UMYU Scientifica, Vol. 1 NO. 1, September 2022, Pp 268-273
https://doi.org/10.56919/usci.1122.034
ISSN: 2955 – 1145 (print); 2955 – 1153 (online)
A periodical of the Faculty of Natural and Applied Sciences, UMYU, Katsina

ORIGINAL RESEARCH ARTICLE

Vegetative Growth Responses of Castor (*Ricinus communis*) and Senna (*Senna occidentalis*) to Low Dose Zinc (Zn) Spiking of Agricultural Soil in Kano, Northern Nigeria

Halima Musa Rabiu
Department of Biological Science, Bayero University Kano, Nigeria

ABSTRACT

The aim of the research is to assess the viability of castor (*Ricinus communis*) and senna (*Senna occidentalis*) plants up to 90 days after planting (DAP) in agricultural soil spiked with different concentration of zinc in the screen house. Agricultural soil was collected from Bayero University Kano, at 11° 98′ 32.59"N; 8°42′ 43.97"E. Soil texture, pH, electrical conductivity (EC), organic carbon (OC), nitrogen (N), phosphorus (P) and exchangeable cations (K^+, Ca^+, Mg^+ and Na^+) were determined. Castor and senna were planted in soil spiked with 2 mg/kg, 4mg/kg and 8 mg/kg of zinc sulphate ($ZnSO_4$) each. Control plants containing only agricultural soil without spiking with zinc were added and the set up replicated 4 times. Plant height, number of leaves and root length were assessed at 45 and 90 days after planting (DAP). The soil was sandy loam, slightly acidic, C, N, P and K^+ had mean values of 0.41%, 0.33 mg/kg, 14.33 mg/kg and 0.39 cmol/kg respectively. There were significantly higher ($p<0.05$) mean values for height (16.85cm) and root length (17.35 cm) of control castor plants than those treated with zinc at 45 DAP. At the termination of the experiment (90 DAP), senna plants in control had significantly higher mean values for height (29.5 cm) than all other treatments. All concentrations of zinc used in this work did not seem to have much negative effects on the vegetative growth of both test plants.

ARTICLE HISTORY
Received Augus 8, 2022
Accepted September 17, 2022
Published September 30, 2022

KEYWORDS
Ricinus communis, Senna occidentalis, heavy metals, soil, phytoremediation

INTRODUCTION

Heavy metals are naturally occurring elements, which are widely distributed in the Earth's crust; they derive from rocks of volcanic, sedimentary or metamorphic origin (Azeez, 2021; DalCorso *et al.*, 2019). Heavy metals include the transition-metal elements essential to plant nutrition, for nitrogen fixation in legumes, cell protection, gene regulation such as iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), nickel (Ni) and molybdenum (Mo), cobalt (Co), which is imperative for survival of the plants (Bortoloti and Baron, 2022; Ekta and Modi, 2018). Excessive accumulation of these heavy metals can be toxic to most plants. In urban areas, activities like industrial and municipal effluent discharge without proper treatment, sewage disposal, mining, smelting processes, etc. are the main source of the metal contamination in the water bodies and soil. In Kano, Nigeria, large amounts of industrial wastes, domestic and abattoir wastewater are discharged into city streams and used for irrigation, which may contain large amounts of toxic heavy metals (Abdu, 2010). Plant species have been shown to tolerate degrade, extract, contain, or immobilize excessive amounts of heavy metals from soil and water (Azeez, 2021; Ekta and Modi, 2018; Abbaslou and Bakhtiari, 2017) in the process of phytoremediation. *Ricinus communis* (L) also known as castor bean, castor oil plant, wonder tree or zurman, in the local language belongs to the family Euphorbiaceae. It is a fast-growing, perennial shrub growing up to 6 meters or more. It is an economical plant cultivated mainly for oil production which is obtained from its seed (Kiran and Prasad, 2017). Castor is widely available (Weiss, 2000), therefore there are negative tradeoffs in utilizing thereby making it a suitable candidate for sustainable environmental solutions such as phytoremediation. *Senna occidentalis* commonly known as coffee senna and 'rai dore' in Hausa language belongs to the family Fabaceae is a common crop throughout the tropics and subtropics (Burkill, 1995). Agricultural soils in Kano metropolis are at risk of contamination with various pollutants due to major industrial activities in the city. As one of the most populous and a business hub of the Nation, the state is endowed with industries and dumpsites that discharge effluents containing heavy metals (Karkarna and Matazu, 2021).

