BIOACCUMULATION OF MINERALS AND HEAVY METALS IN THREE SPECIES OF STRIGA GRASS (S. hermonthica, S. aciatica and S. gesnerioides)

[1]Mohammed Musa Lawan, [1]Idris Baba Garba

[1] Department of Chemistry, Yobe State University Damaturu

ABSTRACT This research work examined the nutrient and heavy metal accumulation capacity of three different species of *Striga* plant from two different locations (western and eastern Yobe) in Yobe State; Kukar Gadu and Damaturu towns respectively. Atomic absorption spectrometry and other analytical techniques were employed to estimate the amount of nutrient and heavy metal bioaccumulation of the three (3) species of Striga grass.

Nitrogen, Potassium and Phosphorus were also within the optimum recommended levels in the parasitic plant but lower in the host plant. The concentration of nitrogen analysis in the three (3) species range between 479.75- 826.91 mg/kg in stem, 145.60-532.09mg/kg in leaves and 701.33 – 859.06mg/kg in root. **Concentration of p**hosphorus **in the** three (3) species ranged between 18.83+ - 202.76 mg/kg in stem, 17.40-176mg/kg in leaves and 49.28 – 275.27mg/kg in root while the hostorium of *S. gesneriodes* has between 56.75-265.49mg/kg. Potassium concentrations in the three (3) species, the range is between 335.55+ to 1360.54 mg/kg in stem, 115.61-956.64mg/kg in leaves and 634 – 1245.18mg/kg in root while the hostorium of *S. gesneriodes* has capacity between 664.05-1689.66mg/kg. Concentrations of N, P and K in the roots of sample beans (host plant) are between 153.95 mg/kg, 200.01 mg/Kg and 104.07 mg/Kg respectively. Zinc concentration in the three (3) species, the range is between 9.750 - 21.740 mg/kg in stem, 1.42-10.83mg/kg in leaves and 13.94-45.14mg/kg in root while the hostorium of *S. gesneriodes* has 14.91-32.16mg/kg. Manganese in the three (3) species revealed a range between 4.19-39.58 mg/kg in stem, 0.00-8.38 mg/kg in leaves and 9.09-77.30mg/kg in root. The root-bulb of *S. gesneriodes* had 11.58-89.106mg/kg of manganese. The levels of manganese concentration in all parts of the plants are also within the optimum requirement of 25-100 ppm (Srivastava & Shyam, 2004) and WHO limits of 500mg/kg. Lead concentration in samples ranges between 1.10-3.11mg/kg in stem, 2.08-5.03mg/kg in root and 0.37-0.98 in leaves. The hostorium has 1.91-10.37mg/kg. Cadmium concentration in samples ranges between 1.21-9.92mg/kg in stem, 1.46-13.92mg/kg in root and 0.42-7.65 mg/kg in leaves. The root-bulb has 1.32-10.56mg/kg. The heavy metal concentrations in all the samples were higher than the WHO recommended level that may cause toxicity in plants.

I. INTRODUCTION

Nutrients are defined as substances obtained from diet, which are required by the body to perform its basic functions. Human nutrition deals with the provision of essential nutrients in foods that are necessary to support human life and health. The ability of different plant varieties (cultivars) to absorb micronutrients from soil as well as their micronutrient requirements may vary considerably. (Naeem, Abid, & Sarvajeet, 2017). Plants are of significant part of mankind because they are essential for nutrients. Vegetables constitute important functional food components by contributing protein, vitamins, iron, calcium and other nutrients which have marked health effects. There is an inherent tendency of plants to take up toxic substances including heavy metals that are subsequently transferred along the food chain (Singh *et al.*, 2010)

A **hyperaccumulator** plant is a plant capable of growing in water with very high concentrations of metals, absorbing these metals through their roots, and concentrating extremely high levels of metals in their tissues (Arruti, 2015; Rascio & Navari-Izzo, 2011)

The metals are concentrated at levels that are toxic to closely related species not adapted to growing on the metalliferous soils. The roots extract metal from the soil at a higher rate, transfer it more quickly to their shoots, and store large amounts in leaves and roots. The ability to hyperaccumulate toxic metals compared to related species has been shown to be due to differential gene expression and regulation of the same genes in both plants (Rascio & Navari-Izzo, 2011). Hyperaccumulating plants are of interest for their ability to extract metals from the soils of contaminated sites (phytoremediation) to return the ecosystem to a less toxic state. The plants also hold potential to be used to mine metals from soils with very high concentrations (phytomining) by growing the plants, then harvesting them for the metals in their tissues. The genetic advantage of hyperaccumulation of metals may be that the toxic levels of heavy

metals in leaves deter herbivores or increase the toxicity of other anti-herbivory metabolites (Hossner, Loeppert, Newton, & Szaniszlo, 1998).

Striga grass (commonly called witch-weed) is a plant pathogen that affects cereal crops in sub-Saharan Africa. It is a parasitic plant with attractive beautiful flowers (Runo, 2018). Most cultivated cereals, including maize, millet, sorghum, and rice, are parasitized by at least one *Striga* species, leading to enormous economic losses (Runo, 2018). The management and control of *Striga* infestation proved to be difficult especially in Africa. (Gethi, 2004; Parker, 2008; Runo 2018). It mostly affects cultivated cereals and legumes leading to enormous economic losses (Sand 1990; Nickrent 2004). Striga is obligate hemiparasite of roots and require a living host for germination and initial development, though they can then survive on their own (Young, 1999). The number of species is uncertain, but may exceed 40 by some counts (Mohamed *et al.*, 2007).

