EVALUATION OF EFFECTS OF SOIL PH LEVELS AND ORGANIC MATTER CONTENTS ON PHYTOACCUMULATION OF LEAD AND CADMIUM HEAVY METALS BY IMPERATA CYLINDRICA

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Abstract

Heavy metal contamination of soil pose risks and hazards to humans and the ecosystem through. Imperata cylindrica is a fast growing plant and often used for phytoremediation. The plant was tested in different growth media of spiked heavy metal, soil pH and organic matter contents for 60-day. After harvesting, the plant was washed, separated into roots and shoots. The soil samples were digested using 1.0g portion of dried the soil, 10.0cm³ of 1:1 HNO₃: H₂O, 5.0cm³ of HNO₃, 1.0cm³ of H₂O₂, and 5.0cm³ of HCl while the plant samples were digested using 0.50g of the powdered sample, 5cm³ of HNO₃ and 2cm³ HClO₄. Prior to digestion, each sample were oven-dried at 70°C until it achieved a constant weight, grounded (using mortar and pestle) and milled (using a milling machine). Atomic absorption spectrophotometry was used to analyze the accumulation of cadmium, and lead in roots and shoot of the plant. Bioaccumulation factor (BF), biological accumulation coefficient (EC) and translocation factor (TF) was applied to evaluate the metal translocation ability in the plant. Between soil pH and soil organic matter, the highest total biomass of Cd was found in 300g of organic matter treatment
(13.48 ± 2.69 mg/kg), while Pb in basic treatment was 18.09 ± 0.66 mg/kg. The result suggests that soil pH has most effect on Pb; while organic matter in Cd in the phytoaccumulation by Imperata cylindrica. The growth of phytoremediation plants like Imperata cylindrica should be encourage to neutralize the heavy metals pollution.

**Keywords**: Heavy Metals, Phytoremediation, Cadmium, Lead, Plant, Soil

**INTRODUCTION**

The heavy metals available for plant uptake are those present as soluble components in the soil solution or those solubilized by root exudates (Blaylock and Huang, 2000). Plants require certain heavy metals such as Co, Cu, Fe, Mn, Mo, Ni, V, and Zn for their growth and upkeep. However, excessive amounts of these metals can become toxic to plants and ability of plants to accumulate essential metals equally enables them to acquire other non-essential metals such as Pb, Cd and Hg which do not have any beneficial effect on organisms and are thus regarded as the “main threats” since they are very harmful to both plants and animals. These pollutants in the environment (air, water and soil) may be poisonous or toxic and will cause harm to living things especially when in excess (Djingova and Kuleff, 2000; Umar et al., 2022).

Heavy metals pollution is ubiquitous in the earth’s environment and can result from both anthropogenic activities and natural events (He et al., 2005). Industrialization, urbanization and intensified agriculture are the main causes of heavy metal contamination of soils and the environment. Heavy metals are elements with metallic properties, a density of >5 g cm⁻³ and an atomic mass of >20. The most common heavy metals in the environment are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni) (He et al., 2015; Sarkingobir et al., 2023ab).

Meanwhile, two approaches have been proposed for phytoaccumulation of heavy metals and one of the approaches is based on the use of natural hyperaccumulator plants with exceptional metal accumulating capacity. Hyperaccumulators are species capable of accumulating metals at levels 100 fold greater than those typically measured in shoots of the common non-accumulator plants (Baker et al., 1989 and Lasat, 2002). It is no doubt, a publicly appealing (green) remediation technology (Vyslou et al., 2003). They are used on metalliferous sites due to their tolerance of relatively high levels of pollution. Some of the
families that can accumulate heavy metals are Brassicaceae, Fabaceae, Euphorbiaceae, Astereaceae, Lamiaceae, and Scrophulariaceae (Salt et al., 2003; Schmidt, 2003). Crops like alpine pennycress (Thlaspi caerulescens), Ipomoea alpina, Haumaniastrum robertii, Astragalus racemosus, have very high bioaccumulation potential for Cd, Zn, Cu, Co, Se, and Ni, respectively. Willow (Salix viminalis L.), Indian mustard (Brassica juncea L.), corn (Zea mays L.), and sunflower (Helianthus annuus L.) have reportedly shown high uptake and tolerance to heavy metals (Schmidt, 2003). Approximately 400 plant species from at least 45 plant families have so far been reported to hyperaccumulate metals (Ghosh et al., 2005).