Correspondence: Halima Musa Rabiu . Department of Biological Science, Bayero University Kano, Nigeria
hmrabiu.bio@buk.edu.ng; Phone: 2348060851382

How to cite: Halima Musa Rabiu (2022). Vegetative Growth Responses of Castor (*Ricinus communis*) and Senna (*Senna occidentalis*) to Low Dose Zinc (Zn) Spiking of Agricultural Soil in Kano, Northern Nigeria. *UMYU Scientifica*, 1(1), 268-273. https://doi.org/10.56919/usci.1122.034

These industries are often located in the suburbs where farming activities also take place in close proximity, using the effluents for irrigation (Abdulrashid *et al.* 2017). Dawaki *et al.* (2013) reported high levels of zinc in three agricultural soils around Kano metropolis. It is therefore essential to explore sustainable methods of polluted agricultural soils remediation. Zinc is one of many heavy metals pollutants found in soils whose accumulation often results in soil/water degradation and ecosystem malfunction (He *et al.,* 2015). Zinc is also plant micronutrient which is involved in many physiological functions its inadequate supply will reduce crop yields (Hafeez *et al.,* 2013). There are no published works to the author's knowledge on the tolerance of *R. communis* and *S. occidentalis* to different concentrations of zinc in agricultural soils of Kano State.

The aim of this work is to assess the viability of castor (*R. communis*) and senna (*S. occidentalis)* plants up to 90 days after planting (DAP) in agricultural soil spiked with different concentration of zinc. It is hypothesized that no significant differences will be observed in plants subjected to different treatments and both castor and senna will equally respond to the treatments.

MATERIALS AND METHODS

Soil Sample Collection and

Agricultural soil on land used for agricultural research with no history of heavy metals contamination was collected from Bayero University Kano at 11° 98′ 32.59"N; 8°42′ 43.97"E. Four replicate quadrant plots (100 m^2) were determined, with six soil cores per quadrant randomly removed using a 6 cm diameter corer, to a depth of 20 cm. The six soil core samples were combined into a composite sample which made a replicate (Rabiu, 2017). Two replicates were collected and air-dried on an open bench in the laboratory for 72 h before conducting the following physico-chemical analyses.

Determination of Physico Chemical Parameters

Texture

Particle size distribution was determined by the hydrometer method after dispersion with sodium hexametaphosphate (International Institute for Tropical Agriculture IITA, 1982).

Soil pH in H_2O

Ten grams of air-dry soil (passed 2-mm Sieve) was added to 25 ml of distilled water and stirred for 30 minutes with a glass rod. The soil suspension was allowed to stand for about 30 minutes to allow most of the suspension clay to settle out from the suspension. The pH of the soil was measured using a glass electrode pH meter by inserting the electrodes of the meter into the suspension without touching the bottom of the beaker without stirring the suspension (IITA, 1982).

Organic carbon (%)

The determination of soil organic carbon is based on the Walkley-Black chromic acid wet oxidation in 1 N $K_2Cr_2O_7$ solution. The reaction was assisted by the heat generated by the addition of sulfuric acid (H_2SO_4). The remaining dichromate was titrated with ferrous sulphate. The titre was inversely related to the amount of C present in the soil sample (IITA, 1982).

Total nitrogen

The Total was determined using a micro-Kjeldahl digestion based on the wet oxidation of soil organic matter and botanical materials using H_2SO4 and digestion catalyst and conversion of organic nitrogen to the ammonium form. Ammonium was determined using the diffusion-conductivity technique (International Center for Agricultural Research in the Dry Areas, ICARDA, 2013).

Available phosphorus (Bray-I method)

A 1 gram scoop of air-dried soil and 10 milliliters of extractant were shaken for 5 minutes. The amount of phosphorus extracted was determined by measuring the intensity of the blue color developed in the filtrate when treated with molybadate-ascorbic acid reagent (ICARDA, 2013).

