ISSN: 2287-688X

Annals of
Plant Sciences

Volume 11, Issue 03 (2022) pp. 4865-4875

Research Article

Mitigating the Toxicity Effects of Heavy Metals in Plants

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Abstract

This work focuses on the growth performance of *Cyperus iria* grown in a heavy metal polluted soil amended with NPK, orange and plantain peels. The ex-situ experiment was conducted at the Centre for Ecological Studies, University of Port Harcourt. Two (2) kilograms of heavy metal polluted soil was weighed into polythene bags (height 18 cm, diameter 14 cm and surface area 0.095 m^2) and arranged in 5 batches (A, B, C and D) alongside with uncontaminated soil (batch E), batch A, B and C were subdivided into 3 sub plots with amendment as: A (100g OP/2kg + *Cyperus iria,* 200g OP/2kg + *Cyperus iria,* 300g OP/2kg + *Cyperus iria*); B: (100g PP/2kg + *Cyperus iria,* 200g PP/2kg + *Cyperus iria,* 300g PP/2kg + *Cyperus iria*); C (40g NPK/2kg + *Cyperus iria,* 80g NPK/2kg + *Cyperus iria,* 120g NPK/2kg + *Cyperus iria*). D (0g /2kg + *Cyperus iria*; polluted unamended soil). E (0g /2kg + *Cyperus iria* unpolluted with no amendment), stands as control and double control respectively. This was monitored at 60-day interval. Findings showed that amendment with 300g PP caused increase in plant height, shoot fresh weight, shoot dry weight, shoot moisture content, root fresh weight, root dry weight and root moisture content, and orange peel amendment was the second best option while inhibition in growth parameter were observed in soil amended with 40g NPK and polluted soil with no amendment. Therefore, 300g plantain peel waste is observed to be more effective in ameliorating the toxicity effects of heavy metal on plant growth.

Keywords: *Heavy metal, Cyperus iria, Plant growth parameters.*

Introduction

Environment is regarded as the fundamental and conspicuous habitat of living things (Masindi. *et al.*, 2018). The environment is the habitant for living things (plants, animals and micro-organisms). The living portion of the environment is influenced by three main spheres: the lithosphere, atmosphere and hydrosphere which work in synergy. Recently, increase in demand of innovation and exploitation of natural resources indiscriminately has exacerbated the problem of environmental perturbation (Gautam. *et al.*, 2016). Anthropogenic interference has contributed several pollutants such as inorganic ions, organometallic compounds, heavy metals etc on the environment along with its negative impact (Walker. *et al.*, 2012).

The characteristics of a given soil is influenced by environmental pollution. The introduction of noxious and harmful materials into the environment by natural occurrence or human activities is known as pollution (Ramesh. *et al.,* 2013). Nevertheless, pollution issues are always critical in less developed countries than in technological advance countries (Ramesh. *et al.,* 2013). Pollution could be from point and non-point sources (McGrath. *et al.*, 2001). Each point of pollution influenced negatively plant metabolic processes and animal health. Pollutants such as printed circuit board (PCB's) from computers and nickel- cadmium from car batteries contain noxious metals. Heavy metals are elements with metallic properties and atomic numbers

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DOI: http://dx.doi.org/10.21746/aps.2022.11.3.5

greater than 20 (Lasat, 2002). Furthermore, metals are ubiquitous since they constitute in earth crust formation (Lasat, 2002). Human interference contributes immensely in heavy metal occurrence (Ali. *et al*., 2013). The harmful effect of heavy metals, their persistency and vulnerability to plants has drawn the attention of researchers (Maiti. *et al*., 2004; Ali. *et al*., 2013). Heavy metal is also part of the component of soil parent materials, making it ubiquitous in the environment. Imminent surge of heavy metal deposition in the environment is proportional to its use (Gautam. *et al*., 2016). Upsurge of heavy metal in environment is due to human interference such as metal mining, sewage sludge, fuel combustion, batteries, pigment and paint. The secondary source of heavy metal is generated from agricultural field such as pesticides, insecticides, fertilizer (Gautam. *et al*., 2016).

