Biological and Environmental Sciences Journal for the Tropics
Volume 21, Number 3, December 2024. Pp 249 - 257
https://dx.doi.org/10.4314/bestj.v21i3.24

Research article

Effects of heavy metals (Cu, Zn, Cd and Pb) on growth of selected maize and sorghum cultivas.

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Submission: 02/12/2024
Accepted: 31/12/2024

Abstract
Heavy metals, often introduced into the environment through industrial activities and agricultural practices, can have profound effects on plant health and development. These metals can disrupt physiological processes, impair nutrient uptake, and induce oxidative stress, leading to reduced growth and productivity. Understanding the mechanisms heavy metal toxicity and plant responses is critical for developing strategies to mitigate their impact on ecosystems. In this study, aside from the the effects of heavy metals (Cu, Zn, Pb and Cd) on plant height, root and shoot biomass, the bioaccumulation properties of maize cultivars, and Sorghum was studied to determine their potentials as susceptibility (bio indicators) or tolerance (bioremediators). Two maize varieties (Oba 98 and Oba super11) and one sorghum variety (Sk5912) were grown under varying concentrations of Zn(50, 75, and100 mg kg), Cu(36, 50, and 75 mg kg-1), Pb(85, 130, and 150 mg kg-1), and Cd(0.8, 1.3 and 1.8 mg kg^{-1}) and different growth parameters i.e plant height and biomass were studied. Likewise the bioaccumulation of heavy metals was also assessed on the root and shoot of the plants. Studied plant attributes were adversely affected by heavy metals toxicity. Heavy metals impacted plant height and biomass. Maize varieties and sorghum showed a significant phytoremediation potential i.e. uptake of heavy metals (Cu, Zn, Pb and Cd), however Cu-accumulation was higher in shoots and roots of sorghum (Sk 5912).These maize and sorghum varieties may be recommended for general cultivation in heavy metal (Cu, Zn, Pb and Cd) contaminated areas.

Keyword: Toxicity, Screen house, Bioaccumulation, Biomass, Environment

Introduction

Heavy metal contamination in soil is a critical environmental issue with severe implications for crop production, food safety, and human health. The presence of these toxic elements in agricultural soils threatens crop productivity, food quality, and the overall sustainability of agriculture (Golia, 2023). Heavy metals are persistent, non- biodegradable, and have a long half-lives. They can be bioaccumulated through the biologic chains: soil- plant-food and seawater-marine organism-food leading to unwanted side effects. High amount of heavy metals in environment represents a potential danger to human health and environment due to their extreme toxicity. Heavy metal contamination can happen as a result of irrigation with contaminated water, the addition of fertilizers and metal-based pesticides, industrial emissions, transportation, harvesting process, storage and/or sale (Hebrom, *et al*., 2020). Crops and vegetables grown in soils contaminated with heavy metals have greater accumulation of heavy metals than those grown in uncontaminated soil (Bempah *et al.*, 2011). There are plant species have capacity to grow in contaminated soil and bioaccumulate high amount of the metals (hyperaccumulation) as an eco-physiological adaptation in metalliferous (Yugada *et al*, 2018; Garba *et al*., 2021).

Pesticides are extensively employed in agriculture to kill pests or unwanted organisms that may reduce crop yield and increase agricultural production. The use of pesticides has been on the increase and these pesticides have been shown to contain heavy metals (Barau *et al*., 2018). Metal pollutants in soil may be absorbed by the plants through their roots and vascular system. Absorption of metals in soil could affect the ecosystem safety and cause a serious health risk to animals, plants, and human. High concentrations of metals in the plant could inhibit chlorophyll synthesis, increase oxidative stress and weaken stomata resistance (Garba *et al*., 2021). Of all toxic heavy metals, cadmium (Cd) ranks the highest in terms of damage to plant growth and human, Lead (Pb) is one of the most abundant toxic metal in the earth crust. Exposure to lead in the environmental and occupational settings continues to be a serious public health problem (WHO 1995). Elevated Pb in soils may compromise soil productivity and even a very low concentration can inhibit some vital plant processes, such as photosynthesis, mitosis and water absorption with toxic symptoms of dark leaves, wilting of older leaves, stunted foliage and brown short roots (Mohan and Hosetti 1997, Patra *et al*. 2004). The objective of this research is to determine the toxicity of Cd, Pb, Zn and Cu on the plant height, shoot and root biomass of maize and sorghum cultivars, to determine the bioaccumulation of Cu, Zn, Pb and Cd in the maize and sorghum cultivars compared to their control.

