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FIELD ACCUMULATION AND TRANSLOCATION OF POTENTIALLY TOXIC ELEMENTS (PTES) FROM INDUSTRIAL SOIL BY THE BIODIESEL PLANT, *Jatropha Curcas*

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ABSTRACT
Samples of Jatropha curcas,a non-edible biodiesel plant, which tolerates harsh environments was collected from an industrial area with high anthropogenic activities (Challawa Industrial area, Kano, Nigeria)and sorted into leaves, stems and roots. The aim is to assess the potentials of Jatropha curcas in accumulation and translocation of six Potentially Toxic Elements (PTEs) (Zn, Cu, Cd, Cr, Pb and Ni) from the soil media. Atomic Absorption Spectroscopy (AAS) was used to assess the concentrations. The bioaccumulation/ transfer of metals from roots to shoots and from soil to roots were evaluated in terms of translocation (TF) and bioconcentration factor (BCF). TF values of 1.02, 4.92, 2.68, 3.73, 1.5 and 3.19 for Zn, Cu, Cd, Cr, Pb and Ni respectively indicate that J. curcas was efficient in translocation of PTEs from roots to shoots. This is an indication that the plant is therefore suitable for phytoextraction of Zn, Cu, Cd, Cr, Pb and Ni. But BCF value of 0.66 and 0.70 for Cu and Pb on the other hand shows that J. curcas is less able to translocate these two metals (Cu and Pb) indicating ineffective transfer. This show that J. curcasmay be suitable a candidate for phytostabilization of Copper and lead in contaminated soils in the study area.

Key words: PTEs, *Jatropha curcas*, *translocation, phytoextraction, bioaccumulation and phytostabilization*

INTRODUCTION

Potentially toxic elements (PTEs) pollution has become a major environmental issue worldwide (Xiaogang Li *et al.*, 2020; Si *et al.*, 2021). As a result, soil, an important sink of nutrients and pollutants, plays a vital role in environmental sustainability and security(Wu *et al.*, 2018). Unfortunately, soil pollution has turned out to be a drawback in terms of human advancement and general health wellbeing recently(Jiang *et al.*, 2017; Padoan *et al.*, 2017). Soil contaminated with PTEs is of great environmental concern since these contaminants are taken up by living organisms, added as run-offs to water bodies and transported to other remote areas Ghosh & Maiti, (2020). Heavy metals, which are among the Potentially Toxic Elements (PTEs), are defined as metallic constituents with atomic number > 20 and density > 6 g cm^{-3} (Zulfiqar *et al.*, 2019).They have attracted attention in recently due to the fact that these heavy metals are generally refractory and cannot be degraded (Xingyuan Li *et al.*, 2021). Over the years vast number of research has been carried out to solve this challenging scenario. Physical, chemical and biological methods have been advocated to remediate metal contaminated soils (Sivakumar *et al.*, 2020). Most of these techniques are conventional remediation technologies which has to do with physical, and chemical methods in order to bring contamination to adequate level (Guo *et al.*, 2020). However, phytoremediation has been recognized as cost effective method for remediation of metal contaminated soils (Chauhan *et al.*, 2020). Phytoremediation in simple terms refers to the use of plants and associated soil microbes to reduce the concentrations or toxic effects of contaminants in the environment (Álvarez-mateos & García-martín 2019). There are two major approach to phytoremediation. One of such approach is phytoextractionuses plants ability to assimilate toxic metals from belowground parts and transfer them to other tissues of plants where they may accumulate. Phytoextraction is a solar-driven technique which uses plant roots to translocate heavy metals from soil to other tissues of plants located above the ground (Xiong Li & Yang, 2020). As for phytostabilization, it's a technology which utilizes the ability of plants to reduce the bioavailability and mobility of toxic metals and stabilize them below the ground in soils(Xiong Li & Yang 2020). Despite the fact that traditional phytoremediation by using green plants to