Phytoaccumulation is the name given to the process where plant roots uptake metal contaminants from the soil and translocate them to their above soil tissues. A plant used for phytoremediation needs to be heavy metal tolerant, grow rapidly with a high biomass yield per hectare, have high metal accumulating ability in the foliar parts, have a profuse root system, and a high bioaccumulation factor (Scragg, 2006; Jadia et al., 2008).

Soil characterization can reveal the distribution, speciation and bioavailability of heavy metals, while environmental assessment can provide information on the sources of contamination, health hazards and possible remediation strategies (Wuana and Okieimen, 2011). The vegetative parts of plants, such as leaves, generally accumulate more heavy metals than seeds and fruits (Nogueira et al., 2013) and plants roots are the primary contact site for heavy metal ions. The bioavailability of heavy metals in soils is influenced by soil properties and climatic conditions.

Meanwhile, several species of weeds commonly grown in the Sokoto area mostly creating additional cost to crop production. Some weed species have the capability to phytoaccumulate heavy metals from the soil into their root, stem and leaf tissues. Some of the heavy metals in question include cadmium, lead, copper, zinc etc. which tends to pollute the environment and if not removed they can create health hazards to human beings and animals both on soil and in water. Moreover, most of the land areas in the locality are utilized for production of food crops, this may further aggravate the level of contamination when the crops produced on the soil are consumed and the entire soil, water and air environment may be affected (Scragg, 2006; Jadia et al., 2008; Sarkingobir et al., 2023ac).
Many researches have been conducted on the same subject matter using varieties of plant species some of which are consumed by humans and animals and can present a source of danger when they accumulate the contaminant (heavy metals) in their tissues, the consumption of which can be detrimental (Labbo et al., 2021; Umar et al., 2023). This research is therefore targeted towards investigating the potentials of a selected savanna weed species, *Imperata cylindrica* to phytoaccumulate lead, and cadmium in root, stem and leaf tissues at varying soil pH and organic matter concentrations. Thus, the objective of this research is to study the effects of soil pH levels and organic matter contents on phytoaccumulation of Pb and Cd heavy metals by *Imperata cylindrica*.

**METHODS**

**The Study Area**

The research was conducted in the Biological Garden of Usmanu Danfodiyo University Sokoto, situated between longitudes 5° 11” 30’E and 5° 14” 30’E and latitudes 13° 8” 30’N and 13°7”0’N in Wamakko Local Government Area of Sokoto State, Nigeria (SERC, 2014). Sokoto lies between longitudes 4° 8’E and 6° 54’E and latitudes 12° N and 13° 58’N with an altitude of 351m above sea level within Sudan Savanna Region of Nigeria. The climate of the area is hot, semi-arid tropical type. It is characterized by a long and severe dry season lasting from October to May, and short but intensive wet season from June to September. The rainfall pattern is characteristically distributed with a peak in August. Sokoto falls under the Sudan savanna agro-ecological zone North- Western Nigeria. The area has annual rainfall range of 550-700 mm and mean annual temperature ranging from 38° C to 42° C or more around April. The lowest mean temperature in December-January (Harmattan period) is about 13-15°C. The mean maximum temperatures are highest generally from Mach to June. The mean relative humidity reaches its peak of over 90% in August and lowest in December and January (10-30%). There are hot humid days during the raining days. The soil of the area is sandy-loam. Wind direction is North-West and south-west for dry and wet seasons respectively (SERC, 2014, Adejuwon, 2016).

**Collection of Soil and Plant Samples**

Clean uncontaminated soil was obtained in the Biological garden, followed by <4mm sieving, using a stainless steel test sieve to remove gravels and large non-soil particles and analyzed for pH, particle size and organic matter content.
For the purpose of this study, three hundred (300) seedlings of uniform height *Imperata cylindrica* were purchased from Federal University of Agriculture, Abeokuta (FUNAB) Biological garden. These were packaged in a white polythene bag and transported to Usmanu Danfodiyo University Sokoto Biological garden and a sample was later taken to the herbarium for identification.