Heavy metals effect has been seen morphologically in decrease plant growth (Shankar *et al*., 2005). The part of plant which have direct link with pollutant is the root which exhibit changes in their rooting system in other to adapt and survive such stress (Baker and Walker, 1989). It is exposed to toxic effects more than other plant parts (Rout. *et al*., 2001). The first pronounced effects of heavy metals on plant are observed in root length inhibition. Other morphological and structural effect of heavy metals includes decrease in plant root elongation, decrease in biomass and vessel, reducing root number and enhancement in lignification’s and changes in hypodermis and epidermis structure (Rout. *et al*., 2001). Heavy metals retard plants growth through excess production of Reactive Oxygen Species (ROS) which affects plants via oxidative damage of cellular components (Gill, 2010). Furthermore, the negative influence of heavy metals on soil microbial may also indirectly affect plant growth. Reduction in number of useful microorganisms based on heavy metal toxicity could lead to decrease in the breakdown of organic materials thereby affect soil nutrient content. These noxious effects of heavy metals on plants could give rise to a decline in growth (Schaller and Diez, 1991). The consequence of heavy metal toxicity varies among plants.

Materials and Methods

Study Area and Experimental Design

This Research was conducted at the Centre for Ecological Studies, University of Port Harcourt. It is located in the Niger Delta area of Nigeria on geographical coordinates: latitude 4° 65′ N and longitude 7° 5′ E. A Completely Randomized Design (CRD) was used for the experiment. Soil samples used (suspected of heavy metal pollution) was obtained from an abandoned metal scrap site. The soil was collected at 0-20 cm depth with a spade as composite sample. The total soil was mixed thoroughly, dried and sieved through a 2 mm wire mesh to obtain a homogenous 'fine fraction' of soil composites. A baseline analysis was done to ascertain the concentrations of metals and other nutrients in the polluted soil. Two (2) kilograms of homogenous soil composite was weighed with a weighing balance (Setra 480S, USA) into polythene bags of height 18 cm, diameter 14 cm and surface area 0.095 m^2.

Plate 2.1: *Cyperus iria* 4 weeks after planting

Table 2.1: Nutrient and metal of the peels waste used

S/N	Parameter	Orange peels waste
1	Phosphorus (mg/kg)	66.51
2	Sodium (mg/kg)	474.85
3	Potassium (mg/kg)	66,285
4	Magnesium (mg/kg)	1208
5	Calcium (mg/kg)	278.70
6	Nitrogen %	0.119
7	Ash %	11.50
8	Fe (mg/kg)	767.7
9	Zn (mg/kg)	13.05
10	Pb (mg/kg)	ND
11	Cd (mg/kg)	ND
12	pH	5.56

ND = Not detected

Table 2.2: Physicochemical properties and heavy metal content of polluted and unpolluted soil

S/N	Parameter	Unpolluted	Polluted soil
1	Moisture (%)	45	43
2	Bulk density (%)	1.5	1.7
3	Particle density (%)	5.8	5.1
4	Porosity	0.35	0.3
5	SOM (%)	12	24
6	Sand (%)	95.6	93.6
7	Silt (%)	0.10	0.7
8	Clay (%)	4.3	5.7
9	Chloride (mg/kg)	213	3687
10	Sulphate (mg/kg)	28.4	269
11	Nitrate (mg/kg)	71.9	138
12	Phosphorus (mg/kg)	1.35	0.82
13	Sodium (mg/kg)	120	132
14	Calcium (mg/kg)	110	120
15	Magnesium (mg/kg)	258	280
16	Potassium (mg/kg)	43	68
17	pH	5.10	8.43
18	Conductivity (μsCm^{-1})	90	1193
19	Iron (mg/kg)	48.2	4410
20	Zinc (mg/kg)	0.94	107.5
21	Lead (mg/kg)	130	167.3
22	Cadmium (mg/kg)	0.80	15.3

