062de	0.456b	0.062d	4.091de	1.434c	3.732d	723.432c	7.292d	11.413c	14.281d
Raka-poshi	Control	17.763a	14.655a	0.497c	0.092b	4.580d	1.732ab	10.610a	842.711a	15.751a	26.414a	44.321a
	0.5 mM/500ml CrCl <sub>3</sub>	12.982b	12.854c	0.636a	0.100a	6.320c	1.677c	5.562b	841.401a	9.654b	15.336b	31.962b
	0.5 mM/500ml of cadmium as CdCl <sub>2</sub>	9.335c	13.855b	0.509b	0.079c	4.445d	1.470d	4.845c	798.442b	7.336d	11.663c	24.761c
	0.5 mM+0.5mM CrCl <sub>3</sub> + CdCl <sub>2</sub>	7.626e	10.510d	0.416cd	0.068d	8.908a	1.911a	4.536d	719.623c	5.438e	7.264e	14.335d
	0.5mM/500ml Pb(NO <sub>3</sub> ) <sub>2</sub>	8.453d	10.101d	0.386cd	0.039e	7.691b	1.809b	3.454e	708.310d	8.262c	9.264d	8.986e
	0.5 mM+0.5mM+0.5mM CrCl <sub>3</sub> +CdCl <sub>2</sub> +Pb(NO <sub>3</sub> ) <sub>2</sub>	8.442d	13.876b	0.511b	0.077c	4.432d	1.463d	4.512d	718.238c	7.346d	9.234d	14.345d

Table 2a: Mean performance of maize genotypes for uptake of heavy metals by morphological traits under different treatments of heavy metals

Genotypes	Treatments	cduproot	cdupstem	cdupleaves	cruproot	crupstem	crupleaves	pbuproot	pbupstem	pbupleaves
SWL-2002	Control	0.034f	0.098d	0.004f	0.029e	0.109e	0.148e	0.023d	0.097de	0.072d
	0.5 mM/500ml CrCl <sub>3</sub>	0.332c	0.240c	0.537c	0.065d	0.422c	0.299c	0.023d	0.109d	0.023de
	0.5 mM/500ml of cadmium as CdCl <sub>2</sub>	16.246b	23.087a	15.256a	42.435b	20.462b	14.472b	0.120c	0.274b	0.563c
	0.5 mM+0.5mM CrCl <sub>3</sub> + CdCl <sub>2</sub>	20.345a	8.252b	2.835b	53.534a	39.533a	18.287a	0.341b	0.234c	0.876b
	0.5mM/500ml Pb(NO <sub>3</sub> ) <sub>2</sub>	0.087d	0.087e	0.245d	0.087c	0.189d	0.175d	12.455a	24.245a	23.437a
0.5 mM+0.5mM +0.5mM CrCl <sub>3</sub> +CdCl <sub>2</sub> ,Pb(NO <sub>3</sub> ) <sub>2</sub>	0.067e	0.056f	0.138e	0.011f	0.012f	0.035f	0.019e	0.087f	0.019f	
Raka-poshi	Control	0.124e	0.188d	0.094e	0.119e	0.199e	0.238e	0.113d	0.187de	0.162d
	0.5 mM/500ml CrCl <sub>3</sub>	0.422c	0.330c	0.627c	0.155d	0.512c	0.388c	0.113d	0.199d	0.113e
	0.5 mM/500ml of cadmium as CdCl <sub>2</sub>	16.336b	23.177a	15.346a	42.525b	20.552b	14.562b	0.210c	0.364b	0.653c
	0.5 mM+0.5mM CrCl <sub>3</sub> + CdCl <sub>2</sub>	20.435a	8.342b	2.925b	53.624a	39.623a	18.377a	0.431b	0.324c	0.966b
	0.5mM/500ml Pb(NO <sub>3</sub> ) <sub>2</sub>	0.177d	0.177e	0.335d	0.177c	0.279d	0.265d	12.545a	24.335a	23.527a
0.5 mM+0.5mM+0.5mM CrCl <sub>3</sub> +CdCl <sub>2</sub> ,Pb(NO <sub>3</sub> ) <sub>2</sub>	0.089f	0.092f	0.023f	0.087f	0.054f	0.042f	0.067e	0.056e	0.069f	

cduproot = Cd uptake by roots, cdupleaves = Cd uptake by leaves, cdupstem = Cd uptake by stem, cruproot = Cr uptake by roots, crupleaves = Cr uptake by leaves, crupstem = Cr uptake by stem, pbuproot = Pb uptake by roots, pbupleaves = Pb uptake by leaves, pbupstem = Pb uptake by stem,