Materials and Methods

Study Area/Study Site

The research work was carried out at the screen house of Biological Science Department, Abubakar Tafawa Balewa University Bauchi.

Collection of Plant material

Seeds of two Maize cultivars (Oba 98 and Oba Super 11) and Sorghum (SK 5912) were obtained from Bauchi State Agricultural Development Program (BSADP).

Treatments

Five heavy metals were used in this experiment along with two cultivars Maize and sorghum. Cu in form of CuSO4.H2O, Zn in form of ZnSO4.H¬2O, Pb in the form of PbSO4 and Cd in the form of CdSO4.H2O, to each metal three different concentrations were prepared; Copper concentrations were 36, 50 and 75 $mgkg^{-1}$, Zinc Concentrations were 50, 75, and 100 $mgkg^{-1}$, Lead concentrations were 85, 130, and 150 $mgkg^{-1}$, and Cadmium concentrations were 0.8, 1.3 and 1.8 $mgkg^{-1}$ while water was used as control. The concentrations chosen were at and above WHO permissible limits to test and assess the toxic effects of these heavy metals on the growth of maize and sorghum including their bioaccumulating/bioremediating properties.

Planting

Seeds of two maize (Zea mays) cultivars of Oba 98 and Oba Super 11, and one cultivar of Sorghum (Sorghum bicolor), were sterilized with 10% sodium-hypochlorite (NaOCl) solution for 20 min and washed with distilled water five times and sown in 1kg pot of sandy-loam soil from 0-20cm depth of the screen house vicinity and 65ml of prepared heavy metal (Copper, Zinc, Lead and Cadmium solutions) were added of the three different concentrations of heavy metal mentioned above in a kilogram of soil respectively to each and control treatments for each were supplied with distilled water. The experiment was arrange in three replicates. After six weeks each pot was harvested by removing the plant from the soil, and the roots were washed thoroughly till there was no trace of soil particle.

Application of NPK fertilizer.

The recommended agricultural dose of NPK (ratio 120: 40:40 kg/ha) which sums up to 200kg/ha was adopted.

Harvesting of plants

Plants were uprooted at eight weeks after sowing, and washed with running water to remove dirt and other contaminants. The samples were separated into root and shoot before dried at 70°C for 3 days (Ma *et al.*, 2001) and latter pulverized.

Digestion of samples

One gram of sample of both plant (root and shoot) and soil was placed in 100 ml conical flask separately, 1ml H_2SO_4, 1.2 ml concentrated HNO3 and 3.6 ml concentrated HCl were added to the samples. The mixture was then digested at 95°C for 1hour till the solution became colorless (Sharma et al., 2008). The resulting solution was filtered to 20 ml using deionized water and determine Cd, Cu, Zn and Pb using Atomic Absorption Spectrophotometer (AAS) (APHA, 1990).

Data Collection

Data on plant height was measured using a metre rule, shoot and root biomass were measured. Data collected were subjected to Microsoft Excel 2016

Version to determine the differences between and within the treatments and cultivars.

Result

The Effect of Heavy Metals on plant heights of Maize cultivas (Oba 98 and Oba Super 11) and Sorghum (SK 5912).

The Cd has more adverse effects on plant height than any of the other heavy metals. Comparatively, the Oba 98 and Oba super 11of the maize variety showed a pronounced decreasing trend in plant height with increase in concentration of Cd for this agronomic trait as. Same pattern was recorded for Cu, Zn, and Pb (Figures 1a-1d). Plant height decreased much at higher metal concentrations (75 mg/kg of Cu, 100 mg/kg of Zn, 150 mg/kg of Pb and 1.8 mg/kg of Cd). Plant height in Sk5912 under 75 mg/kg and 100 mg/kg were 47.6 cm and 46.5 cm respectively, no significant difference was recorded ($p < 0.05$). The trend was same at 1.3 and 1.8 mg/kg of Cd. Both the maize varieties (Oba 98 and Oba super 11) and sorghum variety (Sk5912) showed a tolerant behavior and were least affected at 36, 50, 85 and 1.8 mg/kg of Cu, Zn, Pb and Cd respectively, whilst rapidly declining at 75, 100, 150 and 1.8 mg/kg of Cu, Zn, Pb and Cd respectively.