Exchangeable cations (K^+, Ca^+, Mg^+ and Na^+) and cation exchange capacity (CEC)

Exchangeable basic cations were extracted with neutral normal ammonium acetate with potassium (K) and sodium (Na) determined by flame photometry and calcium (Ca) and magnesium (Mg) by EDTA titrations. Cation exchange capacity was the sum of exchangeable cations (ICARDA, 2013).

Electrical conductivity (EC) was determined using a glass electrode conductivity meter (ASTM, 2009).

Study Plant and Metal Collection

Ricinus communis seeds were obtained from Kurmi market, Kano State and the seeds were also identified with accession number BUKHAN 0062 at the Department of Plants Biology, Bayero University Kano. The seeds of *S. occidentalis* were obtained from their natural habitat in Bayero University Kano new campus, Gwale Local Government Area of Kano state, Nigeria at 11° 58' 36.2" N; 8° 25' 32.6"' E. They were identified in the Herbarium of Department of Plants Biology, Bayero University Kano with accession number BUKHAN 0073. Zinc sulphate ($ZnSO_4$) collected from the laboratory of Department of Biological Sciences, Bayero University, Kano, Nigeria.

Soil Spiking with $ZnSO_4$ (Chen et al., 2020)

Air dried soil was ground and passed over 2 mm sieve. 4 mg, 8 mg and 16 mg of ZnSO4 was added to series of 2 kg of the prepared soil and mixed thoroughly with spatula. This gave zinc/soil mixtures of 2 mg/Kg, 4 mg/Kg and 8 mg/Kg respectively. Each the soil and metal mixture was divided into four parts and ground into fine powder with mortar. The homogenized dry mixture was then placed in sterile planting buckets, moistened and incubated for 7 days in the dark before planting. This spiking method carried out under the hood is safe, accurate, quick and easy spiking method compared to the traditional spiking with salt solutions. Salt solutions added to soil create difficulty in homogeneity due to adsorption and localization of metals in soil creating heterogeneity in planting containers.

Experimental Setup, Planting and Agronomical Practices

The experimental design consisted of 4 buckets per treatment per plant plus 4 controls. Buckets containing contaminated and uncontaminated soils were planted with 6 seeds each of *R. communis* and *S. occidentalis*. After germination, each bucket was thinned to 4 healthy looking plants. The pots were labeled and placed in completely randomized design in the Screen house with watering and weeding by hand were done as needed.

Assessment of Vegetative Growth of Castor and Senna Plants

Growth assessments of shoot length, number of leaves and root length were conducted at 45 and 90 days after planting (DAP). The choice of 45 days is to allow growth to be established. An assessment at 90 days was to establish viability up to 3 months. One plant per pot per treatment was selected at random for the analyses.

Statistical Analyses

Data were analyzed with One Way Analysis of Variance ANOVA to determine significant differences in each growth parameter between contaminated and control plants using Minitab software version 18. Treatments were randomly assigned with four replications while mean comparison was conducted using Turkey test at $P< 0.05$.

RESULTS AND DISCUSSION

Soil characterization

The result for the various analyses of the physicochemical properties of the soil was represented in Table 1. The soil was sandy loam (83% sand, 12% silt and 05% clay). The pH was slightly acidic (6.02). Mean values for EC and CEC were 0.03 ds/cm and 4.14 cmol/kg, respectively. Essential elements for plant growth C, N, P and K^+ had mean values of 0.41%, 0.33mg/kg, 14.33 mg/kg and 0.39 cmol/kg respectively. Mean Ca^+ content was 2.2 cmol/kg; Mg^+ was 1.1 cmol/kg, while Na^+ was 0.05 cmol/kg. These values were also reported by Rabiu and Abdulkadir (2022). The fertility status of soil is generally low is as reported by Chude *et al.* (2012).

