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Uptake, Translocation and Hyperaccumulating Potentials of Bahama Grass (*Cynodon dactylon)* for some Heavy Metals in Soil

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Abstract

Heavy metals are popular pollutants due to their persistence, toxicity, accumulative nature in living things, and lack of biodegradability. This study evaluated the phytoremediation potentials of Bahama grass (Cynodon dactylon) for Cr, Zn, Ni, Cd and Pb. Pot experiments were conducted using soil (2 kg) mixed with Cr, Zn, Ni, Cd and Pb salt solutions. The soils were treated with Cr, Zn, Ni, Cd and Pb salt solutions at a concentration of 100 ppm, 200 ppm, 300 ppm. Seeds of the grass (Bahama) were planted in to pots. Untreated soils (2 kg) containing seeds of the grasses pots were used to serve as controls. The experimental pots were irrigated with 500 mL of water in the evening hours for twelve weeks. The entire experiments were replicated four times for statistical purpose. After twelve weeks, the grass samples were collected, washed and separated into root and shoot. The soil, root and shoot samples were digested and analyzed for the heavy metals using AAS (Agilent 200 series Model No.240Fs). The result revealed that the Bioconcentration (BCF), Enrichment (EF) and Translocation (TF) Factors generally decrease with increase in the concentrations of the heavy metals using the C. Dactylon. The highest levels of BCF, TF and EF were 1.42 (Cd), 7.34 (Cd) and 1.36 (Ni) C. Dactylon. This indicate that the C. Dactylon is having highest phytoextraction potential in the Cadmium-contaminated soils and highest phytostabilization potential in the Nickel-contaminated soils. Therefore, C. dactylon have potential for phytoremediation of the heavy metal-contaminated soils.

Keywords: Uptake, Translocation, Hyperaccumulating, Bahama Grass, Heavy Metals

INTRODUCTION

Heavy metals pose a serious problem to environment and living things (Iqbal *et al.*, 2023). Some heavy metals such as cadmium, lead, mercury, and arsenic are not dangerous but have an impact on plants (Ahmad *et al.*, 2023). Heavy metals are popular pollutants due to their persistence, toxicity, accumulative nature in living things, and lack of biodegradability (Usman 2022; Jehan *et al.*, 2021). These metals play an important role in both animals and plants due to their chemical coordination, redox properties, and maintenance of regulatory processes like degradation, transport, homeostasis and binding to target cells (Khan *et al.*, 2019). Heavy metals are among other contaminants found in the environment that cause a serious threat. Naturally human activities have contributed to alarming concentrations of

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heavy metals contamination in the environment. These heavy metals move into non-contaminated areas by the process of leaching via the soil or by spreading via the sewage sludge. Several methodologies are used in order to remediate the environment from these heavy metals, but most of the methodologies are not only expensive but do not give their best results. Different physical and chemical methods used to generate sludge, thus increasing the costs. These technologies used to affect the land usage as they remove the nutrients from the soil. Currently, phytoremediation is the now preferred technology for an efficient and affordable solution that can be used to remove the inactive pollutants from contaminated water and soil. Phytoremediation is an eco-friendly and cost-effective technology (Dhingra *et al.,* 2021).

The efficient managing of wastewater and soil pollution will not only benefit the environment and the ecosystem, but also human life. That is why it is important to design a suitable method to solve the issues of contaminated soil and wastewater, with cost effective and good operational efficiency. One the suitable, sustainable and green approaches to treat wastewater and contaminated soil is through phytoremediation (Xilong *et al.,* 2015).

Phytoremediation is the technology that is based on the combined action of plants and their associated microbial communities to degrade, remove, transform, or immobilize the toxic compounds present in soils, sediments, and more recently in polluted groundwater and wastewater in treatment wetlands (Xilong *et al.,* 2015).

Bahama grass is a major turf and forage specie and is a highly sod forming perennial that propagates by stolons, rhizomes, and seeds thus, it could be established in contaminated soil vegetatively (Anderson *et al.,* 1993). It has perennial, fibrous root systems with deep and vigorous rhizomes. Bahama grass grows well on different soil from deep sands to heavy clay. It tolerates both acid and alkaline soil conductions and is highly tolerant to salt, drought, anoxia (flooding), cold and soil compaction (Buble, 2009).