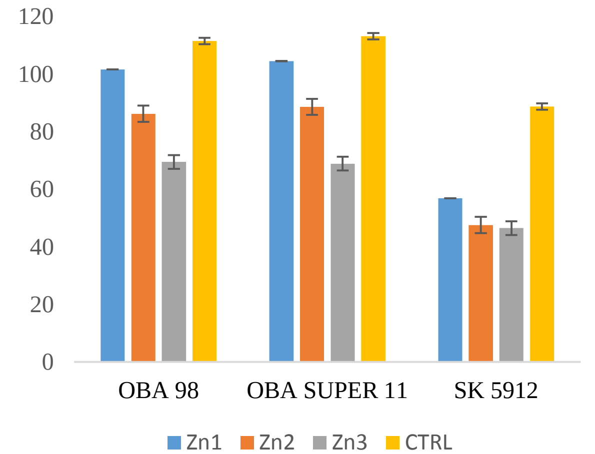

Figure 1a: Effect of Zn on Plant Height cm

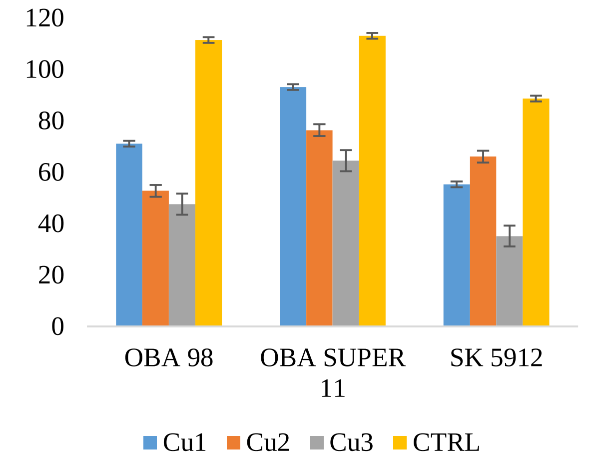

Figure 1b: Effect of Cu on Plant Height cm

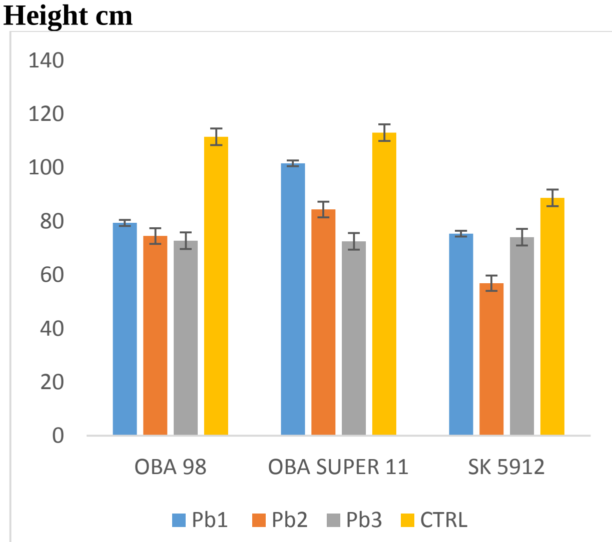

Figure 1c: Effect of Pb on Plant Height cm

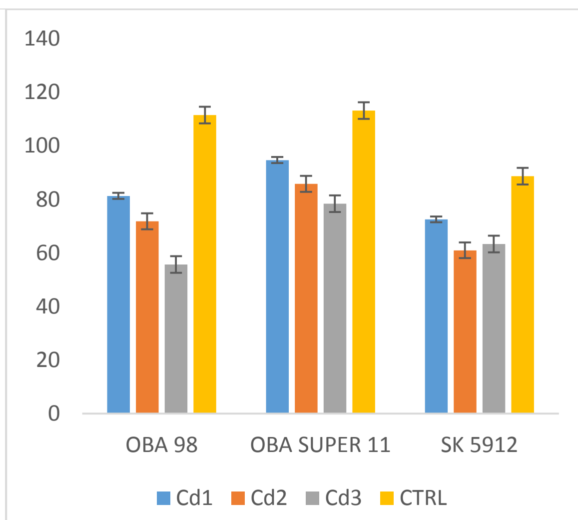

Figure 1d: Effect of Cd on Plant Height cm

Key:				
	Cu1- 36mg/kg	*Zn1- 50mg/kg*	*Pd1- 85mg/kg*	*Cd1- 0.8mg/kg*
	Cu2- 50mg/kg	*Zn2- 75mg/kg*	*Pd2- 130 mg/kg*	*Cd2- 1.3mg/kg*
	Cu3- 75mg/kg	*Zn3 – 100mg/kg*	*Pd3- 150mg/kg*	*Cd3- 1.8mg/kg*
	CTRL- Control			

Effect of Heavy Metals on Plant Biomass

Shoot and root were assessed under four different metals that revealed metal-induced toxicity on plants. Comparative to their control values, the shoot and root biomass of Oba 98, Oba Super 11 and Sk 5912 showed significant difference (Figure 2a- 2d). The effect of the three level of Cu used on Oba super 11, Oba 98 and Sk 5912 showed a remarkable difference in biomass of shoot and root as compared with the control, ($p < 0.05$). 75 mg/kg affected the cultivars the most, as concentration increased shoot and root biomass reduced except in the case of Sk 5912 (Figure 2a). For Zn, only Oba Super 11 showed significant difference when compared at the three levels of concentration and as compared with the control, Oba 98 recorded the largest biomass amongst all crops used. Sk 5912 recorded the lowest shoot and root biomass for all three levels of concentration of Pb (85, 130, and 180 mg/kg) while Oba super 11 recorded the highest. Same result was recorded in the case of Cd.