**Determination of Chemical Properties of Soil**

The pH of the soil was determined using a calibrated pH meter, and each sample was subjected to three replicated measurements (Abdullahi *et al*., 2016). The Walkley-Black wet oxidation technique was used to quantify soil organic carbon, then it was transformed to organic matter by multiplying the percent organic carbon content by a factor of 1.724, assuming that organic matter equals 58% carbon (Walkley *et al*., 1984) while soil particle size was determined using hydrometer after making soil suspension with distilled water and 50 ml of sodium hexametaphosphate reagent (Meira *et al*., 2008).

**Soil Contamination with Different Concentrations of Heavy Metals and Plant Preparation**

Soil contamination procedure was done by polluting the soil with lead, and cadmium. Lead nitrate (Pb (NO₃)₂) was added separately to 6kg of treated garden soil in three places at the rate of 30mg/kg, 60mg/kg and 300mg/kg. The concentration of lead in the soil was 10mg of lead per 2kg of soil, 20mg of lead per 2kg of soil and 100mg lead per 2kg of soil. The (Pb (NO₃)₂) compound was dissolved in distilled water to reach the desired concentration target level and then transferred to the soil which was mixed homogeneously. The three varied concentrations of lead were replicated in three places to give us nine treatments (3×3 = 9). The same set of procedure was applied to cadmium using (Cd (NO₃)₂·4H₂O), and for each metal concentration, there was one control treatment (zero concentration) for each metal contaminants.

**Variation in pH Level of Contaminated Soil**

The contaminant level of heavy metals (lead, and cadmium) was the same concentration i.e 100mg per 2kg of soil. Variation in the pH level of the soil samples was however imposed by using vinegar to acidify the soil (pH of 5), addition of calcium carbonate in case of alkaline soil (pH of 9) or neither of the two in case of slightly neutral soil (pH of 7). Each pH variables occurred in three replicates 3×3 = 9, and additional one control experiment for each soil contaminants pH variables.
Variation in Organic Matter Content of Contaminated Soil

The heavy metals (lead, and cadmium) contaminated soil (100mg per 2kg) was treated with different levels of organic matter contents (cow dungs). Three levels of organic matter content were measured with the aid of weighing balance (75g/kg of soil for low organic matter, 150g/kg of soil for medium and 300g/kg of soil for high organic matter content). The measured content was transferred to different treated soil and mixed homogeneously. The three levels of organic matter in the experimental soil sample occur in three replicate, and one control experiment for each levels of organic matter in the contaminated soil samples.

Arrangement of the Polluted Soil

The arrangement was done in three phase the first phase include the polluted soil with variation of heavy metals only; the second phase was variation in spiked soil pH which will be followed by variation in soil organic matter content. After which it was followed by careful planting of three seedlings per each polythene pot. Prior to planting, each seedling was rinsed in running tap water to remove impurities and any adhering contaminant. All plants were watered with tap water once a day throughout the sixty (60) days of the experiment.

Post Plant and Soil Preparation

The plants were collected intact from each polythene pots at the conclusion of the testing periods; label separately, packed in black plastic bags, and transferred to the laboratory. The soil sample in each pot was also taken to the laboratory. The harvested plants were then washed with distilled water to remove any contaminants from the plant’s body (Audu et al., 2016) before separating them into roots and shoots and the samples were oven-dried for at 70°C until it achieved a constant weight. The dried samples were grounded into fine powder by using a ceramic pestle and mortar, mill with the aid of milling machine and stored in a brown envelope (Ng et al., 2016).

Soil samples were also air-dried and the particle size of soil samples was reduced <2 mm for analytical experiments using a laboratory sieve to remove un-decomposed organic materials as described in (Abdullahi et al., 2016).
Samples Digestion

The soil samples were digested USEPA Method 3050 (1990), whereby a 1.0 g portion was weighed into a 100cm³ beaker, followed by the addition of 10.0 cm³ of 1:1 HNO₃: H₂O. The mixture was then heated on a hot plate at 105 °C for 1 h and allowed to cool to room temperature. This was followed by the sequential addition of 5.0cm³ of concentrated HNO₃, 1.0 cm³ of Hydrogen peroxide (H₂O₂), and 5.0cm³ of HCl (hydrochloric acid). The resulting solution was filtered and diluted with de-ionized water to a final volume of 100cm³ in a volumetric flask.

