The Effect of Phosphate Fertilizer on Heavy Metal in Soils and Amaranthus Caudatus

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ABSTRACT

The study examines the effect of Phosphate fertilizer on heavy metals in soils and Amaranthus Caudatus. Pot experiment was carried out to assess the effect of Phosphate fertilizer on heavy metal uptake by Amaranthus Caudatus. Single Super Phosphate fertilizer (SSP) was applied at the rates of 0, 60, 80 and 100kg fertilizer/ha and replicated three times in a completely randomized design. The parameters measured were plant height, number of leaves, and heavy metals (Cu, Zn, Cd, Pb and Ni) concentration in the soil before and after the experiment, heavy metal concentration in the stem and roots of the vegetable used were also measured. The results of this experiment shows that there were no significant difference in plant height and number of leaves among the treatments considered, but the number of leaves increases from the second to the fourth weeks after sowing before it begin to decline. Only Cu, Zn and Cd were taken up by the root and stems of the vegetable with Zn having the highest concentration at 100kg/ha and 80kg/ha level of application for stem and root respectively. The concentrations of all the metals (Cu,Zn, Pb and Cd) increases in the soil after the experiment except for Nickel. Increase in the concentration of Zinc in the soil was more pronounced than other metals. It is therefore recommended that Phosphate fertilizer should be analyzed to determine the concentration of heavy metals before its application to the soil for plant growth.

Keywords: Heavy metals, Phytoremediation, Amaranthus Caudatus

INTRODUCTION

Heavy metals are currently of more environmental concern to scholars in various fields owing to its associated effects on humans and the environment. They are harmful to humans and animals as they tend to bio-accumulate in the food chain. Activities such as mining and smelting of metal ores, industrial emissions and applications of insecticides and fertilizers have all contributed to elevated levels of heavy metals in the environment (Alloway; 1990). Although, heavy metals occurs naturally in low concentration in soil, but they are considered as soil contaminants due to their widespread occurrence, acute and chronic toxicity (Das, et al., 1997). Soil contamination by heavy metals is one of the most serious ecological problems all over the world. These metals include; cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), nickel (Ni), mercury (Hg), and the metalloid arsenic (As). When plants accumulate metals, they can be ingested by animals, thus creating the potential for toxic effects at higher trophic level (Crowder, 1991). The exposure to acute Cd and Zn concentrations often results in gastrointestinal and respiratory damage, as well as damages to heart, brain, and kidney (Friberg, et al., 1986).

Amaranthus caudatus belong to the amaranthaceae family the leaves and seeds are edible and nutritious like any other amaranth. Amaranthus caudatus used in this study is a grain and ornamental vegetable crop with quick growth and great biomass. Phosphorus fertilizers are among the sources of heavy inputs into agricultural activities .Superphosphate fertilizers contain in addition to nutrient elements trace metal impurities like Cd, Pb or Hg (Oyedele et al, 2006, Zhang and Shan, 2001 Nicholson and Jones, 1994)). According to Mortvedt and Beaton (1995), on the average phosphate rock contain 11, 25, 1888, 32, 10 and 239mgkg-1 of As, Cd, Cr, Cu, Pb and Zn, respectively. Therefore the objective of this study is to evaluate the effect of phosphorus fertilizer on heavy metal accumulation in Amaranth caudatus and soil.

MATERIALS AND METHODS

Description of Experimental Site: This study was carried out using pot experiment planted within the crop garden of Agronomy Department of the University of Ibadan, Ibadan, and Oyo State, Nigeria. Ibadan is in the tropical rainforest of south west Nigeria between latitudes 7° 15'N to 7° 30'N and longitude 3° 45'E

Sample Collection: The soil sample used for this experiment was collected from Bodija dump site located at Kara in Bodija. The seeds of *amaranthus caudatus* were obtained from the department seed store.

Basic physico-chemical soil characteristics: Particle size distribution was determined by Bouyoucus hydrometer method as cited by Tel and Hargaty (1991) using sodium hexametaphosphate (Calgon) as the dispersing agent.

Soil pH was determined using distilled water and potassium chloride (KCI) with a mobile pH meter. Organic carbon was analyzed by the dichromate wet oxidation method. Total nitrogen was determined by macro Kjedahl method. Available phosphorus was determined by the Bray P1 (0.03m N NH₄F + 0.02m HCI) solution and determined Calorimetrically by the molybdenum blue method. Micronutrients, (Mn, Fe, Cu and Zn) were extracted with Melich solution and determined with Atomic absorption spectrophotometer (AAS). The exchangeable acidity was determined using titration method. The total heavy metal content (Cd, Pb, Ni, Zn and Cu) was also determined with the AAS. Exchangeable bases, were leached using 1N NH₄ and were determined by AAS.