alleviate soil contamination seems a viable approach to tackle the Problem of Potentially toxic elements, it has not been applied successfully as a result of a number of limitations. Some of these limitations are slow growth and low biomass of plants and low bioavailability of heavy metals in soil(Álvarez-mateos & García-martín, 2019). Others are, the fact that it takes time to clean up the contaminated soil and very small concentrations of metals is bioavailable which varies with some soil properties like pH and organic matter. *J. curcas* (Family: Euphorbiacae) a non-edible, potential biodiesel plant, which can survive harsh environments of semi-arid agro-climatic conditions and wastelands (Moursy *et al*., 2014)was selected for this study. Literature is abound on research using this plant as an accumulator of metals however report on its accumulation ability in proportion to background metal concentration in this industrial area is limited. The aim of the study is to assess the potentials of *J. curcas* in the accumulation and translocation of six heavy metals in tissues of this plant growing naturally at Challawa Industrial Estate and its suitability in phytoremediation. A Picture of *J. curcas*is shown in plate 1.

MATERIALS AND METHODS

Preparation of Reagents

In the preparation of reagents, chemicals of analytical grade purity and deionized water were used throughout the analysis. All the laboratory apparatus (glass wares and the plastic containers) were first soaked in nitric-acid and thoroughly washed with detergent solution, followed by several rinses with tap water, deionized water and finally with the analyte samples.

2Study Area

The field study was carried out in the vicinity of Challawa Industrial area. The area is located in Kumbotso local government of Kano state. Sampling was done at Yandanko village in Challawa Industrial area, located between latitudes 11°52´48.81" and along longitudes 8°28´17.25". The Global Positioning System (GPS) was used in recording the coordinates and Geographical Information System (GIS) was used to locate the map of the study area as shown below (Figure 1).

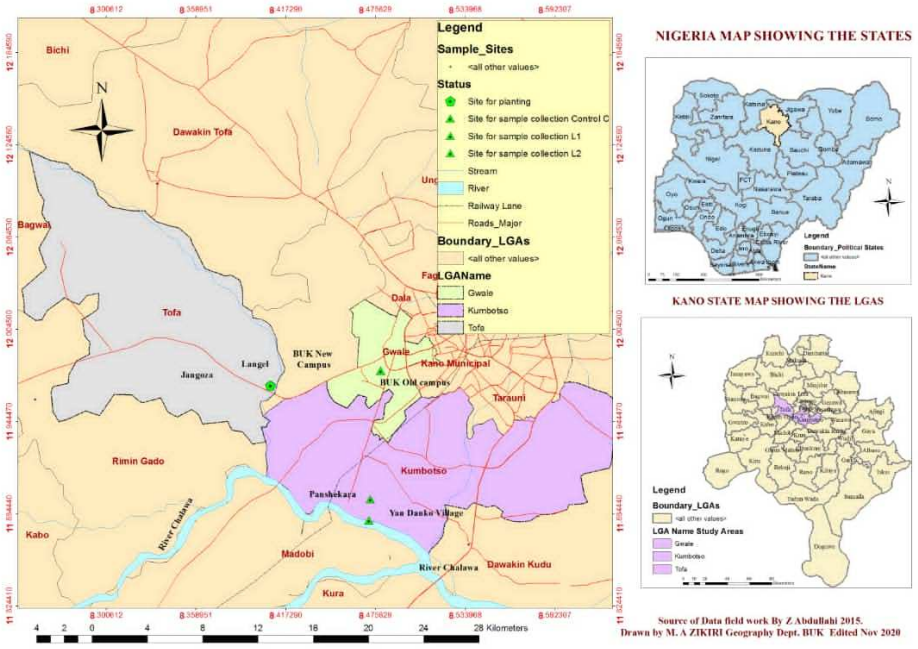

Figure 1: Map of Kumbotso and Tofa LGA Showing Sampling location

Field Sampling of Soil and Plant Species (Yan danko Challawa and Langel Village, Tofa LGA).