The plant samples were digested according to Audu et al., (2016), whereby 0.50 g of the powdered sample was weighed into a 100cm³ beakers and 5cm³ of concentrated HNO₃ and 2cm³ perchloric acid (HClO₄) were added. The mixture was then heated on a hot plate at 95 °C until it became clear. The digest was diluted with de-ionized water, filtered into a 100cm³ volumetric flask, and then made up to the mark with more de-ionized water.

Heavy Metals Analysis

The concentration of Pb, and Cd in the digested samples was determined using an Atomic Absorption Spectrophotometer (Shimadzo UK digital AAS, Model 6300) equipped with a digital read-out system. In each case, working standards were created by serially diluting a 1000 ppm metal stock solution. Calibration curves were constructed by plotting absorbance values versus concentrations. By interpolation, the concentration of the metals in sample digests was determined (Guangming et al., 2017).

Statistical Analysis

The experimental data were analyzed by two-way analysis of variance (ANOVA) to evaluate metal accumulation in Imperata cylindrica. Further statistical validity test for significant differences among treatment means was carried out using Duncan’s New Multiple Range Test DNMRT (α = 0.05) method.

Evaluation of Phytoaccumulating Activity

To evaluate the phytoaccumulating ability of the plant, both the above-ground biomass metal concentration and the soil metal concentration were considered. The accumulation/enrichment coefficient, translocation factor, and absorption/bioaccumulation factor were all considered in order to assess this (Ali, et al., 2013, Xiao, et al., 2017; Cacic, et al., 2019, Wu, et al., 2021).
Accumulation/Enrichment Coefficient (EC)

Enrichment coefficient was described in Xiao, et al., (2017) as the heavy metal element concentration in plant above ground part divided by this heavy metal element concentration in soil. Enrichment Coefficient was evaluated using the following equation:

Enrichment Coefficient = (metal in shoot) / (metal in soil).

Translocation Factor (TF)

Xiao et al., (2017) describe translocation factor as the ratio of heavy metals in plant shoot to that in plant root. It was evaluated using the following equation:

Translocation Factor = (metal in shoot) / (metal in root).

Absorption/Bioaccumulation Factor (BF)

Bioaccumulation factor is the ratio of heavy metals in root to that in the soil. Bioaccumulation factor was evaluated using the following equation as described in Ali et al., (2021); Cacic et al., (2019) and Wu et al., (2021):

Bioaccumulation Factor: = (metal in root) / (metal in soil).

RESULTS

Table 1: Metal accumulation of Cadmium (Cd) in mg/kg, its BF, EC and TF as influenced by different types of spiked heavy metal treatments, soil pH and organic matter.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Treatment</th>
<th>ROOT</th>
<th>SHOOT</th>
<th>Total</th>
<th>EC</th>
<th>BF</th>
<th>TF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>10mg</td>
<td>0.98 ± 0.12c</td>
<td>0.87 ± 0.08a</td>
<td>1.85 ± 0.14c</td>
<td>0.853b</td>
<td>0.954a</td>
<td>0.893b</td>
</tr>
<tr>
<td></td>
<td>20mg</td>
<td>2.13 ± 0.08b</td>
<td>2.20 ± 0.16a</td>
<td>4.33 ± 0.25b</td>
<td>1.007a</td>
<td>0.975a</td>
<td>1.032a</td>
</tr>
<tr>
<td></td>
<td>100mg</td>
<td>6.86 ± 2.02a</td>
<td>7.77 ± 1.58a</td>
<td>14.64 ± 2.92a</td>
<td>1.092a</td>
<td>0.964a</td>
<td>1.132a</td>
</tr>
<tr>
<td>PH</td>
<td>Neutral</td>
<td>6.86 ± 2.02a</td>
<td>7.77 ± 1.58a</td>
<td>13.16 ± 1.81a</td>
<td>0.910b</td>
<td>0.951a</td>
<td>0.957b</td>
</tr>
<tr>
<td></td>
<td>Basic</td>
<td>5.91 ± 0.66c</td>
<td>5.92 ± 1.09c</td>
<td>11.82 ± 1.27c</td>
<td>0.835c</td>
<td>0.833b</td>
<td>1.002a</td>
</tr>
<tr>
<td></td>
<td>Acidic</td>
<td>6.34 ± 0.67b</td>
<td>6.51 ± 1.30b</td>
<td>12.86 ± 1.22b</td>
<td>1.016a</td>
<td>0.974a</td>
<td>1.043a</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>75g</td>
<td>6.51 ± 1.72c</td>
<td>5.77 ± 1.01b</td>
<td>12.28 ± 2.78b</td>
<td>1.058a</td>
<td>1.193b</td>
<td>0.887b</td>
</tr>
<tr>
<td></td>
<td>150g</td>
<td>6.67 ± 0.10b</td>
<td>6.60 ± 0.61a</td>
<td>13.24 ± 0.61a</td>
<td>0.994b</td>
<td>1.010c</td>
<td>0.984a</td>
</tr>
<tr>
<td></td>
<td>300g</td>
<td>7.68 ± 1.99a</td>
<td>5.80 ± 0.72b</td>
<td>13.48 ± 2.69b</td>
<td>1.063a</td>
<td>1.407a</td>
<td>0.756c</td>
</tr>
</tbody>
</table>