Moreover, Bahama grass is very aggressive species that grows very fast leading to a rapid leaf turnover and nutrient cycling, which in turn increases nutrient availability, improve or stabilize soil structure and composition, and enhance dissipation of oil contaminates in the soil, these factors enhance degradation of oil contaminants (Merkl *et al*., 2005; Abedi-Kupai *et al*., 2007).

C. dactylon was found to possess phytoremedial potential against dibenzofuran contaminated soil and petroleum sludge (Hutchinson *et al.,* 2001). Bahama grass can accumulate very high concentration of Pb (0.15-0.65%) and Zn (0.22-1.56%) in the roots; waste elements (like Ca, Cr, Cu, Pb, Zn, Mn and Fe) in wetland plants, certain concentration of Cu, arsenic amongst others and thus can serve as potential candidate for revegetation in many heavy metal contaminated wastelands (Maiti and Nandhini, 2006). The *Cynodon dactylon* can transform Cu forms in rhizosphere soil. The grass withstands many of the elements and can probably serve as phytostabilization of spill-affected soil. A mutual relationship between *C. dactylon* and specific microorganisms can result in phytobioconversion of hard coal in the rhizosphere (Wang *et al.,* 2001). Mukasa-Mugerwa *et al.* (2011) suggested that the relationship between *C. dactylon, Neosartorya fischeri* arbascular mycorrhizal fungi, and other coal biodegrading rhizosphere fungi could result to the biodegradation of hard coal onsite and application of these organisms could be a novel method for coal dump remediation.

Contamination of soil with heavy metal poses risks and hazards to human life and the environment. The physical and chemical treatment methods for the remediation of heavy metals are ineffective. Therefore, phytoremediation is an effective and affordable treatment method used to remediate heavy metals from the contaminated soil.

MATERIALS AND METHODS

Sampling site.

The seed samples of the grass along with the soil that support the growth of the grasses were collected from Lake Chad Research Institute situated at Five Kilometer Gamboru Ngala Road, Maiduguri, Borno State. Maiduguri is situated at 11.85^o North latitude, 36.16^0 East longitude and 300 metres elevation above, Maiduguri is a very large town in Nigeria having about 1,112,449 inhabitants.

Sample Collection

The seed samples of the grass were collected from the seeds store of the Lake Chad Research Institute, Maiduguri. While the soil samples were also collected from the surface to sub-surface portions at a depth of five centimeters (0-5 cm) at the experimental farm of the institute.

Pot Experimental Design

Pot experiments were conducted using soil (2 kg) mixed with Cr, Zn, Ni, Cd and Pb salt solutions based on early research (Ahalya *et al.*, 2005). The soils were treated with Cr, Zn, Ni, Cd and Pb salt solutions at a concentration of 100 ppm, 200 ppm, 300 ppm. Seeds of the grass (Bahama) were planted in to the pots. Untreated soils (2 kg) in the pots containing seeds of the grasses (Bahama) were used to serve as controls. The experiment was watered with 500 mL of water in the evening hours. Leached water was collected in plastics trays placed under each pot. The leached water was put back. This is to prevent loss of nutrients and trace elements from the samples (Garba *et al.*, 2011). The entire experiments were replicated four times for statistical purpose.

Sample Preparation and Analysis of Physicochemical Properties

After twelve weeks, the grass samples were collected, washed and separated into root and shoot. These were dried to a constant weight at room temperature. The dried samples were ground and sieved according to standard method (Lombi *et al.*, 2001). The dried soil sample was characterized for some physicochemical properties (Lombi *et al.*, 2001).

Digestion and analysis of Heavy Metals

The sieved plant samples were digested using 6 M HCL at 500 °C according to standard method (Radojevic and Baskin, 1999). Sieved soil samples were fifteen millilitre (15 mL) of concentrated HNO_3, H_2SO_4, and $HClO_4$ acid in a ratio of (5:1:1) at 80 °C. The digested samples were analysed for the heavy metals by the use of atomic absorption spectroscopy (AAS (Agilent 200 series Atomic Absorption Spectrophotometer Model No.240Fs).

Statistical data Handling

SPSS 17 package was used for handling the statistical data. Difference in the levels of the heavy metals among the various samples was calculated using one-way. Turkey test was used for multiple comparisons. A significant level of $P \geq 0.05$ was used throughout the study.

RESULTS AND DISCUSSION

The physiochemical properties of the experimental soil are as shown in table 1.