Note: SOM = Soil Organic matter

Amendment Treatments

Land race of sweet orange peels (waste) used was acquired from Otutu-Amaumara Ezinihitte Mbaise LGA. Imo State Nigeria and the ripe plantain peel (waste) was obtained from Kaiama in Kolokuma/Opukuma L.G.A Nigeria. Planting bags were arranged in 5 batches (A, B, C and D), alongside uncontaminated soil designated as batch E of 12 replications, batch A, B, and C were sub divided into 3 sub plots while batch D(control polluted soil) and E (control unpolluted soil).

Table 2: 3 Experimental design and treatment applications

Batches	Treatment and Plant Species
Batch A	100g OP/2kg + *Cyperus iria*
	200g OP/2kg + *Cyperus iria*
	300g OP/2kg + *Cyperus iria*
Batch B	100g PP/2kg + *Cyperus iria*
	200g PP/2kg + *Cyperus iria*
	300g PP/2kg + *Cyperus iria*
Batch C	40g NPK/2kg + *Cyperus iria*
	80g NPK/2kg + *Cyperus iria*
	120g NPK/2kg + *Cyperus iria*
Batch D	0g /2kg + *Cyperus iria*
Batch E	0g /2kg + *Cyperus iria*

Op = Orange peel, PP = Plantain peel.

At two weeks, seedings of *Cyperus iria* raised in nursery was transplanted into batch A, B C and D as shown in table 2.3. Watering was done twice daily and weeds control was done by handpicking when necessary. The experiment was monitored at 60 days interval. At 60th day, six replications were harvested from each batch destructively while the plants were removed for anatomical analysis.

Plant Growth Parameter Measurements

Shoot Length (cm)

Each plant species was measured from plant base to apex using a transparent metre rule. The average per bag was recorded.

Fresh Weights (g)

The fresh weights were measured using weighing balance calibrated in gram (g) to weigh the plants from each treatment. This was taken immediately after harvest to circumvent water loss. The plant roots were weighed using Sartorius Analytical Weighing Balance after getting rid of soil particle attached to the plant root by washing and damping them with filter paper. The fresh weight of shoots and roots of the plant species were recorded.

Dry Weight (g)

The harvested plants after taken their fresh weight were placed in brown envelopes, labelled according to treatment from which they were harvested and dried in hot oven (unicon) at 50 ^{0}C for 7 days. After that, their dry weight (DW) were measured using Sartorius Analytical Weighing Balance. The mean dry weight of each treatment was calculated and expressed in gram (g).

Moisture Content (%)

This was determined by standard procedure and calculated as described below. Moisture content (MC) was obtained by subtracting the dry weight of a particular plant from its fresh weight and result obtained multiplied by 100, MC was expressed in percentage (100%).

$$\text{Moisture Content (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

Statistical Analysis

From the data generated means and standard error mean (SEM) were calculated from the data obtained. Least Significant Difference (LSD) was used to separate means using SAS data analysis package.

Results

Result in Figure 3.1.

Result of the effects of soil amendments on plant height at 60 and 120 days of post planting showed that highest growth rate in terms of height was recorded for *Cyperus iria* which was grown in a 300g and 200g plantain peel (waste) amended soil respectively, this indicated the effectiveness of the treatment to mitigate heavy metal toxicity. The least decrease in height was observed in plant grown in polluted control with 0g amendment. The test plant (*Cyperus iria*) grown in powder orange peel, plantain peel and double control showed an increase in height. It was found that there was significant difference in plant height between and within amendment treatments with time at ($p = 0.05$).