Mean ± standard error, followed by the same letters are not significantly different for each treatment means at 0.05 levels of probability.
Table 2: Metal accumulation of Lead (Pb) in mg/kg, its BF, EC and TF as influenced by different types of spiked heavy metal treatments, soil pH and organic matter.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Treatment</th>
<th>ROOT</th>
<th>SHOOT</th>
<th>Total</th>
<th>EC</th>
<th>BF</th>
<th>TF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>10mg</td>
<td>0.93 ± 0.22&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.85 ± 0.05&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.82 ± 0.20&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.009&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.059&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.953&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>20mg</td>
<td>1.97 ± 0.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.93 ± 0.12&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.89 ± 0.29&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.063&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.086&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.978&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>30mg</td>
<td>8.40 ± 0.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.85 ± 0.68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.25 ± 1.81&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.983&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.206&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.815&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>PH</td>
<td>Neutral</td>
<td>7.27 ± 1.68&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.33 ± 1.31&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15.60 ± 2.93&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.015&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.885&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.146&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Basic</td>
<td>9.28 ± 2.19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.64 ± 1.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.09 ± 0.66&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.036&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.090&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.950&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Acidic</td>
<td>7.94 ± 2.86&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.52 ± 4.61&lt;sup&gt;c&lt;/sup&gt;</td>
<td>15.47 ± 7.18&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.119&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.181&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.947&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>75g</td>
<td>6.54 ± 0.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.35 ± 0.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.89 ± 1.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.977&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.006&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.972&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>150g</td>
<td>7.09 ± 1.93&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.74 ± 1.99&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.83 ± 2.62&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.969&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.449&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.669&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>300g</td>
<td>5.56 ± 0.59&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.62 ± 1.77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.18 ± 1.57&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.978&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.821&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.190&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Mean ± standard error, followed by the same letters are not significantly different for each treatment means at 0.05 levels of probability.

**DISCUSSION**

The physical nature of the soils used in the study is slightly acidic (pH 6.70) with organic matter contents of 15.64. The particle of the soil was silty clay sand in proportion: 3.78, 9.82 and 86.40 respectively. Soil pH was affected by the spiked heavy metal treatments in all the treatments as shown in figure and similar result was also reported by Ng *et al.*, (2016). The changes in soil pH observed could be related to the proton ion (H<sup>+</sup>) concentration in the soil, whereby a pH reduction would mean more protons are present and vice versa (Tischner, 2000; Sorgona *et al.*, 2011). Soil pH has a strong influence on the availability of plant nutrients and can affect the soil-plant interaction with regard to heavy metal accumulation (Husson, 2013).

The result in table 1 revealed that there is more effect on Root at 100mg with mean ± SE value of 6.86 ± 2.02, followed by at 20mg and 10mg with mean ± SE values of 2.13 ± 0.08 and 0.98 ± 0.12 respectively. Similarly, the higher effect on shoot is at 100mg (7.77 ± 1.58), followed by 20mg (2.20 ± 0.16) while the least effect is at 10mg (0.97 ± 0.14). The result
from the table further shows that EC is high at 100mg with same effect at 20mg while the least effect at 10mg, BF shows that there is no significant different across the concentration used while TF shows equal effect at 100mg and 20mg and a significant different at 10mg. Furthermore, the table 1 shows that effect of pH on Root is higher at neutral with mean ± SE values of 6.86 ± 2.02 followed by acidic while the least is at basic with mean ± SE values 6.34 ± 0.67 and 5.91±0.66 respectively. The pH effect on shoot is high at neutral, acidic and basic in ascending order with mean ± SE values of 7.77 ± 1.58, 6.51 ±1.39 and 5.92 ±1.09 respectively. EC shows a significant different with most effect recorded at acidic (1.016) followed by neutral (0.910) and basic with value of 0.835. BF shows no significant different between the effect at acidic (0.974) and neutral (0.951), with least effect at basic (0.833). However, TF shows that there is no significance effect on acidic (1.043) and Basic (1.002) while on neutral (0.967).