Table 1: Physicochemical Properties of the experimental soil

Parameters	Soil of *C. dactylon*
pH	6. 60 ±0.021
EC (dsm^{-1})	0.47±0.002
CEC (cmol/100kg soil)	3.98±0.007
Organic carbon (%)	0.53±0.005
Organic Matter (%)	0.69±0.008
Silt (%)	24.70±0.006
Clay (%)	20.20±0.004
Sand (%)	59.20±0.006
Textural Class	Sandy Loamy

Data are presented as mean ± SD, SD= Standard deviation, EC= Electrical Conductivity, CEC= Cation Exchange Capacity.

The taxonomy classification of the soil was found to be sandy loam with pH of 6.60±0.02. The less acidic nature of the soil is generally within the range for soil in the region; soil pH plays an important role in the absorption of heavy metals, it controls the solubility and hydrolysis of metal hydroxide, carbonate and phosphates (Garba *et al.,*2011). The levels of Electric Conductivity, organic matter content, Cation Exchange Capacity and silt in the experimental soil were found to be 0.47±0.02 ms/cm, 0.69±0.01, 98±0.01 mol/100g and 24.70±0.006 respectively. Cation Exchange Capacity indicate the capacity of soil to allow mobility of electron within the soils. Silt help the soil by promoting better plant growth.

Table 2 show the mean Concentration (µg/g), BCF, EF and TF of Chromium (Cr) in the samples.

Table 2: Mean Concentration (µg/g), Bioconcentration factor (BCF), Enrichment factor (EF) and Translocation factor (TF) of Chromium (Cr) in the Samples

Concentration	Shoot	Root	Soil	BCF	EF	TF
100 ppm	0.75a±0.04	0.69a±0.03	0.74a±0.01	0.93	1.01	1.08
200 ppm	0.84ab±0.11	1.01b±0.11	1.12a±0.95	0.90	0.75	0.83
300 ppm	0.86b±0.15	0.81a±0.21	2.43b±0.44	0.33	0.35	1.06
Control	0.12c±0.00	0.16c±0.01	0.16c±0.00	1.00	0.75	0.75

Within the same column, means (4 replicates) that are statistically different ($p<0.05$) are indicated with different letters.

The highest Cr concentrations (2.43±0.44 µg/g) were observed in the soil, treated with 300ppm of Cr. As the Cr concentration in the soil increased, Cr accumulation in the plants also increased. It was also observed that the species showed similar Cr concentrations in their shoots, indicating comparable translocation efficiency. Mean concentration variation of Cr between similar samples were statistically difference ($p<0.05$). This is in line with the values (1.064 and 2.706 µg/g) of Garba *et al* (2012b). Also, it was generally found that the BCF values were lower than 1, indicating that the plants accumulate Cr to levels significantly lower than those in the soil. There was a consistent translocation factor (TF) values around 1.0 which indicate that Cr was potentially transported from the roots to the shoots in the plant species. *C. dactylon* consistently showed high enrichment factor (EF) values, suggesting its greater efficiency in enriching its tissues with Cr.

Table 3 show the mean Concentration (µg/g), BCF, EF and TF of Cadmium (Cd) in the samples.

Table 3: Mean Concentration (µg/g), Bioconcentration factor (BCF), Enrichment factor (EF) and Translocation factor (TF) of Cadmium (Cd) in the Samples

Concentration	Shoot	Root	Soil	BCF	EF	TF
100 ppm	0.08a±0.00	0.04a±0.05	0.52ab±0.55	0.16	0.63	2.00
200 ppm	1.59b±0.12	3.12b±1.27	2.19a±0.29	1.42	0.72	0.50
300 ppm	1.91c±0.29	0.26a±0.14	3.60b±0.35	0.12	0.33	7.34
Control	ND	ND	ND	N/A	N/A	N/A

ND = Not Detected, N/A = Not Available. Within the same column, means (4 replicates) that are statistically different ($p<0.05$) are indicated with different letters.