Nine sampling points from three locations were systematically established after every 100m. *Jatropha curcas* was collected for analysis with Identification of the collected plant specie was done at the Plant Biology Department of Bayero University Kano and a herbarium number*Jatropha curcas (bukhan 0060)* was at least three species per sampling point including the control site (Langel village), which was far away from Challawa Industrial area. The plant specie was collected from this sites at almost similar stage of growth as that from the Challawa sample and were used as the control.

assigned to the plant. The sample was labeled, placed in polythene bags and transported to the University and air-dried. Three soil samples were also collected at each sampling point for the plant and composites obtained. The composite soil samples was air dried and ground into fine powder using pestle and mortar and sieved through 2mm plastic mesh and stored in labeled polythene bags.

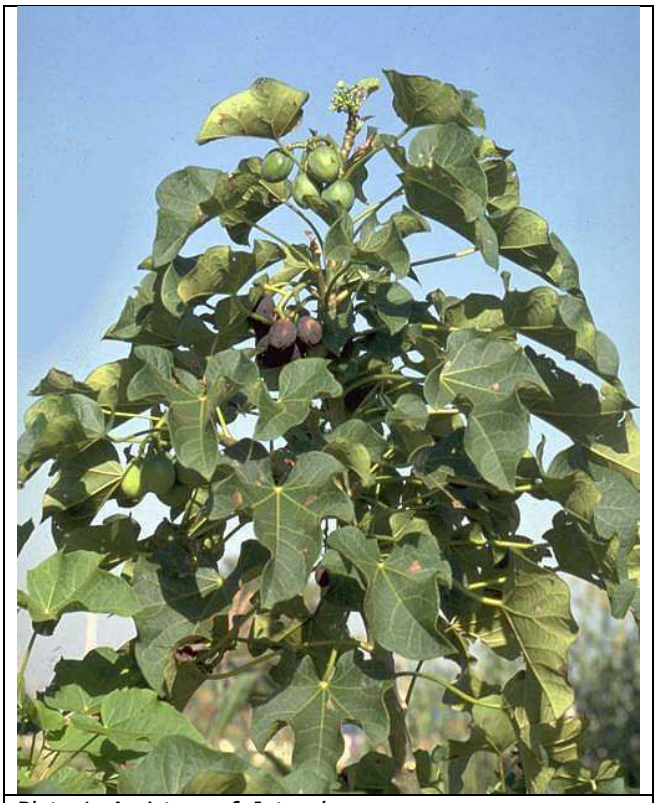

Plate 1: A picture of *Jatropha curcas*

Digestion of Soil Samples

1g of the soil sample from Yandanko, at Challawa was mixed with 20cm^3 of nitric acid (HNO_3) (70% w/v, S.G 1.42g/cm^3) and allowed to stand for 1hour. 15cm^3 of perchloric acid ($HClO_4$) (70% w/v, S.G 1.67g/cm^3) was then added and the mixture was placed in a sand bath and heated at 55°C until dense white fumes were observed. It was allowed to cool and filtered into the 100cm^3 volumetric flask and made to the mark. The resulting solution was analyzed for metal concentrations using Atomic Absorption Spectrophotometer Buck scientific, Model-210VGP (Tanee aand Amadi, 2016).

Plant Tissue Analysis

Before the analyses root and shoot samples were thoroughly washed using distilled water to remove all adhering soil particles. Samples were then oven dried to constant weights at 105°C. Each dried sample was ground to powder and 0.5 gram of each sample was used for analysis. These samples were placed in a crucible and transferred to the muffle furnace and ashed at 550°C.The ash is then dissolved in 10ml 0.1M nitric acid, filtered and made up to the 100cm^3 mark and analyzed for metal content using Atomic Absorption spectrophotometer (Inuwa and Mohammed, 2018).

Statistical analysis

All data gathered were analyzed statistically using analysis of variance (ANOVA). When significant differences were detected between treatments, Tukey test (at $P < 0.05$) was calculated for each parameter and all graphs were plotted by employing Microsoft Excel.

RESULTS AND DISCUSSION

The soil physico-chemical characteristics from the study area have been reported in our earlier works. Results revealed that the area is characterized by sandy texture (66.8%).As indicated from earlier report, the pH of soil was slightly acidicwith a value of 6.0 while that of the control is 6.8 (Zakari and Audu, 2021).