The table 1 also portrayed the effect of organic matter on Root and shoot, the result shows that 300g has more effect on root with mean ± SE values of 7.68±1.99, followed by 150g with mean ± SE value of 6.67±0.10 while the least effect was recorded at 75g with mean ± SE value 6.51±1.72. However, most effect on shoot is recorded at 150g with mean ± SE value of 6.60±0.61, while there is no significance different in the effect at 75mg and 300mg with mean ± SE values of 5.77±1,01 and 5.80±0.72 respectively. We can further deduce from the table that EC shows most effect at 300g (1.63), followed by at 75g (1.058) while least is recorded at 150 (0.994). Also, BF shows most effect at 300mg, followed by at 75mg and 150mg with values of 1.407, 1.193 and 1.010 respective. On TF, the most effect is at 150mg with value of 0.984, followed by 75mg with value of 0.887 and the least effect is at 300mg with value of 0.756.

It can be observed from the table 2; that there is more effect on Root at 100mg with mean ± SE value of 8.40 ± 0.30, followed by at 20mg and 10mg with mean ± SE values of 1.97 ±0.14 and 0.93 ± 0.22 respectively. Similarly, the highest effect on shoot is at 100mg (6.85 ±0.68), followed by 20mg (1.93 ± 0.12) while the least effect is at 10mg (0.85 ± 0.05). The result from the table further shows that EC is high at 20mg with value of 1.063, followed by 10mg (1.009) while the least effect at 100mg (0.983), BF shows that there is a significant different across the concentration used with most effect at 100mg, followed by at 20mg and 10mg with values 1.206, 1.086 and 1.059 respectively. While TF shows that most effect at 20mg, then at 10mg and 100mg with value of 0.978, 0.953 and 0.815 respectively.
Furthermore, the table 2 shows that there is a significant different on effect of Pb on Root with most effect at basic then acidic and least at neutral with mean ± SE values of 9.28 ± 2.19, 7.94 ± 2.19, and 7.520 ± 4.61 respectively. The Pb effect on shoot is high at basic, followed by at neutral with mean ± SE values of 9.64 ± 1.44 and 8.33±1.31 while at acidic recorded least effect with mean ± SE of 7.52 ± 4.61. EC shows a significant different with most effect recorded at acidic (1.119) followed by basic and neutral with values of 1.036 and 1.015 respectively. BF also shows a significant different in the effect with most is recorded at acidic (1.181), then Basic (1.090), with least effect at neutral (0.885). However, TF also revealed that neutral has most effect with value of 1.146, followed by Basic and acidic with values of 0.950 and 0.947 respectively.

The table 2 also portrayed the result of effect of organic matter on Root and shoot, the result shows that 150g has more effect on root with mean ± SE values of 7.09 ± 1.93, followed by 75g with mean ± SE value of 6.54 ± 0.82 while the least effect was recorded at 300g with mean ± SE value 5.56 ± 0.59. However, most effect on shoot is recorded at 300g with mean ± SE value of 6.62 ± 1.77, followed by 75g and 150g with mean ± SE values of 6.35 ± 0.87 and 4.74 ± 1.99 respectively. We can further deduce from the table that EC shows no significant different effect with 75g (0.977), 150g (0.969) and 300g (0.978). However, in BF there is significant difference, with most effect is at 150g, followed by at 75g and 300g with values of 1.449, 1.006 and 0.821 respective. On TF, the most effect is at 300g with value of 1.190, followed by at 75g with value of 0.972 and the least effect is at 150g with value of 0.669.