It was found that the level of Cd in the roots was consistently higher than the level in the soil, especially at higher Cd concentrations, indicating efficient Cd uptake. *C. dactylon* also translocated Cd from the roots to the shoots at all Cd levels, with the highest shoot concentration observed at 300 ppm. *C. dactylon* were able to take up and translocate Cd from the soil, which suggest their capacity to build up Cd in their bodies, with *C. dactylon* showing a high overall accumulation capacity. Concentration variation of Cd between similar samples show statistically significant difference ($p<0.05$). This observation agrees with the report of Gudusu *et al,* 2019 that high level of cadmium was observed in the shoot of *E. Indica* (223.5± 0.01 µg/g). The bioconcentration factor (BCF) values was generally lower than 1 (with exception at 200 ppm). *C. Dactylon,* on the other hand, demonstrated consistently high translocation factor values. It was also found that *C. Dactylon* consistently exhibited high enrichment factor (EF) values, indicating its greater efficiency in accumulating and translocating Cd. There were no amounts of Cd detected in all the control.

Table 4 show the mean Concentration (µg/g), BCF, EF and TF of Nickel (Ni) in the samples.

Table 4: Mean Concentration (µg/g), Bioconcentration factor (BCF), Enrichment factor (EF) and Translocation factor (TF) of Nickel (Ni) in the Samples

Concentration	Shoot	Root	Soil	BCF	EF	TF
100 ppm	ND	0.65±0.07	ND	N/A	N/A	N/A
200 ppm	1.03a±0.05	ND	0.82a±0.14	N/A	1.36	N/A
300 ppm	0.02b±0.00	ND	1.40b±0.11	N/A	0.01	N/A
Control	ND	ND	ND	N/A	N/A	N/A

ND = Not Detected, N/A = Not Available. Within the same column, means (4 replicates) that are statistically different ($p<0.05$) are indicated with different letters.

It was observed that at the root, 0.65±0.07 was the only absorption detected because the metal was not detected at both 200 and 300 ppm. But there was a translocation to the shoot at 200 ppm, (1.03±0.05 µg/g). Concentration variation of Ni between similar samples were statistically difference ($p<0.05$). This result contradicts with the report by Subhashini and Swamy 2013, who observed that Ni (67.34 and 20.63 µg/g) was highly absorbed in the root than in the stem and leaves of plant. The bioconcentration factor (BCF) and Translocation factor (TF) values could not be calculated for the samples due to the lack of detectable Ni in the soil and shoot at 100 ppm and roots at 200 ppm and 300 ppm. The enrichment factor (EF) values was high at 200 ppm and low at 300 ppm.

Table 5 show mean Concentration (µg/g), BCF, EF and TF of Zinc (Zn) in the samples.

Table 5: Mean Concentration (µg/g), Bioconcentration factor (BCF), Enrichment factor (EF) and Translocation factor (TF) of Zinc (Zn) in the Samples

Concentration	Shoot	Root	Soil	EF	BCF	TF
100 ppm	1.27a±0.26	0.37a±0.05	1.18a±0.30	1.16	0.31	3.43
200 ppm	0.33bc±0.04	0.39a±0.01	2.43b±0.25	0.13	0.16	0.84
300 ppm	0.63c±0.09	1.28b±0.21	4.06c±0.52	0.65	0.31	0.52
Control	0.13b±0.01	0.14c±0.01	0.12d±0.01	1.13	1.16	0.92

Within the same column, means (4 replicates) that are statistically different ($p<0.05$) are indicated with different letters.

The accumulation and translocation of Zn in the plants spiked with different levels of 100, 200 and 300 ppm for *C. dactylon* revealed that the level of Zn in the roots of *C. dactylon* was generally higher than the concentration in the soil, especially at higher Zn concentrations. *C. dactylon* also translocated Zn from the roots to the shoots at all Zn concentrations, with the highest shoot concentration observed at 100 ppm (Table 5). Concentration variation of Zn between similar samples were statistically difference ($p<0.05$). This report agrees with the observation reported by Gudusu *et al,* 2019 that high level of Zn was naturally retained in the root of *E. Indica* (2553.5±0.10 µg/g). The bioconcentration factor (BCF) values were generally lower than 1 (with exception at the control). *C. Dactylon*, on the other hand, demonstrated consistently high translocation factor values. It was also found that *C. Dactylon* consistently exhibited high enrichment factor (EF) values, indicating its greater efficiency in accumulating and translocating Zn. Translocation factor (TF) values were generally lower than 1 (with exception at the 100 ppm).

Table 6 show the mean Concentration (µg/g), BCF, EF and TF of Lead (Pb) in the samples.