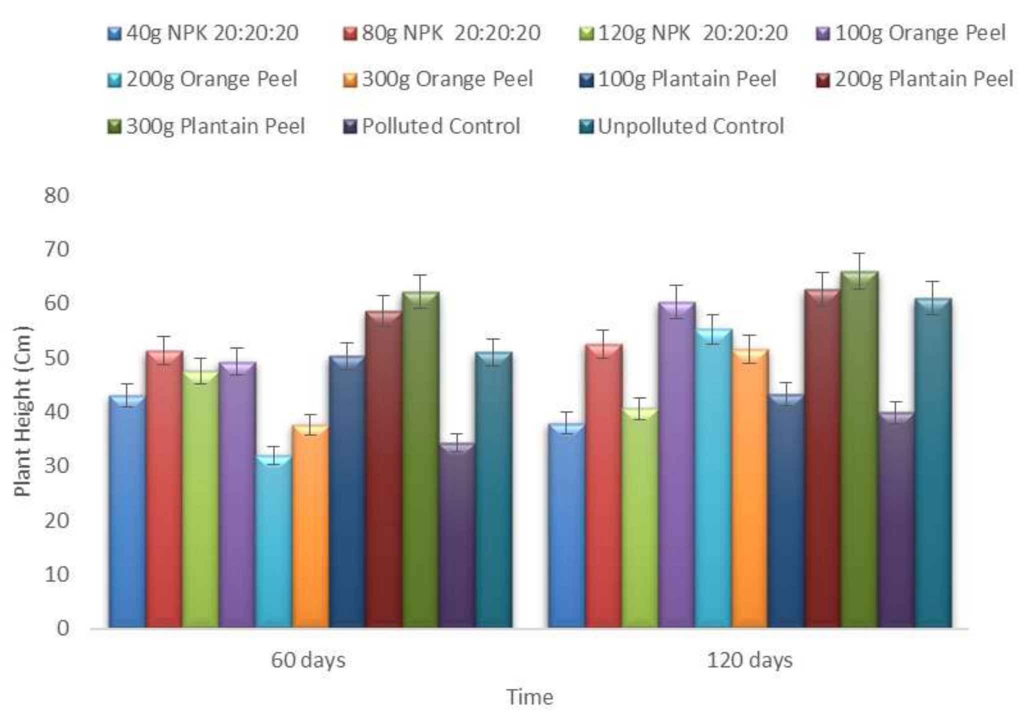

Fig 3.1 Effectsof amendments on the height of *Cyperus iria*

Result on the effect of amendments on shoot fresh weight (SFW) at 60 and 120 days of post planting, the result showed that highest SFW was recorded for *Cyperus iria* grown on 300g plantain peel (waste) amended soil. The least decrease in SFW was observed in test plant grown 120g NPK soil amendment and polluted control with 0g amendment at 60 and 120days respectively. The test plant (*Cyperus iria*) grown in powder orange peel also showed a corresponding increase in SFW as compared with plantain peel. It was found that there was significant difference in SFW between and within amendment treatments with time at p = 0.05 (Figure 3.2).