In all the variables, relatively more heavy metals were accumulated in the roots than shoots, where it was observed that the root and soil concentration ratio (BF) was >1 suggesting that heavy metal translocation from the soil to root was substantially higher and the roots acted as the sink for heavy metal accumulation. All the metals recorded remarkably higher BF (> 1) when grown under spiked organic matter treatments. Pb-spiked treatments exhibited higher accumulation (1.449) in 150g of organic matter, followed by Cd-spiked treatments in 300g of organic matter (1.407). Comparatively, in all the metals higher EC values> 1 was observed in Cd (1.092) in 100mg spiked treatment, Pd (1.119) in acidic treatment.

In general, the BF accumulation in all the treatment is high in all the acidic soil which is in support of Gentili et al., (2018) who stated that majority of micronutrients are better
available to plants cultivated in acidic soils than in neutral or alkaline conditions which is observed only in the BF accumulation in all lead variables. On the other hand, soil pH mediates metal toxicity (Strawn et al., 2021). At high pH, metals tend to form barely soluble phosphates and carbonates. On the contrary, at low pH they are likely to exist in more bioavailable free ionic forms (Olaniran et al., 2013). Their migration is to a large extent mediated by Coulombic forces (Kim et al., 2015).

The TF is one of the vital to estimate the phytoaccumulation potential of a plant species. Malik et al., (2010) and Nazir et al., (2011) suggested that a plant would be suitable for phytoremediation when the BF, EC and TF values are >1. In this study, the 300mg organic matter-spiked treatment recorded relatively higher TF for the accumulation of Pb (1.190), and 100mg spiked treatment in Cd (1.132). However, among the two variables for all the metals, basic treatment and 300spiked organic matter) tested in this study satisfied the conditions that require all the BF, EC and TF values to be > 1.

The results concur with Umar et al., (2022), which reported that increase in availability of metals in soils increases their rate of uptake by phytoremediation plants. This effect has also been reported in several phytoremediation plants (Jeanna and Henry, 2000; Lombi et al., 2009; Marques et al., 2009).

The amount of metal content (10mg/kg 20mg/kg and 100mg/kg for all the metal) present in the spiked heavy metal treatments were above the maximum acceptable levels in soils (WHO, 1998) and a clear indication that the soils were experimentally amended with the heavy metal. Studies by the DOE (2009) observed that, for Malaysian soils, typical concentration range for naturally occurring heavy metals are as follows: Cd (0.09 – 14.40 mg/kg), Pb (0.18 – 36.00 mg/kg), Zn (6.90 – 54.30 mg/kg) and Cu (4.00 – 19.80 mg/kg). The use of direct pot assays for spiked heavy metals instead of field-site application may be a possible cause for the high concentration of heavy metal accumulation found in the roots and shoots of this plant.

Consequently, the plant used in this work showed high level of tolerance to these concentrations of metals throughout the study period. This is an indication that the plant has mechanisms to tolerate the presence of heavy metals in soils in which they grow and withstand their toxic effects. Many phytoremediation plants have also been reported as developing mechanism against toxicity of heavy metals in their surroundings (Jarup, 2003; Li et al., 2007). However, this was unlike observations by some workers (Chen et al., 2004;
Marques et al., 2009) that reported symptoms of leaf chlorosis and yellowishness in plants grown in high dosage of Cd and Pb in artificially polluted soils.

CONCLUSION

This finding revealed that, in all the constant spiked treatment i.e 100mg/kg the level of Pb biomass were found to be higher in the study samples obtained from basic treatment, while higher organic matter in the aspect of Cd. This shows that alkaline soils have most effect on the accumulation of lead by *imperata cylindrica* plant, but it can accumulate higher concentration of cadmium in soil with high organic matter.

Recommendations

The followings are recommended:

- The growth of phytoremediation plant like *Imperata cylindrica* should be encouraged in the agricultural areas to extract or stabilize the heavy metals contaminate release to the environment due to long term application of impure inorganic pesticides fertilizers or organic manure such as liquid or solid manure or their derivative such as compost or sludge containing relatively high content metallic element.

- The cultivation of the plant on the contaminated areas should be encouraged e.g. mining areas to reduce soil pollution in such environments

- The farmers should be enlightened about the use of *Imperata cylindrica* as a phytoremediation plant which can be used to increase crop yield through reduction in soil degradation and also to avoid mobilization of contaminant through food chain.

- More researches should be done on native plants in other to know their phytoremediation potentials
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