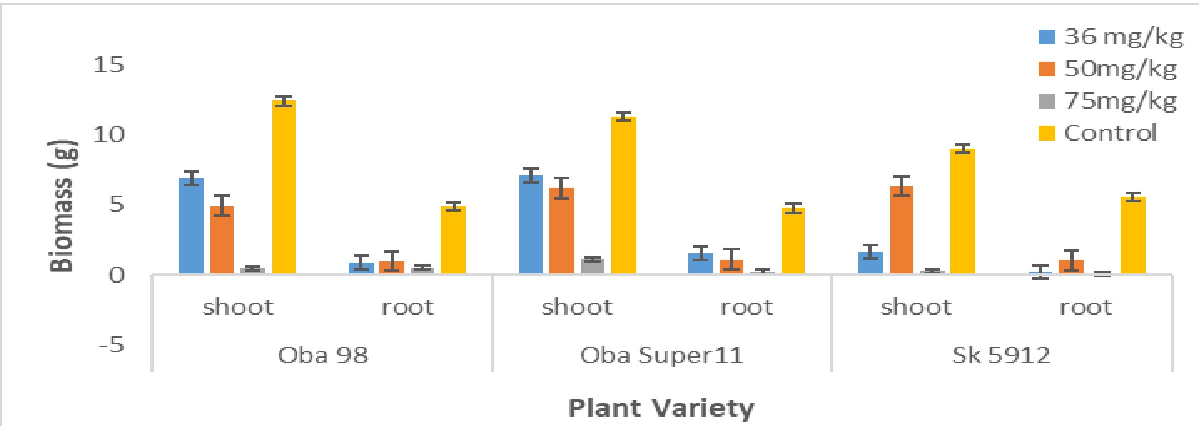

Figure2a: Effect of Cu on Shoot and Root biomass

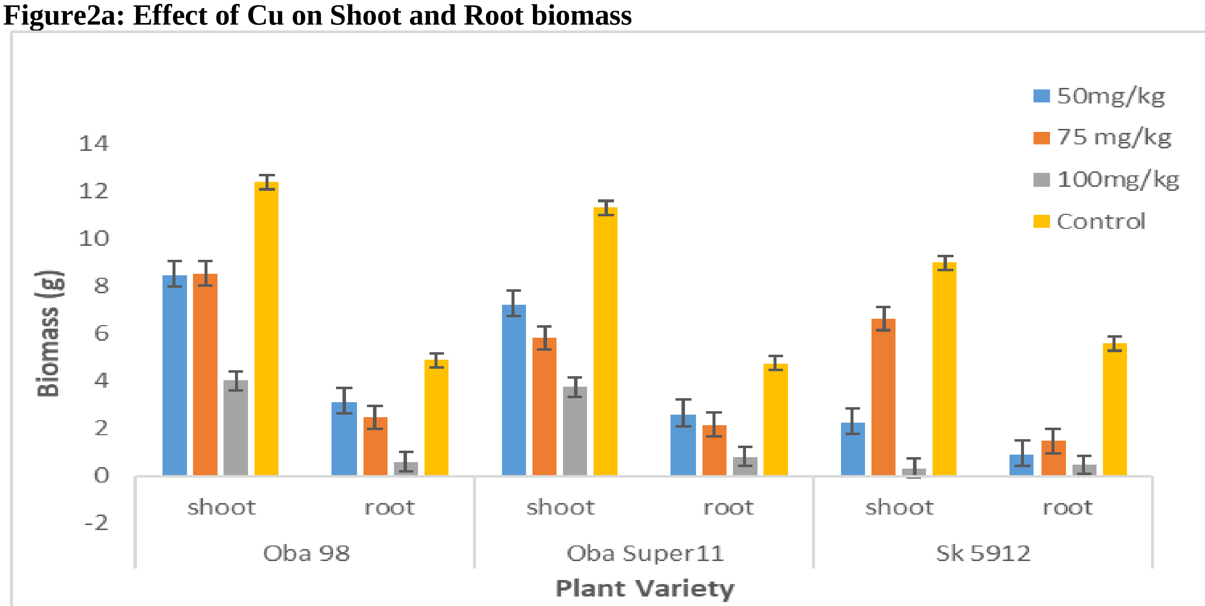

Figure 2b: Effect of Zn on Shoot and Root biomass

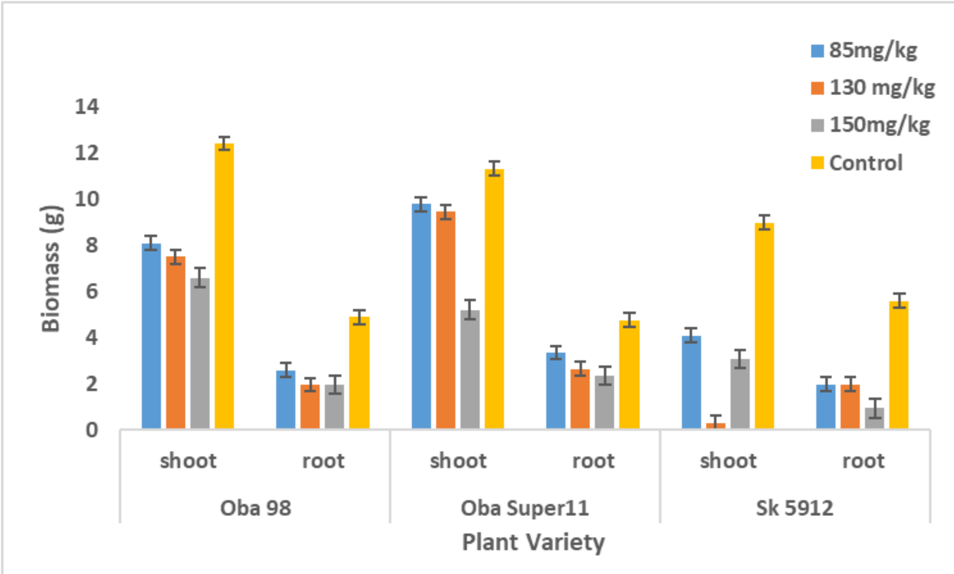

Figure2c: Effect of Pb on Shoot and Root biomass

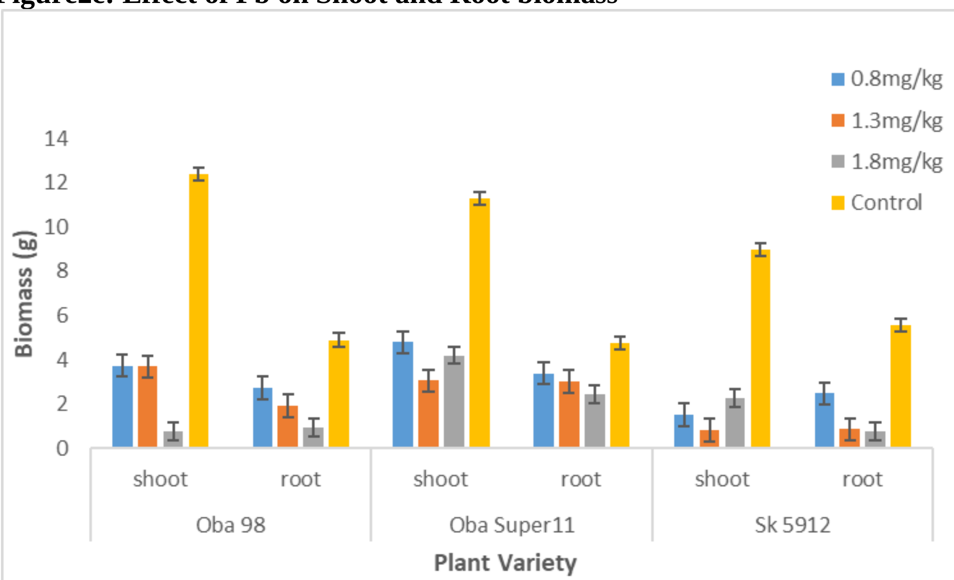

Figure 2d: Effect of Cd on Shoot and Root biomass

Bioaccumulation of heavy metals in root and shoot

The accumulation of heavy metals in the different parts of Maize and Sorghum (roots and shoots) showed significantly difference ($p<0.05$) compared with the control treatment. At 36 mgkg-1, shoot and root of Sk 5912 had the highest bioaccumulation of all the three plants (Oba 98, Oba super 11 and Sk 5912), the lowest bioaccumulation in the shoot was recorded for Oba 98 and the lowest residual concentration in roots was recorded for Oba Super 11.(Figure 3a). The residual concentration of Cd in both shoot and root of Sk 5912 was recorded as shown in figure 3b to increase as concentration increased. At the lowest concentration of 0.8 mg/kg, residual concentration in shoot was recorded lowest for Oba super 11 and highest for Oba 98. Residual concentrations in both shoot and root of Oba 98, Oba super 11 and Sk 5912 at 1.3 and 1.8 mg/kg increases as concentration increased.

Concentration of heavy metals in shoots of crops treated with 85mg/kg of Pb is in the order Sk 5912> Oba super 11 > Oba 98 while reverse was the case for same crops treated with 130 mg/kg of Pb. At 150mg/kg Oba 98 had the highest in its shoot. Bioaccumulation of heavy metals in roots of crops treated with 150 mg/kg of Pb recorded the highest concentration in the root of Oba super 11 and lowest in Sk 5912. Zn had the lowest bioaccumulation level for both roots and shoots in all crops across all heavy metals and concentrations.