Potentially Toxic Elements (PTEs) in *J. curcas*

The data obtained from the field studies show that the PTEs contents in the plant tissues varied among plant species, which reflected the edaphic metal conditions in the area under study. Fig 2-7 is a chart representing the levels of all six studied PTEs (Zn, Cu, Cd, Cr, Pb, and Ni) in tissues (leaf, stem, roots) and rhizospheric soil samples in *J. curcas* sampled from Challawa Industrial Area. In Fig 2, the observed Zn concentrations (mg kg^{-1}) in *J. curcas* are; 55.16 ± 15.49, 84.09 ± 24.09, 136.16 ± 38.34, and 93.16 ± 24.08 in leaf, stem, root and rhizospheric soil samples respectively. The Zn concentration in the tissues follows the decreasing order as root > stem > leaf. One way Anova shows that there is significant difference between the Zn levels in the leaf, stem, root and soil at $P < 0.05$. The Turkey test however, revealed that the Zn levels in the root is significantly higher than those obtained in the stem, soil and leaf. However, there is no significant difference at $P < 0.05$ between the levels of zinc in the leaf and stem. This observation was also noticed for the soil and the stem which shows no significant difference. However, the results showed that roots were found to accumulate considerable amounts of Zn than leaf and stem tissues compared to their levels in similar tissues of the control as depicted by fig 2. This results agrees with the findings of Abdullahi *et al*, 2016,Waziri *et al*., 2016, Wu *et al*., 2011and Ahmadpour *et al*., 2010, for the same plant. Zinc is an essential trace element required for plant growth and it is very important in many metabolic processes in plants(Ji *et al*., 2021).

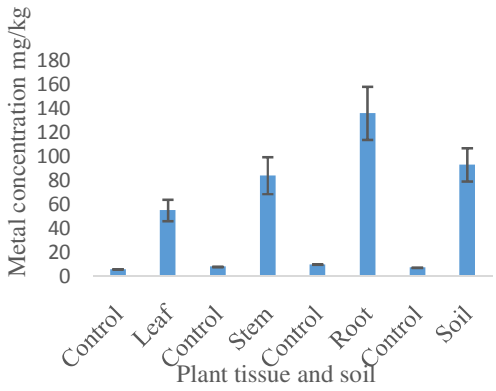

Fig 2:Distribution of Levels of Zinc in Tissues and Soil Samples of *J.curcas*

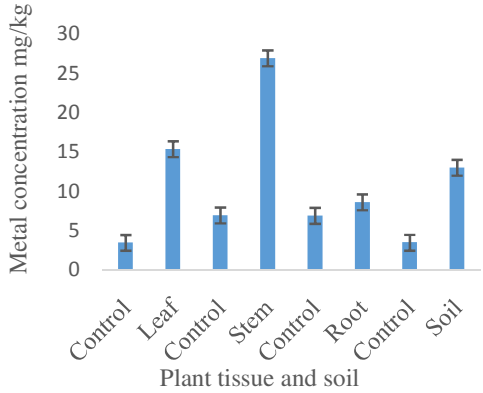

Fig 3:Distribution of Levels of Copper in Tissues and Soil Samples of *J. curcas*

The Cu concentration in the *J. curcas* tissues follows the decreasing order pattern as stem > leaf > root. One way Anova shows that there is significant difference between the Cu levels in the leaf, stem, root and soil at $P < 0.05$. The Tukey test however, revealed that there is no significant difference at $P < 0.05$ between the levels of Cu in soil, leaf and root. However, the Cu levels in the stem is significantly higher than those obtained in the root and leaf. However, results showed that stem tissues were found to accumulate a very high amounts of Cu than the roots and leaf as depicted by fig 3. Our results agree with the findings of Abdullahi *et al*, 2016, Wu *et al*., 2011 for the same plant. Cu is an essential micronutrient in trace quantities, but it can be a potential toxicant at high concentrations(Hou *et al*., 2018).It can also lead to morphological, anatomical and physiological changes in plants (Hou *et al*., 2018).