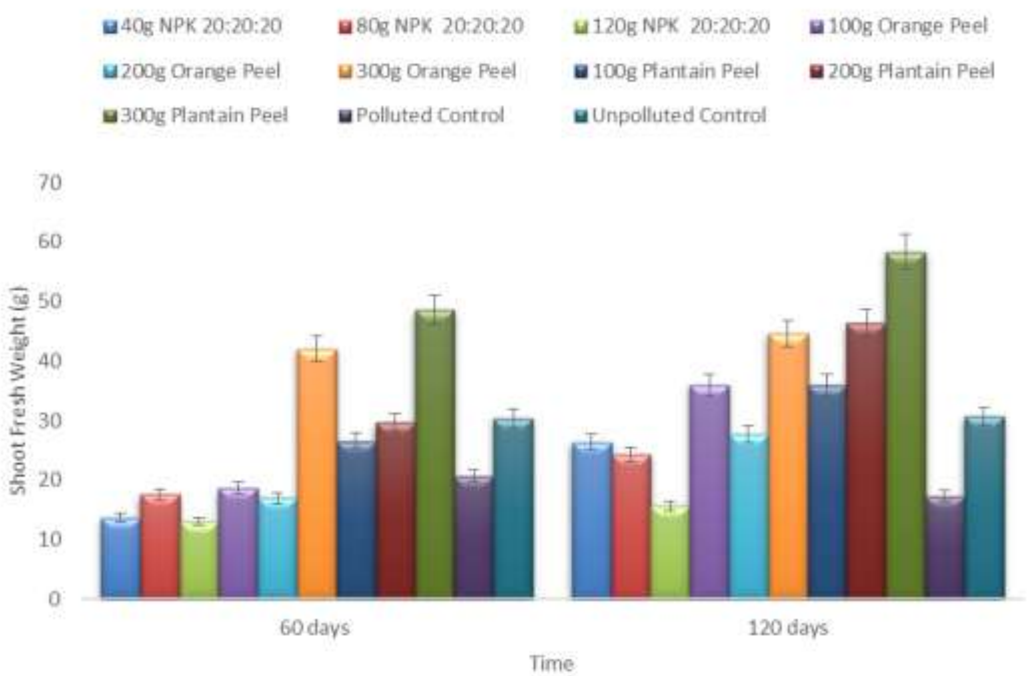

Fig 3.2 Effects of amendments on Shoot Fresh weight of *Cyperus iria*

The effect of amendments on shoot dry weight (SDW) at 60 and 120 days of post planting, indicated the highest SDW in *Cyperus iria* grown in a 300g plantain peel (waste) amended soil. While least decrease in SDW was observed in test plant grown in 40g, and 200g orange peel amended soil at 60 and 120days respectively. There were significant difference in SDW between and within amendment treatments with time at p = 0.05 (Fig 3.3).

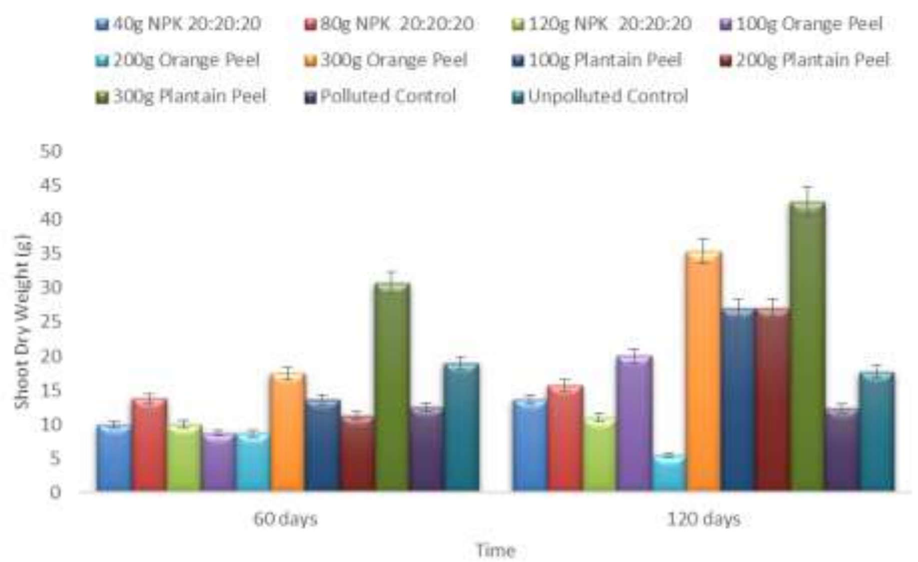

Fig 3.3 Effects of amendments on Shoot Dry weight of *Cyperus iria*

Result of the effect of amendments on shoot moisture content (SMC) indicated highest increase in SMC was in 300g plantain peel amended soil followed by orange peel amended soil at amendment. The least decrease in SMC was observed in test plant grown in 40g NPK amendment and polluted control soil at 60 and 120days respectively. The results further showed significant differences in SMC between and within amendment treatments with time at p = 0.05 (Fig. 3.4).