Table 3: Correction among morphological traits and uptake of heavy metals by maize

Traits	DLW	DRW	FRW	LA	FLW	LPP	RD	RL	SD	SDW	SFW	Cdlv	Cdrt	Cdst	Criv	Crst	Pblv	Pbrt
DRW	0.214																	
FRW	-0.610*	0.021																
LA	0.680*	-0.033	-0.791*															
FLW	0.980*	0.148	-0.695*	0.796*														
LPP	0.632*	0.184	-0.815*	0.818*	0.734*													
RD	0.486*	-0.026	-0.573*	0.833*	0.629*	0.775*												
RL	0.965*	0.146	-0.640*	0.828*	0.989*	0.709*	0.656*											
SD	0.265*	0.046	-0.420*	0.774*	0.385*	0.669*	0.689*	0.466*										
SDW	0.999*	0.218	-0.617*	0.685*	0.977*	0.628*	0.474*	0.964*	0.277*									
SFW	0.845*	0.028	-0.752*	0.939*	0.933*	0.833*	0.829*	0.942*	0.603*	0.839*								
Cdupleave	-0.394*	-0.215	-0.436*	0.051	-0.278*	0.293*	0.129	-0.356*	0.059	-0.398*	-0.086							
Cduproot	-0.668*	-0.286	0.252*	-0.380*	-0.573*	-0.162	-0.007	-0.616*	-0.259	0.696*	-0.380	0.634*						
Cdupstem	-0.475*	-0.246	-0.309*	-0.048	-0.357*	0.210	0.107	-0.435*	-0.023	-0.486*	-0.155	0.982*	0.767*					
Crupleave	0.666*	-0.285	0.256	-0.384	-0.572	-0.165	-0.009	-0.616*	-0.264	0.695*	-0.381	0.629*	0.902*	0.763*				
Cruproot	0.664*	-0.287	0.253	-0.385	-0.571*	-0.166	-0.011	0.616*	-0.269	-0.693*	-0.381	0.631*	0.924*	0.764*	0.853*			
Crupstem	-0.659*	-0.268	0.435*	0.463*	-0.585*	-0.285	-0.051	0.611*	-0.322	0.692*	0.420*	0.425*	0.970	0.586	0.971*	0.970*		
Pbupleave	-0.196	0.244*	0.392*	0.661*	-0.375*	-0.595*	0.849*	-0.399*	0.557*	-0.173	0.655*	-0.288	0.376*	0.331*	0.374*	0.372*	0.347*	
Pbuproot	-0.187	0.250*	0.391*	0.654*	-0.366*	-0.590*	0.844*	-0.388*	0.549*	-0.164	0.647*	-0.300	0.388*	0.343*	0.386*	0.384*	0.357*	0.980*
Pbupstem	-0.176	0.249*	0.375*	0.640*	-0.354*	-0.580*	0.838*	-0.377*	0.541*	-0.152	0.636*	0.297*	0.401*	0.344*	0.399*	0.397*	0.373*	0.876*

\*= Significant at 5% probability level, DLW = Dry leaf weight, DRW = Dry root weight, FRW = Fresh root weight, LA = Leaf area, FLW = Fresh leaf weight, LPP = Leaves per plant, RD = Root diameter, RL = Root length, SD = Stem diameter, SDW = Stem dry weight, SFW = Stem fresh weight, cduproot = Cd uptake by roots, cdupleaves = Cd uptake by leaves, cdupstem = Cd uptake by stem, cruproot = Cr uptake by roots, crupleaves = Cr uptake by leaves, crupstem = Cr uptake by stem, pbuproot = Pb uptake by roots, pbupleaves = Pb uptake by leaves, pbupstem = Pb uptake by stem

Table 4: Principal component analysis for different morphological traits under heavy metals treatments