Table 1: Some physicochemical properties of Agricultural soil

Physicochemical Parameters	Mean Values
Sand (%)	83±1.41
Silt (%)	12±0.00
Clay (%)	05±1.41
Texture	sandy loam
pH(H_2O)	6.02±0.04
EC(ds/cm)	0.03±0.00
OC (%)	0.41±0.02
CEC(cmol/kg)	4.14±0.26
N (mg/Kg)	0.33±0.28
P (mg/kg)	14.33±0.39
Ca^+(cmol/Kg)	2.23±0.11
Mg^+(cmol/Kg)	1.11±0.05
K^+(cmol/Kg)	0.39±0.09
Na^+(cmol/Kg)	0.05±0.00

Effect of Concentrations of Zinc on Growth Vegetative of Castor (*R. communis*)

Table 2 shows the effects of agricultural soil spiking with low doses of Zinc (2 mg/kg, 4 mg/kg and 8 mg/kg) on some growth parameters of castor plant. There were significantly higher ($p<0.05$) mean values for height (16.85 cm) and root length (17.35 cm) of control castor plants than those treated with zinc at 45 DAP. The mean number of leaves (5.0) in the control at 45 DAP did not vary significantly with 2 mg/kg (4.5), 4 mg/kg (4.0) and 8 mg/kg (4.0). At 90 DAP; the values assessed parameters for control plants were higher but not significantly different from all treatments. Lowest mean values for height (10.0 cm) were recorded in plants treated with 2 mg/kg and 8 mg/kg of zinc, number leaves. Least number of leaves (1.25) obtained in plants treated with 4mg/kg and 8mg/kg of zinc while shortest root length (10.12 cm) was observed in plants treated 8 mg/kg of zinc.

Table 2: Vegetative Growth of Castor (*R.communis*) in Different Zinc Concentrations

	Growth Parameters					
Treatment (mg)	**Height (cm)**		**Number or Leaves**		**Root Length (cm)**	
DAP	**45**	**90**	**45**	**90**	**45**	**90**
2.0	11.37±0.62b	10.00±2.45a	4.5±1.0a	2.75±3.59a	8.13±3.42b	3.25±2.78a
4.0	8.62±1.37b	10.5±1.91a	4.0±0.81a	1.25±0.5a	7.62±0.85b	8.65±1.37a
8.0	11.50±2.04b	10.0±1.63a	4.25±1.25	1.25±0.5a	7.62±0.85b	10.12±0.85a
Control	16.85±0.50a	11.50±0.57a	5.00±0.81a	3.75±0.957a	17.35±1.10a	13.63±2.43a

DAP= Days after Planting

Means that do not share a letter along columns are significantly different. ($p<0.05$)

Effect of Concentrations of Zinc on Growth Vegetative of Senna (*S. occidentalis*)

There were variations in the mean values of the assessed growth parameters of senna with some differences being significant ($p<0.05$) as shown in Table 3. At 45 DAP, mean plant length was highest in control (16.38 cm) which was significantly different from the lowest (10.5 cm) in plants treated 8 mg/kg of zinc. Mean number of leaves and root length did not vary significantly between plants exposed to the various concentrations of zinc and control. At the termination of the experiment (90 DAP), senna plants in control had significantly higher mean values for height (29.5 cm) than all other treatments. Greatest mean number of leaves (28.5 cm) was not significantly different from the least (17.25 cm) observed in plants treated with 2 mg/kg of zinc. The mean value for root length was highest in control (24.0cm) which was not significantly different from plants exposed to 2 mg/kg of zinc (20.0 cm) but significantly different to treatments with 8 mg/kg of zinc (16.0 cm) and 4 mg/kg of zinc (12.87).