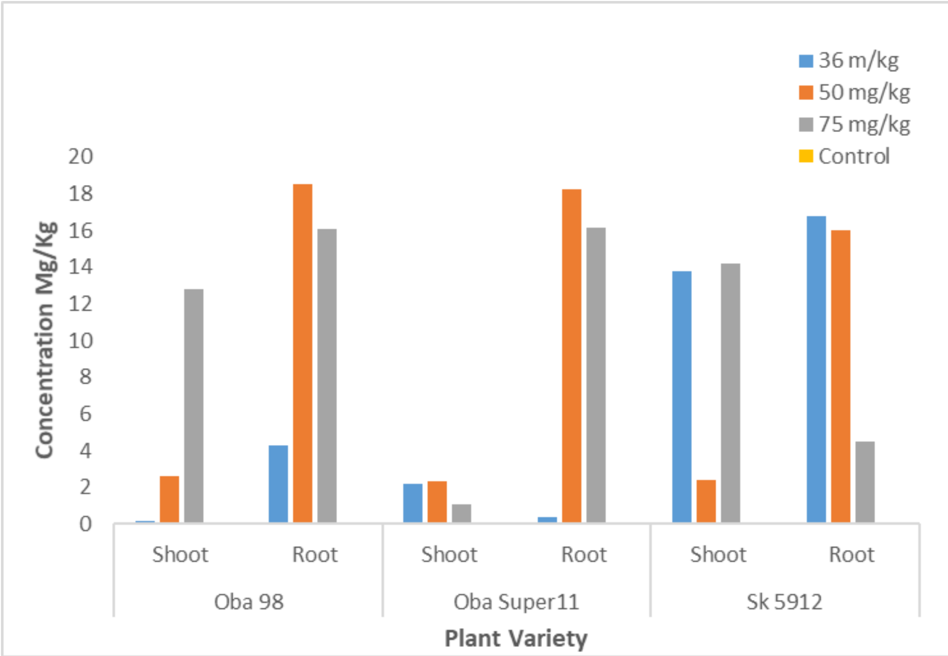

Figure 3a: Mean Bioaccumulation (mg/kg) of Cu in Maize cultivas and Sorghum

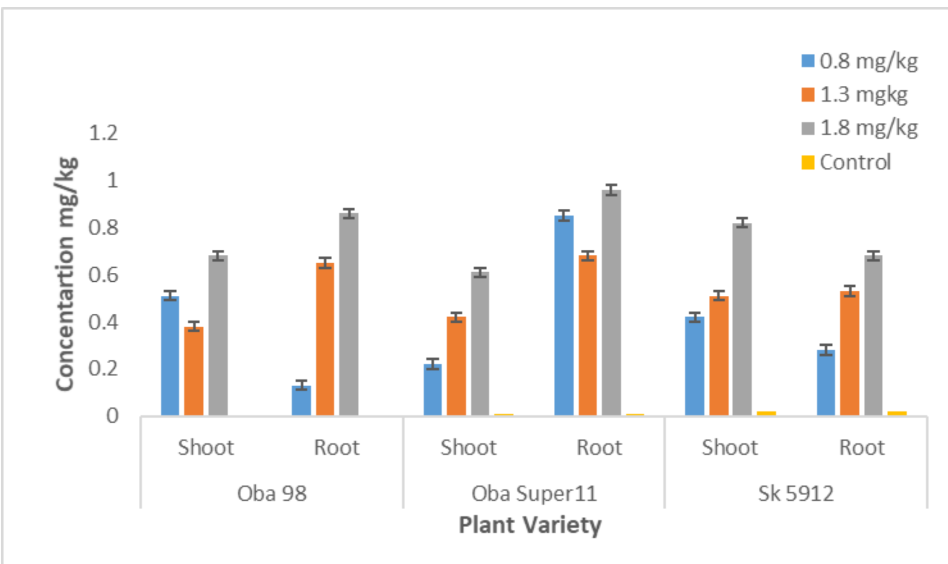

Figure 3b: Mean Bioaccumulation (mg/kg) of Cd in Maize cultivas and Sorghum

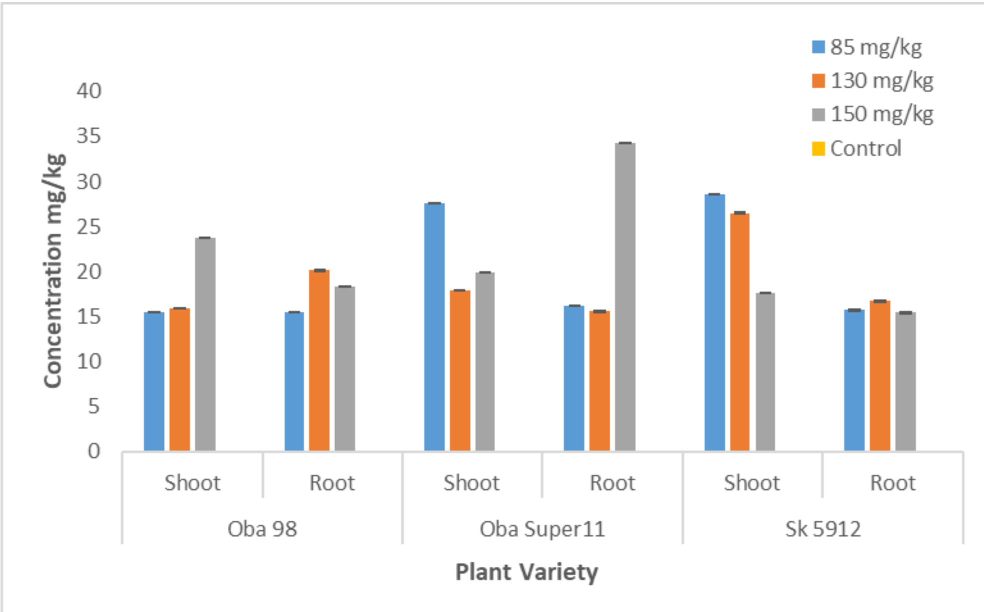

Figure 3c: Mean Bioaccumulation (mg/kg) of Pb in Maize cultivas and Sorghum

Discussion

Treatment of maize and sorghum plant with the heavy metals resulted in decreased plant height and biomass, Cu at all levels tested was found to be the most toxic metal for the maize crop. The effect heavy metals have on plants largely depends on the amount taken by the plant and this could cause stress during early development, the toxicity of some heavy metals could be so enormous that the plant height is impeded (Garba *et al.*,2021). Amendment of soil with the heavy metals at concentrations higher than the normal/permissible levels resulted in a conspicuous decrease of root and shoot biomass (Fig 2a-2b). It has earlier been reported that increasing Cu supply resulted in decreased root biomass indicating the alterations of physiology and metabolism of test plants (Barua *et al.*, 2018). Biomass loss (dry weight) under metal treatment has also been reported by many workers (Barua *et al* 2018, Usman *et al.*, 2021).

Tolerance to heavy metals depends on whether the plant is an accumulator which can take heavy metals from the soil and translocate from root to shoot resulting in the accumulation in the shoot system. On the other hand, it can be an excluder plant that inhibit entrance into plant and thus, restrict root to shoot translocation (Rascio and Navari-Izzo, 2014). Even though maize plants are known to be potentials accumulators of heavy metals (*Li et al.*, 2007).