Eigenvalue	9.7128	6.7104	1.6264	1.1206	0.6857	0.1441
Proportion	0.486	0.336	0.081	0.056	0.034	0.007
Cumulative	0.486	0.821	0.902	0.959	0.993	1
Variable	PC1	PC2	PC3	PC4	PC5	PC6
RL	-0.312	0.027	-0.066	0.186	-0.046	-0.016
LPP	-0.254	-0.159	0.243	-0.032	-0.262	-0.625
SD	-0.204	-0.118	-0.053	-0.652	-0.058	-0.369
RD	-0.246	-0.21	-0.176	-0.243	-0.004	0.07
FRW	0.23	0.111	-0.482	-0.079	-0.094	-0.294
DRW	0.022	0.243	0.063	-0.167	-0.892	0.337
DLW	-0.289	0.09	0.015	0.334	-0.095	-0.133
LA	-0.295	-0.12	0.048	-0.172	0.115	0.315
SDW	-0.291	0.099	0.029	0.307	-0.079	-0.114
LFW	-0.305	0.02	0.012	0.281	-0.075	-0.056
SFW	-0.308	-0.098	-0.026	0.107	-0.025	0.083
cduproot	0.199	0.293	-0.033	0.153	-0.135	-0.076
cdupstem	0.111	0.292	0.434	-0.002	-0.03	0.042
cdupleaves	0.078	0.268	0.529	-0.07	0.009	0.077
cruproot	0.199	0.291	-0.033	0.164	-0.136	-0.076
crupstem	0.209	0.257	-0.206	0.199	-0.159	-0.112
crupleaves	0.199	0.292	-0.036	0.158	-0.137	-0.081
pbuproot	0.14	0.329	0.218	0.006	0.039	-0.18
pbupstem	0.136	0.33	0.227	0.002	0.046	-0.167
pbupleaves	0.143	0.326	0.223	0.01	0.041	-0.173

DLW = Dry leaf weight, DRW = Dry root weight, FRW = Fresh root weight, LA = Leaf area, FLW = Fresh leaf weight, LPP = Leaves per plant, RD = Root diameter, RL = Root length, SD = Stem diameter, SDW = Stem dry weight, SFW = Stem fresh weight, cduproot = Cd uptake by roots, cdupleaves = Cd uptake by leaves, cdupstem = Cd uptake by stem, cruproot = Cr uptake by roots, crupleaves = Cr uptake by leaves, crupstem = Cr uptake by stem, pbuproot = Pb uptake by roots, pbupleaves = Pb uptake by leaves, pbupstem = Pb uptake by stem

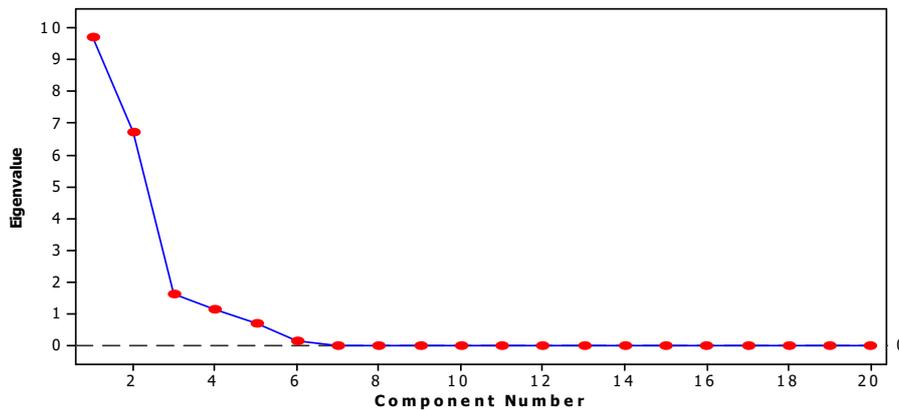


Figure 1: Traits of maize; Egen value as a function of component number

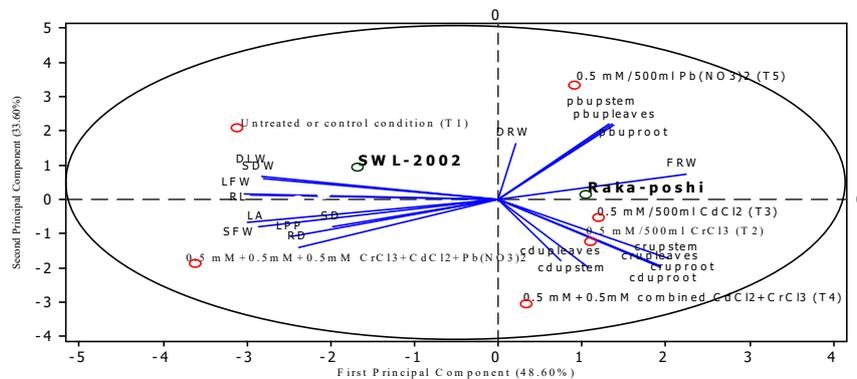


Figure 2: Principal component biplot for studied traits of maize under heavy metal treatment