The Cd concentration in the *J. curcas* tissues follows the decreasing order pattern as leaf > stem > root. One way Anova shows that there is significant difference between the Cd levels in the leaf, stem, root and soil at $P < 0.05$. The Tukey test however, revealed that the Cd levels in the leaf is significantly higher than those obtained in the stem and root. However, there is no significant difference between the levels of Cd in root and stem. Additionally, the Cd levels in the rhizospheric soil is significantly lower than that of the levels in the leaf, root and stem. Among the heavy metals, Cd is relatively mobile in the soil and can be toxic to both plants and animals (Rizwan et al., 2017). Results obtained showed that accumulation of Cd in *J. curcas* is found to be higher in leaf than both the stem and root tissues compared to their levels in similar tissues of the control as depicted by fig 4.This results agrees with the findings of Chang *et al*., (2014), Abdullahi *et al*, (2016) and Waziri *et al*., (2016) for the same plant. Uptake of Cd in plants is controlled by its concentration and bioavailability in soil which are influenced by soil properties(Wang *et al*., 2021).Cd is one of the most phytotoxic elements and does not have a known biological function in plants (Dobrikova *et al*., 2021).

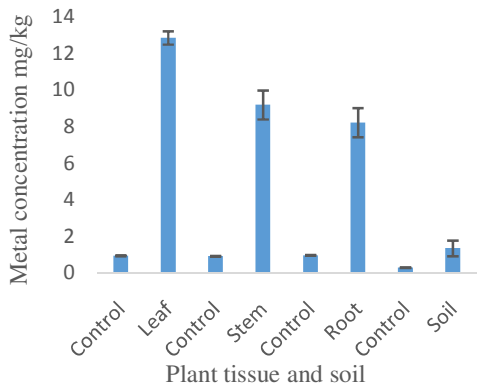

Fig 4:Distribution of Levels of Cadmium in Tissues and Soil Samples of *J. curcas*

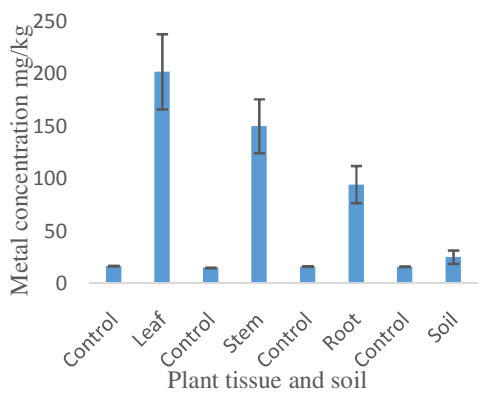

Fig 5:Distribution of Levels of Chromium in Tissues and Soil Samples of *J. curcas*

The Cr concentration in the *J. curcas* tissues follows the decreasing order pattern as leaf > stem > root. One way Anova shows that there is significant difference between the Cr levels in the leaf, stem, root and soil at $P < 0.05$. The Tukey test however, revealed that the Cr levels in the soil is significantly lower than those obtained in the tissues (root, stem and leaf). However, there is no significant difference between the levels of Cr in the root and the stem. It also shows that, there is no significant difference between Cr levels in the stem and leaf. However, results showed that roots were found to accumulate considerable amounts of Cr than leaf and stem as depicted by fig 5. Our results agree with the findings of Chang *et al.*, (2014)Abdullahi *et al*, (2016), Waziri *et al.*, (2016) and Wu *et al.*, (2011) for the same plant. In nature, Cr exists in two different stable oxidation states i.e., trivalent $Cr^{3+}$and hexavalent Cr^{6+} forms. Cr^{3+} and Cr^{6+} differ in terms of mobility, bioavailability and toxicity. Cr^{6+} has been found to be more toxic than C^{r3+}(Patra *et al.*, 2018).