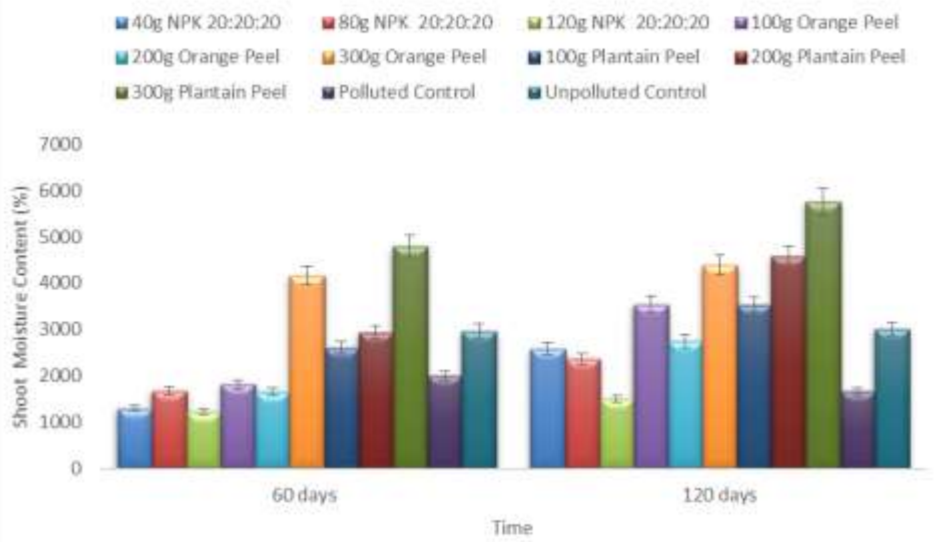

Fig 334 Effects of amendments on Shoot Moisture Content of *Cyperus iria*

The result of the effect of amendments on root fresh weight (RFW) showed highest increase of RFW was found in plant grown in 300g and unpolluted control at 60 and 120days respectively. The least decrease in RFW was recorded in a test plant grown in 100g plantain peel amended soil at 60 days and in polluted control unamended soil at 120 days of post plantain. There was significant difference in RFW between and within amendment treatments with time at p = 0.05 (Fig 3.5).

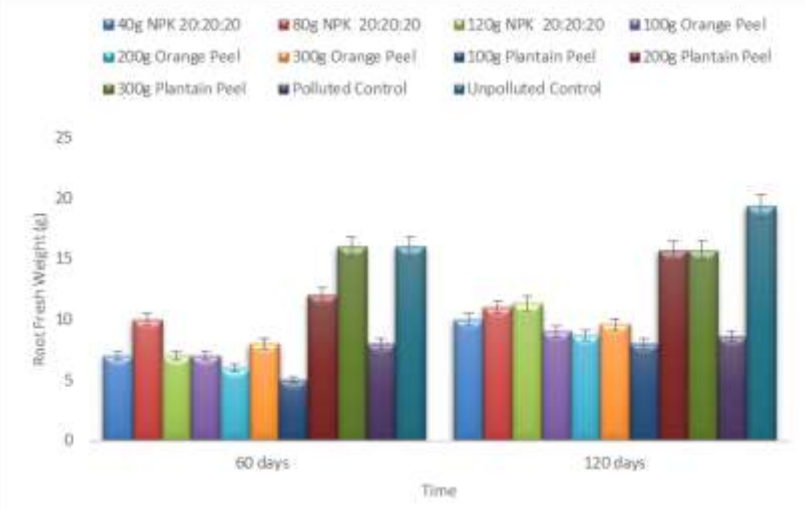

Fig 3.5 Effects of amendments on root fresh weight of Cyperus iria

The effects of amendments on root dry weight (RDW) with the least increase in RDW was recorded in a test plants grown in polluted unamended soil at 60 and 120 days of post planting. Highest increase of RDW was in plants grown in 300g soil amended with 300g plantain peel and unpolluted control at 60 and 120days of post planting respectively. There was significant difference in RDW between and within amendment treatments with time at p = 0.05 (Fig.3.6).