Experimental Design: Three seeds of test crop used *Amarauthus caudatus* was sown directly into the pots

and was later tinned down to 2 plants per pot given a total of 32 plants in all. Each pot contained 1kg of soil. The experiment consists of four treatments (Single superphosphate fertilizer) in the following rates; 0, 60, 80 and 100 kg/ha, replicated five times each given a total of 20 replicates in a randomized complete block design. Plant height and number of leaves were ascertained.

Plant and Soil Analysis: The vegetables were harvested at 5 weeks after sowing and washed with de-ionised water, separated into shoot and root and oven dried at 65° C before wet drying and grinding. 0.5g was weighed from each sample, digested in a mixture of concentrated HNO₃ and HCIO₄(4:1, by volume) and made up to mark (25ml) with distill water for heavy metal analysis (Cd, Pb, Ni, Zn and Cu) through AAS.

Soil samples were collected randomly after the termination of the experiment, air dried and sieved with 0.5mm sieve. 0.5g of soil was taken from each treatment sample and digested using acid mixture made up to 25ml with distilled water for heavy metal analysis. The heavy metals analysed are Cd, Pb, Ni, Zn and Cu.

Statistical Analysis: The results collected from the experiment were subjected to analysis of variance (ANOVA) and the means compared using least significant difference (LSD).

Table 1. Basic Physico-Chemical Son Characteristics, Total Heavy Metal Contents in the Experimental Son				
Parameters	Values			
pH in H₂0	9.1			
%Organic carbon	0.114			
Total nitrogen	0.12			
Available phosphorus	11.9(mgkg ⁻¹)			
Exchangeable bases (Cmolkg ⁻¹) K	10.18			
Na	4.27			
Mg	9.06			
Са	20.06			
Extractable micronutrients (mgkg ⁻¹)				
Mn	80.3			
Fe	54.9			
Heavy metals (mgkg ⁻¹)				
Cu	5.81			
Zn	499.2			
Cd	1.05			
Pb	55.5			
Ni	103.2			

Table 1: Basic Physico-Chemical Soil Characteristics, Total Heavy Metal Contents in the Experimental Soil

RESULT AND DISCUSSION

Textural class

Physicochemical properties of soil: The result of the soil analysis carried out (Table 1) shows that the soil is an alkaline soil, low in organic matter and total

nitrogen but high in available phosphorus. The soil is high in Ni and Zn but low in Pb, Cd and Cu with moderate concentration of other nutrient elements.

Sandy soil

Effect of different levels of phosphate fertilizer on the plant height: Result from the table 2 shows that treatment 1 and 4 (0 and 100kg/ha fertilizer) at 2nd and the 3rd weeks after sowing with 10.50 and 11.47 gave the highest mean values of 3.67 and 3.77 respectively. Conversely, treatment 4 (100kg/ha) at the 5th weeks after sowing has the highest mean value of 30.4. However, Analysis of variance(ANOVA) revealed no significant difference among all the treatments considered on plant height.

Number of Leaves: At the 2nd and 4th weeks after planting, treatment 1(0kg/ha) has mean values of 6.0 and 13.75 respectively. This gives best performance in terms of leaf production as shown in Table 3. However, there was no significant difference in the number of leaves in the different weeks after sowing but a general decrease in the number of leaves was observed at the 5th week after sowing, this was due to senescence.

Heavy metals uptake in the stem of Amaranthus caudatus: Figure 1 shows the concentration of Cu, Zn, Cd, Pb and Ni in the stem of Amaranthus caudatus under different levels of phosphate fertilizer application. Zinc concentration in the stem concentration was highest in all the treatment

compared with the concentrations of the other metals and the highest concentration (105.75mg/kg) was recorded under treatment 4(100kg/ha) though the initial concentration was 499.2 mg/kg. This was closely followed by Cu, which shows an increase in its concentration in the stem for all the fertilizer levels when compared with the initial concentration in the soil before planting (5.8mg/kg) to 7.05, 6.45, 7.06 and 8.9 mg/kg respectively after harvesting, this support the findings of Lafuente et al(2008) . The concentration of Cd in the stem was high compared with its initial concentration in the soil. Pb and Ni were not detected except 5.55mg/kg under 80kg/ha fertilizer used. Pb has a greater retention capacity in soil when compared with other metals (Lafuente et al, 2008).

Heavy metals in the root: The concentration of Cu, Zn, Cd, Pb and Ni in the root of *A caudatus* is represented in Figure 2 The same trend was observed as it is in figure 1. Zinc uptake (92.15) in the root was highest in treatment 3 (80kg/ha) compared to the other metal uptake, closely followed by Cu also with its highest concentration in treatment 3(80kg/ha). Pb and Ni were not detected.