Table 3 Vegetative Growth of Senna (*S.occidentalis)* in Different Zinc Concentrations

	Growth Parameters					
Treatment (mg)	**Height (cm)**		**Number or Leaves**		**Root Length (cm)**	
DAP	**45**	**90**	**45**	**90**	**45**	**90**
2.0	12.0±1.58ab	21.0±1.63b	17.75±3.59a	17.25±3.77a	7.75±0.323a	20.0±1.78ab
4.0	12.63±4.53ab	20.5±4.36b	18.0±3.65a	21.75±3.86a	9.0±1.08a	12.87±0.85c
8.0	10.5±2.04b	21.0±1.63b	15.50±2.65a	20.0±5.66a	8.25±1.19a	16.0±2.16bc
Control	16.38±2.29a	29.5±1.91a	12.75±8.77a	28.5±6.35a	9.5±1.732a	24.0±3.92a

DAP= Days after Planting

Means that do not share a letter along columns are significantly different. ($p<0.05$)

DISCUSSION

There was enough germination in all pots that provided sufficient numbers for assessment (4 replicates) during the two sampling periods (45 and 90) days after planting similar results were reported by Rabiu and Abdulkadir (2022) when the effects of spent engine oil was tested on these crops. Lack of significant differences in most of the parameters assessed in both plants could be because at low doses, Zinc is an enhancer of growth rather than inhibitor. Heavy metals such as Zn are essential for plant and cellular biochemistry being DalCorso *et al.,* (2019), they are involved in cell protection, gene regulation, reproduction, and tolerance to environmental stresses Al-Heety *et al.,* (2021). This perhaps further explains why all the plants thrived till the termination of the experiment, three months after planting.

However, the higher values of the assessed parameters in control could be due to the fact that zinc is also a heavy metal whose excess could be lead to toxicity or uptake by plants. Abba and Ibrahim (2017) reported zinc uptake by vegetables in soils with zinc concentrations of 5.21 mg/kg, 6.25 mg/kg and 6.94 mg/kg in irrigation sites of Katsina metropolis, Northern Nigeria which were lower than the highest concentration used in this work. Lower number of leaves in castor at 90 DAP could be due to other factors such as diseases that were not investigated in the research. Plant height is the parameter most affected by the exposure to zinc in both plants. The reduction in height indicates that higher concentrations of zinc could lead to growth retardation. Zinc toxicity-associated symptoms in plants include reduced yield and stunted growth, reduced export of photoassimilates (Hafeez et al., 2013). Root length of senna was also significantly lower in plants exposed to all concentrations of zinc than the control. The reason for this could be because the root was the first point of contact with metal; the concentrations at the root were higher thereby exerting somewhat deleterious effects. Senna was more influenced by zinc since height at both sampling periods was significantly higher in the control.

Castor and senna being none major sources of food can be exposed to higher levels of contaminants to be screened for possible phytoremediation of contaminated sites. Plants used in phytoremediation should be ideal for the setting and can withstand stress induced by heavy metals (Azeez, 2021). Castor had been shown to tolerate and accumulate lead (Araújo do Nascimento and Marques, 2018). The observed differences in the response of castor and senna to zinc contamination can be attributed the differences to the phenotypic and genetic makeup of the two plants. Senna was a taller and contained higher number of leaves while castor has broader leaves. The threshold of zinc tolerance and toxicity varies among plant species (Hafeez et al., 2013).

CONCLUSION

Castor (*R. communis*) and senna (*S. occidentalis*) exposed to 2 mg/kg, 4 mg/kg and 8 mg/kg of zinc thrived mostly as well as control plants up to 90 DAP in the screen house. The null hypotheses are rejected since some significant differences occurred in plants with treatments and senna was found to be more sensitive to exposure to zinc than castor. It is recommended that the plants to be exposed to higher concentrations of the heavy metal for phytoremediation capacity.

REFERENCES

Abbaslou, H., Bakhtiari, S. (2017) Phytoremediation potential of heavy metals by two native pasture plants (Eucalyptus grandis and ailanthus Altissima) assisted with AMF and fibrous minerals in contaminated mining regions Pollution 3 (3): 471-486

Abdu, N. (2010) Availability, transfer and balances of heavy metals in urban agriculture of West Africa PhD Thesis Kassel University Press GmbH, Kassel Germany 158pp

Abdulrashid L., Yaro A. & Isah A. (2017) Heavy Metals Contamination in Urban Soils of Nigerian: A Review International Journal of Innovative Biosciences Research 5(3):1-12 [Crossref]

Al-Heety, L.F.D., Hasan O. M., Al-Heety E. A. M. S. (2021) Assessment of heavy metal pollution of plants grown adjacent to power generators in Ramadi city IOP Conf. Series: Earth and Environmental Science 779 012023 9pp [Crossref]