The bioaccumulation of Cd in this work agrees with the work of Vasilachi *et al.*, 2023 who stated that Cadmium can be readily taken up by cereal crops and translocated to the edible parts, posing significant health risks to consumers. Lead uptake by cereals is generally lower than cadmium (Figure 3a and 3b) - however, elevated Pb levels in the soil can still lead to some accumulation in cereal crops, particularly in the roots (Vasilachi *et al.*, 2023). Our studies show a higher accumulation of Cd than Pb, which confirms the results of An *et al.* (2004) who observed lesser uptake of Cd in the shoots of Cucumis sativus in presence of Pb. The availability of Zn may have been affected by the fibrous root systems of the maize and sorghum cultivars, that might not aggressively uptake excess zinc if present. Additionally, these crops may produce exudates that alter the rhizosphere environment to control zinc uptake (Saboor *et al.*, 2021) (Leila *et al.*, 2021).

The permissible limits of heavy metals in crops showed that all the studied crops exceeded the permissible reference limit by WHO and could cause risk to humans. Pollution indices indicated that most of the studied crops were contaminated for Pb, Cd, and Cu. This result is similar to that of Usman *et al.*, 2021. The predominant use of metal-based pesticides with high Cd, Pb, and Zn in the study areas could be responsible for the adverse effects suffered by test crops.

Conclusion

The number of heavy metal contaminated sites/soil and the environmental risk they reflect is a source of major concern. This study demonstrates that heavy metals (Cu, Zn, Pb, and Cd) used in this research affected the plant height and ad biomass of Oba 98, Oba Super 11 and Sk 5912. This research highlights the harmful effects of heavy metals (Cu, Zn, Pd and Cd) on specific Maize (Oba 98 and Oba super 11) and Sorghum varieties (Sk 5912) and lays the groundwork for future studies on using cereal crops to clean up and monitor heavy metal pollution.

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