The Pb concentration in the *J. curcas* tissues follows the decreasing order pattern as root > stem > leaf. One way Anova shows that there is significant difference between the Pb levels in the leaf, stem, root and soil at $P < 0.05$. The Tukey test however, revealed that the Pb levels in the soil is significantly higher at $P < 0.05$ than those obtained in the root, stem and leaf. However, there is no significant difference between the levels of Pb in the leaf and stem on the one hand and stem and root on the other hand. In addition, the Pb levels in the leaf is significantly lower than that of the root. However, results showed that roots and stem were found to accumulate large amounts of Pb than the leaf as depicted by figs 6.This results is consistent with the findings of Chang *et al.*, (2014). Pb is known for its negative effect on chlorophyll biosynthesis and nutrient metabolism in several species El *et al.*, (2020).

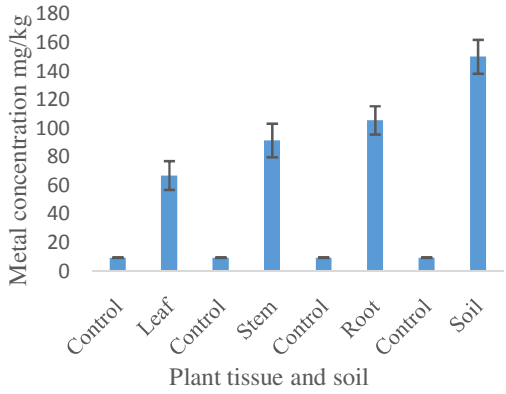

Fig 6:Distribution of Levels of Lead in Tissues and Soil Samples of *J. curcas*

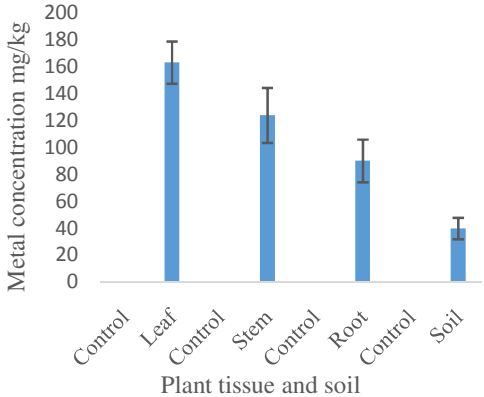

Fig 7:Distribution of Levels of Nickel in Tissues and Soil Samples of *J. curcas*

Nickel is an essential nutrient for plants, but a high concentrations of Ni metal, adversely affects plant growth and both quality and yield of plants Heidari *et al*., (2020). For Ni levels, a decreasing order pattern, leaf > stem >root was observed in the tissues of *J. curcas*. One way Anova shows that there is significant difference between the Ni levels in the leaf, stem, root and soil at $P < 0.05$.The Tukey test revealed that the Ni levels in the leaf is significantly higher than those obtained in the stem, root and soil. However, there is no significant difference between the levels of Ni in root and stem. Also, the Ni levels in the soil is significantly lower than that of the leaf, stem and root. However, results showed that roots were found to accumulate considerable amounts of Ni than leaf and stem as depicted by figs 7. Our results agree with the findings of Abdullahi *et al*, (2016) and Wu *et al*., (2011) for the same plant.

Bioaccumulation and Translocation in Field Plants

The Bioconcentration factor (BCF) was determined by as previously described in-situ Phytoextraction potential in native hyperaccumulator plants Sharma *et al*., (2020).While the translocation factor (TF) was evaluated by calculating the ratio of metal concentration in plant shoot and metal concentration in plant root (Sharma *et al*., 2020;Amir *et al*., 2020). The Translocation and Bioaccumulation in *J. curcas* is as shown in Figs 8 and 9 respectively.