Table 6: Mean Concentration (µg/g), Bioconcentration factor (BCF), Enrichment factor (EF) and Translocation factor (TF) of Lead (Pb) in the Soil, Root and Shoot of the Samples

Concentration	Shoot	Root	Soil	BCF	EF	TF
100 ppm	0.58ab±0.03	0.69ab±0.05	1.29a±0.44	0.53	0.44	0.84
200 ppm	0.77b±0.04	0.64a±0.05	2.49b±0.26	0.36	0.31	1.20
300 ppm	0.51a±0.03	0.82b±0.12	3.19c±0.29	0.37	0.29	0.62
Control	ND	ND	ND	N/A	N/A	N/A

ND = Not Detected, N/A = Not Available. Within the same column, means (4 replicates) that are statistically different ($p<0.05$) are indicated with different letters.

The level of Pb in the soil was consistently higher than the concentration in the roots, indicating some levels of uptake but also potential exclusion mechanisms. *C. dactylon* showed an increase in Pb concentration in the soil with increasing Pb exposure, where the concentration of Pb in the roots was generally higher than the concentration in the soil, especially at higher Pb concentrations. It was also found that *C. dactylon* translocated Pb from the roots to the upper parts of the plants at all levels of Pb, with the highest shoot concentration observed at 200 ppm. Concentration variation of Pb between similar samples were statistically difference ($p<0.05$). This result agrees to the report by Garba *et al* who observed high level of the metal in the shoot of *E. indica* (326.00±4.26 µg/g), but contrary to the report by Subhashini and Swamy who observed that Pb was highly accumulated in the root than the stem and leaves of *Catharanthus roseous* (67.34 and 20.63 µg/g). Bioconcentration factor (BCF) and

Enrichment factor (EF) were very low. Translocation factor (TF) values were high and greater than 1 (with exception at 100 ppm and 300 ppm).

The Bioconcentration Factor of metals was used to determine the quantity of heavy metals that is absorbed by the plant from the soil. This is an index of the ability of the plant to accumulate a particular metal with respect to its concentration in the soil (Akhilesh *et al.*,2009). BCF is calculated by the relation: ratio of the metal concentration in the root to the concentration in the soil. The higher the BCF value the more suitable is the plant for phytoextraction. BCF values > 1 were regarded as high values. To evaluate the potential of plants for phytoextraction the translocation factor was used. This ratio is an indication of the ability of the plant to translocate metals from the roots to the aerial parts of the plant (Dasgupta *et al.*, 2006). TF is calculated by the relation: ratio of concentration of metal in the shoot to the concentration of metal in the roots. Metals that are accumulated by plants and largely stored in the roots of plants are indicated by TF values < 1 with values > 1 indicating that the metals are stored in the stems and leaves (shoot). To evaluate the potential of plants for phytostabilization the enrichment factor was used. This ratio is an indication of the ability of the plant to retain metal in the root of the plant. EF is given by the relation: - The ratio of the concentration of metal in the shoots to the concentration of metal in the soil (Taylor *et al.*, 2010).

In this study, it was found that the BCF, EF and TF generally decrease with increase in the concentrations of the heavy metals using the *C. Dactylon*. The highest values of BCF, EF and TF were 1.42 (Cd), 1.36 (Ni) and 7.34 (Cd) respectively. This indicate that the *C. Dactylon* is having highest phytoextraction potential in the Cadmium-contaminated soils and highest phytostabilization potential in the Nickel-contaminated soils.

CONCLUSION

From the result obtained and the Translocation, Bioconcentration and Enrichment Factors calculated, it was found that *C. dactylon* showed that the Bioconcentration factor (BCF), Translocation factor (TF) and Enrichment factor (EF) generally decrease with increase in the concentrations of the heavy metals using the *C. Dactylon*. The highest values of Bioconcentration factor (BCF), Translocation factor (TF) and Enrichment factor (EF) were 1.42 (Cd), 7.34 (Cd) and 1.36 (Ni) *C. Dactylon.* This indicate that the *C. Dactylon* is having highest phytoextraction potential in the Cadmium-contaminated soils and highest phytostabilization potential in the Nickel-contaminated soils. Therefore, *C. dactylon* have potential for remediation of the heavy metal-contaminated soils.

From these findings it is therefore recommended that further researches should be conducted to evaluate the potential of *C. dactylon* in removing other heavy metals from contaminated soil.

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