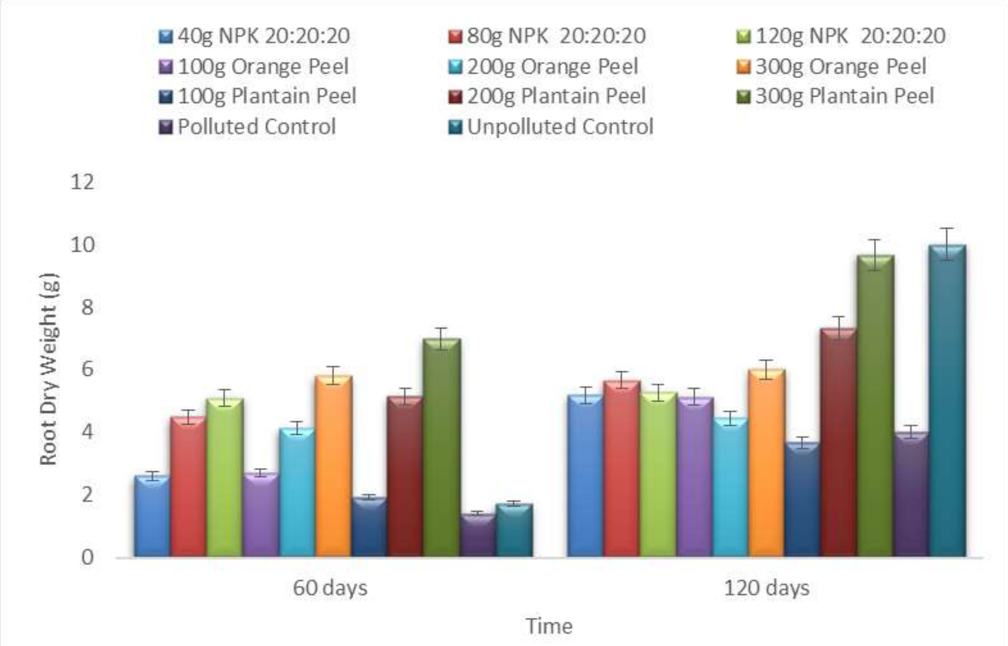

Fig 3.6 Effects of amendments on root dry weight of *Cyperus iria*

The effects of amendments on root moisture content (RMC) showed the least increase was in a test plants grown in 100g plantain peel amended soil at 60 and polluted unamended soil at 120 days of post planting. The highest increase of RMC was found in plant grown in a 300g and unpolluted control at 60 and 120 days respectively. There was significant difference in RMC between and within amendment treatments with time at p = 0.05 (Fig 3.7).