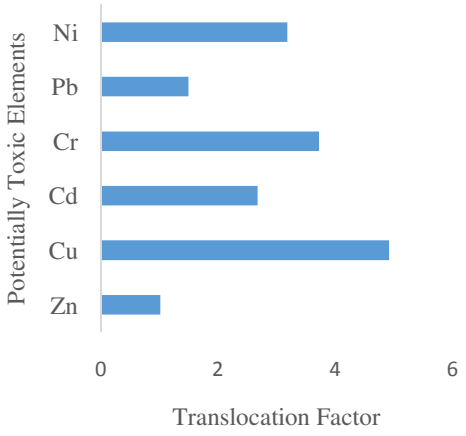

Fig 8: Translocation factor of the six Potentially Toxic Elements *in J. curcas*

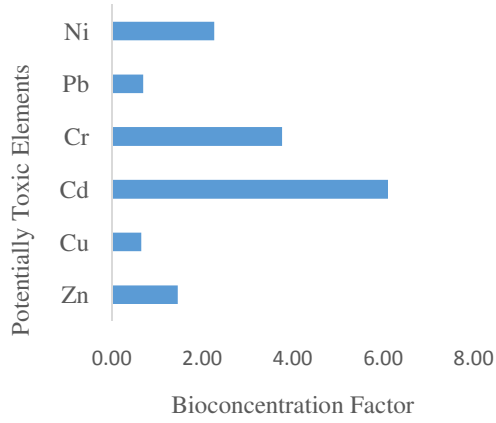

Fig 9: Bioconcentration factor of the six potentially toxic elements *in J. curcas.*

The Translocation and Bioaccumulation in *J. curcas* is as shown in Figs 8 and 9 respectively. The translocation factors (TF) expresses the ability of a plant to translocate heavy metals from the root to shoot in the soil-plant system (Álvarez-mateos & García-martín, 2019). TF determines plant efficiency in heavy metals translocation from the roots to the shoots. It shows whether the native plant can be classified as an accumulator, excluder or indicator. A plant is considered efficient in metal translocation from root to shoot when TF > 1; the reason being an efficient metal transport system TF < 1, suggest an ineffective metal transfer indicating that such plant species accumulate metals mostly or substantially in the roots and rhizomes than in the shoot portions or the leaves of plants (Usman *et al*., 2019). Bioconcentration factor (BCF) on the other hand, can be used to evaluate a plant's phytoremediation potential. A BCF value > 1 indicate that a plant is a hyperaccumulator whereas, a value less than one is indicative of an excluder(Usman *et al*., 2019) .Both BCF and TF have to be considered for evaluating whether a plant is a metal hyperaccumulator. A hyperaccumulator plant should have BCF>1 or TF > 1(Sharma *et al*., 2020). *J. curcas* was screened for Zn, Cu, Cd, Cr, Pb, and Ni. Results show that it has the ability to take up and translocate more than one heavy metal from roots to shoots as shown in figs 8a and 8b with noticeable variations between TF and BCF.

Fig 8depicts that *J. curcas* was able to translocate PTEs from roots to shoots with TF values of 1.02, 4.92, 2.68,3.73, 1.5 and 3.19 for Zn**,** Cu,Cd, Cr, Pb and Nirespectively. This shows that this plant may be considered for phytoextraction of these elements. In Fig 9, which shows the BCF values for *J. curcas*, BCF > 1 were observed for the elements Zn (1.46), Cd (6.11),Cr (3.77), and Ni (2.27)with the exception of Cu (0.66) andPb (0.70)which had a BCF < 1.Therefore, Zn, Cd, Crand Ni with both TF and BCF values greater than 1 shows that J. curcas is able to efficiently translocate all these 4 elements. But BCF value of 0.66 and 0.70 for Cu and Pb on the other hand shows that *J. curcas* is less able to translocate these two metals (Cu and Pb) indicating ineffective transfer.

CONCLUSION

The potential for phytoremediation through bioaccumulation of *J. curcas* against six PTEs (Zn, Cr, Cd, Cu, Ni and Pb) was studied. In the course of this study, we can reasonably conclude that the plantis a resistant species containing in its tissues amounts of PTEs that were much higher than those considered toxic for normal plants.Based on the translocation factor (TF) and the bio concentration factor (BCF) values, the study show the suitability of this plant for both phytoextraction of Zn**,** Cu,Cr and Ni and phytostabilization of Cd and Pb in the study area and where desired.

Disclosure statement: *Conflict of Interest:* The authors declare that there are no conflicts of interest.

Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects.

Author's contributions: Zakari Abdullahi conducted the research while Prof A.A Audu supervised the research.

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