Table 2: Effect of different levels of phosphate fertilizer on the plant height (cm) of A. caudatu	JS

Treatments		Weeks After Sowing			
	2	3	4	5	
0kg/ha	3.67	10.50	22.30	29.2	
60kg/ha	3.23	9.57	15.88	20.4	
80kg/ha	3.08	9.93	19.90	26.6	
100kg/ha	3.77	11.47	19.48	30.4	
LSD	0.915	2.173	4.779	9.93	
	NS	NS	NS	NS	

LSD: Least Significant Difference, NS: Not Significant

Table 3: Effect of different levels of phosphate fertilizer on the number of leaves pr	oroduced by Amaranthus caudatus
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Treatment				
	2	3	4	5
0kg/ha	6.0	10.25	13.75	12.25
60kg/ha	5.75	8.75	11.50	11.00
80kg/ha	5.75	10.25	12.50	12.50
100kg/ha	5.75	11.00	11.25	11.00
LSD	0.667	2.173	2.933	3.137
	NS	NS	NS	NS

LSD: Least Significant Difference, NS: Not Significant

Table 4: Effect of different levels of phosphate fertilizer on heavy metal accumulation in the soil after the experiment

Treatment		Heavy Metals (mgkg ⁻¹)				
	Cu	Zn	Cd	Pb	Ni	
0kg/ha	74.20	2062	2.35	55.5	24.8	
60kg/ha	70.55	2158	6.60	65.5	26.7	
80kg/ha	161.50	2208	1.15	91.5	23.6	
100kg/ha	73.20	2638	1.05	86.5	29.8	

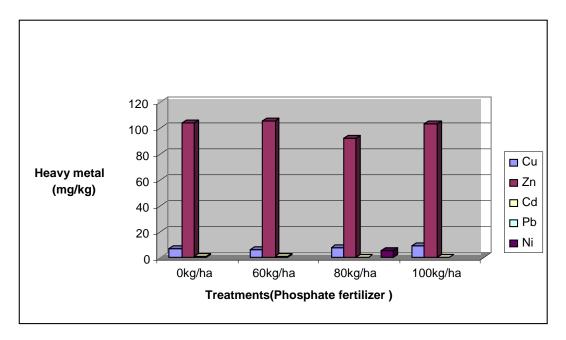


Fig 1. Effect of phosphorus fertilizer on heavy metal uptake in the stem of Amaranthus Caudatus plant

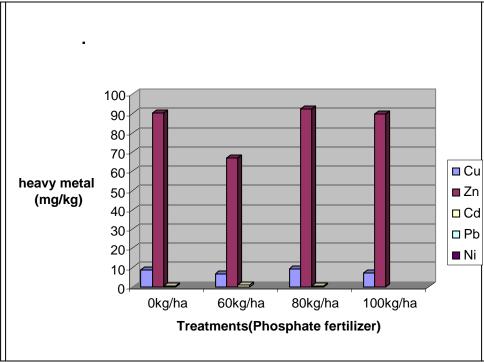


Fig 2. Effect of phosphate fertilizer on heavy metal uptake in the root of Amaranthus Caudatus plant

Heavy Metals In The Soil After Harvest: The concentration of heavy metals (Cu, Zn, Cd, Pb and Ni) in the soil after the experiment is shown on Table 4. The increase in the concentration of the heavy

metals in the soil after the experiment shows that phosphate fertilizers contribute greatly to heavy metal content in soils. This is consistent with the findings of Oyedele *et al.*, (2006). Cu, Zn, Cd and Pb show a high concentration in the soil after the experiment at all treatment levels. Cu and Zn had over 400% increment, Cd increased by over 100% and a little increase in Pb content was recorded this result agrees with the findings of Mirela *et a*l(2008) De Matos et al (2001) which says that Pb has the highest value of retardation factors which shows that it is highly immobilized in the soils also Alloway, (1990) reported that the soil is an important sink for heavy metals. Zinc concentration increased with increase in fertilizer level to further confirm that Zn is mobile .This support the assertions of Vaněk *et a*l, .2005 that Zinc and Cadmium are highly mobile in the soil.

CONCLUSION AND RECOMMENDATION

The result of this experiment shows that different levels of phosphate fertilizer application have no significant effect on the plant height and number of leaves of *Amaranthus caudatus*. From the result *A caudatus* is best harvested for fresh consumption as vegetable at four weeks after sowing because it gives the highest number of leaves at this point

This experiment shows that heavy metals concentration is highest in the soil compared to the stem and root of the vegetable used, the concentration of Ni in the stem and root of the vegetable shows that plant rarely take up Ni from the soil. Only Zn, Cu and Cd shows an increase in the soil concentration with an increase in levels of phosphate fertilizer applied we can safely conclude from this result that heavy metal accumulation in the soil does not depend on levels of phosphate fertilizer but on the levels of heavy metal impurities in the phosphate rock used for the fertilizer production

The fairly high uptake of Cu, Zn and Cd by the plant roots and stems under 0kg/ha phosphate fertilizer shows that *Amaranthus caudatus* has the potential of being used to clean up heavy metal contaminated soils and that only uncontaminated soils should be used to produce the vegetable.

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