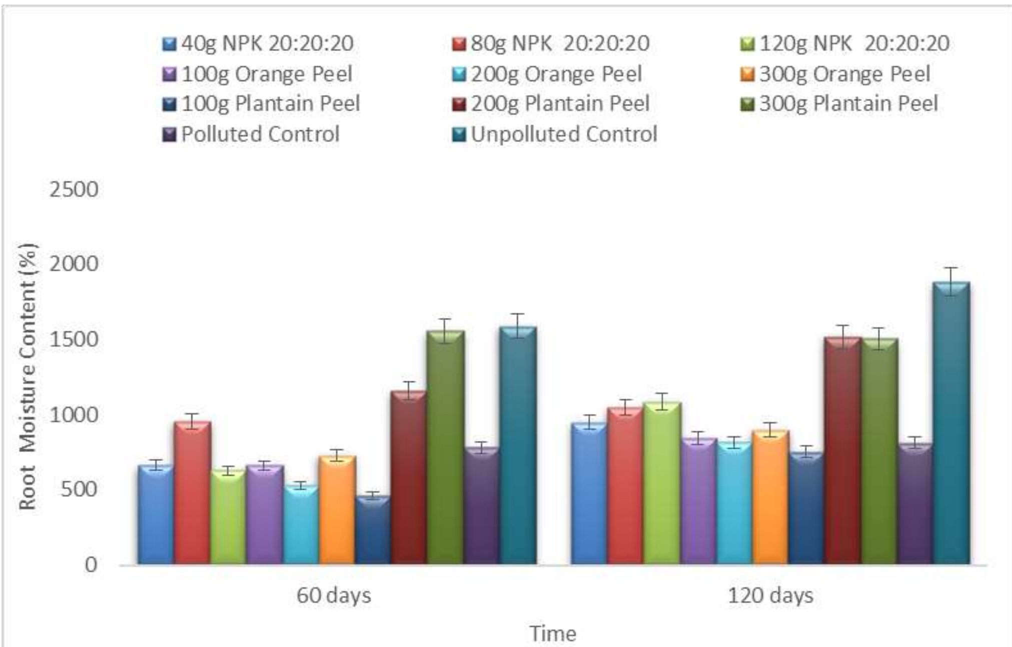

Fig 3.7 Effects of amendments on Root Moisture Content of Cyperus iria

Discussion

It is well known that heavy metal pollution affects the physicochemical characterization and biological properties of soil (Oancea. *et al*., 2005). This can directly and indirectly affect plants by influencing negatively the general performance of plants (Oancea. *et al*., 2005; Castro. *et al*., 2015). The effects of amendment treatments observed in general plant performance, could be attributed to the effectiveness of the treatment to mitigate toxicity due to heavy metal pollution and support plant growth. This assertion is in agreement with Oliver (2016) who reported the efficacy of amendment treatment in enhancing the general performance of plants especially its growth rate. Amendment treatment showed an improvement in plant height, shoot fresh weight, shoot dry weight, shoot moisture content, root fresh weight, root dry weight, root fresh weight and root moisture content. Plants grown in 300g plantain peel (waste), Showed an exceptional increase in the studied plant parameters (plant height, shoot fresh weight, shoot dry weight, shoot moisture content, root fresh weight, root dry weight, root fresh weight and root moisture content). The effectiveness of 300g plantain peel soil amendment in this contest, could be possible since plantain peel amendment may have acted as a biostimulant. This is comprehensible because, the added peels may have stimulated microbial activities which may perhaps have released growth hormone such as auxin. This assertion agrees with Bago (2000) who observed an increase in soil nutrients, and attributed his findings to soil microbial metabolisms. This increase in nutrient availability may have increased shoot length and other growth parameter through the release of growth hormones. The decrease observed in growth performance of test plants grown in NPK amended soil as compared to plantain peel amendment may be attributed to concentration of NPK added to soil. Furthermore, NPK application appears noxious to plant when added above recommended dose to plants (Ibrahim, 2013). Soil mineral nutrients influences shoot length and crop yield. The decrease in biomass observed in the test plant grown in control soil (polluted unamended soil) may possibly be as a result of the negative toxicity effects of heavy metals. Similar finding was reported by Joshi and Mohanty (2010) they also reported that the effect of metals disrupts protein link and substitute itself with important plant nutrient thus influencing plants negatively.

Conclusion

This study has shown that the amendment of heavy metal polluted soil with plantain peels waste has the capacity and potential to enhance plant growth parameter without showing signs of toxicity. The increase in plant growth properties was more in plants grown in a 300g/2kg plantain peel amended soil. Therefore, 300g/2kg plantain peel waste observed to be more effective in ameliorating the toxicity effects of heavy metal on plant growth.

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Source of support: Nil; **Conflict of interest:** Nil.

Cite this article as:

Noble, A., Gbosidom, V.L and Worlu, C.W. "Mitigating the Toxicity Effects of Heavy Metals in Plants." *Annals of Plant Sciences*.11.03 (2022): pp. 4865-4875.

DOI: http://dx.doi.org/10.21746/aps.2022.11.3.5