ASTM (2009) Standard Test Methods for Electrical Conductivity and Resistivity of Water D1125 - 95

Araújo do Nascimento, C. W., and Marques, M. M. (2018) Metabolic alterations and X-ray chlorophyll fluorescence for the early detection of lead stress in castor bean (Ricinus communis) plants Acta Scientiarum Agronomy 40 e39392 9pp. [Crossref]

Azeez, N. M. (2021) Bioaccumulation and phytoremediation of some heavy metals (Mn, Cu, Zn and Pb) by bladderwort and duckweed BIODIVERSITAS 22 (5): 2993-2998. [Crossref]

Bortoloti, G. A., Baron, D. (2022) Phytoremediation of toxic heavy metals by Brassica plants: A biochemical and physiological approach Environmental Advances 8 100204 13pp. [Crossref]

Burkill, H.M., (1995) The useful plants of west tropical Africa Families. Journal of the Royal Botanical Gardens, Kew, United Kingdom 3:160- 163

Chen, L., Larson, S. L., Ballard, J. H., Ma, Y., Zhanga, Q., Li, J., Wu, L., Arslan, Z. and Han F. X. (2020) Laboratory Spiking Process of Soil With Various Uranium and Other Heavy Metals U.S. Army Engineer Research and Development Center (ERDC) ERDC/EL MP-20-5 11p. [Crossref]

Chude, V O., Olayiwola, S O., Daudu, C. and Ekeoma, A., (2012). Fertlizer use and Management Practices for Crops in Nigeria 4th Ed. 215pp

DalCorso G., Fasani, E., Manara, A., Visioli G., Furini A. (2019) Heavy Metal Pollutions: State of the Art and Innovation in Phytoremediation International Journal of Molecular Science 20 17pp 3412; [Crossref]

Dawaki, U.M., Dikko, A.U., Noma, S.S., Aliyu U. (2013) Heavy Metals and Physicochemical Properties of Soils in Kano Urban Agricultural Lands Nigerian Journal of Basic and Applied Sciences 21(3):239-246. [Crossref]

Ekta P., Modi, N. R. (2018) A review of phytoremediation Journal of Pharmacognosy and Phytochemistry 7(4): 1485-1489

Hafeez , B. , Khanif, Y. M. and Saleem, M. Role (2013) Role of Zinc in Plant Nutrition- A Review American Journal of Experimental Agriculture 3(2): 374-391. [Crossref]

He, Z., Shentu, J., Yang, X., Baligar, V.C., Zhang, T & Stoffella, P.J. (2015) Heavy Metal Contamination of Soils: Sources, Indicators, and Assessment Journal of Environmental Indicators 9:17-18

International Center for Agricultural Research in the Dry Areas (2013) Methods of Soil, Plant, and Water Analysis: A manual for the West Asia and North Africa region 3rd ed 244p

International Institute for Tropical Agriculture (1982) Automated and Semi Automated Methods for Soil and Plant Analysis Manual Series 7 International Institute for Tropical Agriculture Oyo Road P M B 5320 Ibadan, Nigeria

Karkarna , M.Z and Matazu, M. A. (2021) Assessment of Heavy Metal Contamination in Surface and Sub-Surface Soils from Dumpsites In Kano Metropolis, Nigeria Dutse Journal of Pure and Applied Sciences (DUJOPAS) 7(1): 260-270

Opaluwa, O. D., Aremu, M. O., Ogbo, L. O., Abiola, K. A., Odiba, I. E., Abubakar, M. M., Nweze, N.O., (2012) Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis, Nasarawa State, Nigeria Advances in Applied Science Research 3(2):780-784

Rabiu, H. M. (2017). Assessments of Symbiotic Compatibility of Cowpea (Vigna unguiculata L Walp) Varieties with Indigenous Rhizobia within Soils in Kano State, Nigeria Techno Science Africana Journal. 14(1) 1SSN 2006 - 2273 p127-134

Weiss, E. A. (2000). Oilseed Crops. 2nd ed. Blackwell Science, Oxford