Higher uptake of cadmium by stem and leaves of both of the genotypes was under the treatment of 0.5 mM/500ml of cadmium as CdCl<sub>2</sub> while lowest was found under the treatment of 0.5mM/500ml Pb(NO<sub>3</sub>)<sub>2</sub>. Higher uptake of chromium by roots, leaves and stem was under the treatment of 0.5 mM+0.5mM CrCl<sub>3</sub>+ CdCl<sub>2</sub>, while lowest was under the treatment of 0.5mM/500ml Pb(NO<sub>3</sub>)<sub>2</sub> for both of the genotypes. The higher uptake of lead was by stem, leaves and root was under the application of treatment of 0.5mM/500ml Pb(NO<sub>3</sub>)<sub>2</sub> while lowest was for 0.5 mM/500ml CrCl<sub>3</sub> for both of the genotypes. The lowest uptake of chromium, cadmium and lead was reported under control and 0.5 mM+0.5mM+0.5mM CrCl<sub>3</sub>+CdCl<sub>2</sub>+Pb(NO<sub>3</sub>)<sub>2</sub> conditions which indicated the presence of these heavy metals in soil with natural conditions and the reactive potential competition of heavy metals due to which each of the heavy metal was up taken in low amount. The uptake of heavy metals by leaves, stem and root indicated that the movement of heavy metal ions was much easy process in plant body. The higher accumulation of heavy metals in leaves caused blockage of photosynthetic process, ultimately the reduction of plant growth and development. Accumulation of

Pb in leaf tissues caused damaging of grana and thylakoid membranes [28-31].

Correlation analysis provides an opportunity to researchers for selecting genotypes with higher genetic potential. Positive correlation reveals the relation of a trait with its contributing trait for fixing the related traits in next generations. Usually a positive correlation is useful for breeding of higher yielding crop genotypes [32-36]. It was revealed from results shown in table 3 that significant and strong correlation was reported among most of the studied traits of maize. Leaf fresh weight was strongly and positively correlated with dry leaf weight, root length, fresh shoot weight and dry shoot weight. Leaf area was significantly and positively correlated with leaf fresh weight, leaves per plant, root length, root diameter and shoot fresh weight. Shoot dry weight was strongly correlated with leaf fresh weight. Root length was positively and significantly correlated with shoot fresh and dry weight, root diameter, leaves per plant, dry leaf weight and leaf area. Cadmium uptake by stem was strongly correlated with cadmium uptake by leaves, cadmium uptake by roots and chromium uptake by leaves. Cadmium uptake by roots showed strong correlation with cadmium uptake by stem,

chromium uptake by leaves, stem and roots. A strong correlation was found between chromium uptake by leaves and stem. Strong positive correlation was found for lead uptake by leaves, stem, root, root length, leaf area and shoot fresh weight. The positive correlation of uptake of heavy metals by roots, stem and leaves by maize plants indicated that maize may be used for the removal of heavy metals from heavy metals affected soils [35,37]. Maize may be used as phytoremediation agent to improve soil quality and productivity even adversely affects the production of maize crop plants [17].

Principal component analysis was carried out to assess the variability potential among the studied traits of maize genotypes. There were six principal components constructed (Table 4) among which PC1 showed 48.6% and PC2 33.6% variation as shown in scree plot (Fig. 1) and principal component biplot figure 2. The uptake of heavy metals showed positive variation in PC1 and PC2. Principal component analysis is very helpful for plant researchers to select the genotypes of crop plants from diverse population for specific traits to be improved. In our study the variation of heavy metals uptake was positive and higher compared by other

studied traits [38-40]. It was suggested that the use of maize for removal of heavy metals from soil biosphere may be helpful and soil health improving process. The accumulation of heavy metals may cause adverse effects on photosynthetic process, metabolism, enzyme activities and damaging effects for membrane structure bodies in maize crop plants [30,31,41,42].

### CONCLUSIONS

It was concluded from results that the heavy metals caused adverse effects on morphological traits of maize which ultimately reduced production and productivity of maize. It was also found beside the adverse effects of heavy metals maize may be used for the removal of heavy metals from soil biosphere.

### CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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