Many approach were attempted to control the effect of striga infestation on crops but no single management option has been found effective across locations and time. Most strategies are limited to agronomic practices of hand weeding, crop rotation, and general sanitization techniques. *Striga*-resistant crops, as well as tolerant ones, have also been used, but this resistance tends to break down with the emergence of new *Striga* variants. *Striga* however, has continued to increase both its host range and area under infestation. In the United States *Striga* has been controlled through injecting ethylene gas (which mimics the natural physiological response tied to host recognition) into the soil to induce the germination of seeds present. Because no host roots are available, the seedlings die (Agrios, 2005). *Striga* grass can produce thousands of seeds which may remain dormant in the soil for many years (Bilalis, et al., 2010).

Apart from devastating effect of most striga species, few like *Striga hermonthica* have a beneficial side in the traditional medicine for the African people, these include the treatment of dermatosis, diabetes, leprosy ulcer, pneumonia and jaundice remedy, trypanocidal effects, antibacterial and anti-plasmodia activities (Faisal, 2011; Elkamali, 2009).

This study determines the macro nutrient bioaccumulation level of three (3) different *Striga* species (*Striga asiatica*, *S. gesnerioides*, and *S. hermonthica*.) with specific reference to mineral and heavy metals accumulation capacity of various parts of the plant (root, leaves and stem). Nutrient deficiencies and toxicities were also studied

RESEARCH METHODOLOGY

3.1 MATERIALS

The equipment and instruments used in this study were all calibrated to check their status before and in the middle of the experiments. Apparatus such as volumetric flasks, measuring cylinder and digestion flasks were thoroughly washed with detergents and tap water and then rinsed with deionized water. All Glass wares were cleaned with 8% concentrated Nitric acid (HNO_3) in order to clear out any heavy metal on their surfaces and then rinsed with distilled-deionized water. The digestion tubes were soaked in 8% (v/v) HNO_3 for 24 hours followed by rinsing with deionized water and then dried in oven and kept in dust free place until analysis began. Prior to each use, the apparatus were soaked and rinsed in deionized water.

3.2 Equipment and Apparatus

The equipment and instruments to be used in this study include:

i. Atomic absorption spectrophotometer (Buck scientific model 210VGP AAS, USA) hollow cathode lamps with air-acetylene flame)
ii. Microwave digester (Master 40, Sineo Chemistry Technology, China)
iii. Muffle Furnace, p-select, Pizzato, Italy
iv. Analytical Balance ($^+$ 0.0001g), PA 214, Ohaus, USA.
v. Oven, Memmert UNB 300, GmbH Co. Germany
vi. Automatic micro kjeldahl apparatus, ZDDN II
vii. Micropipettes (1-10 ml, 100-1000 ml),

3.3 Reagents and Chemicals

Reagents and chemicals used for the laboratory works were all analytical grade: Nitric acid (HNO_3) loba chemie india; Hydrogen peroxide (H_2O_2) Sigma; Deionized water (chemically pure with conductivity 1.5 µs/cm and below was prepared in the laboratory) was used for dilution of sample and intermediate metal standard solutions prior to analysis and rinsing glassware and sample bottles.

3.4 Study Locations

Two (2) different study locations were chosen in Yobe State, of the Federal Republic of Nigeria. The locations include Damaturu and Kukar Gadu towns where susceptible plant/crops are planted.

3.5 Sample collection, preparation and analysis

Three (3) different species (*Striga asiatica*, *S. gesnerioides*, and *S. hermonthica*) were collected. Random sampling technique was employed to collect the Samples during rainy season from various farm lands within Damaturu

and Kukar Gadu towns where susceptible plants/crops were planted. The farm lands include farms within Yobe State University, Damaturu and some farms in Kukar Gadu along Bauchi road, Fika LGA Yobe State.
The samples were collected by digging dip down the ground close to host plants' root and removing the *Striga* from the hosts root. Immediately after which the *Striga* plant were washed with distilled-deionised water, separated into leaves, stem and root and then transported to the laboratory. The samples were air-dried and stored in a drying cabinet (under controlled humidity) prior to analysis.

Figure 1: (*Striga gesneriodes* attacking beans root)

Figure 2: Sample collection

Sample Pre-Treatment/Digestion

The samples were allowed to dry using hot oven (Model 30GC lab oven) and then ground into fine powder using a porcelain mortar and pestle. The grounded samples were kept in a ziplip bags before digestion.
Empty microwave tubes (thoroughly clean plastic container) were weighed and 0.1g of each sample was added and then reweigh. 6ml HNO_3 and 2ml of hydrogen peroxide (3:1) were added, reweighed again and then allowed to stand for a while. The plastic containers (microwave tube) were then covered and placed in to microwave digester (Master 40 serial No: 40G106M) and digested.

The digestion was carried out at a temperature of (120^{o}C) for 40 min and then ramped at 20^{0}C per min to 180^{0}C and hold for 10mins. The digestion was followed by a cooling to room temperature in the microwave. Potential presence of heavy metals in the chemicals used in digestion was determined. Blanks were used simultaneously in each batch of the analysis to authenticate the analytical quality. The digested samples were diluted with de-ionised water to a total volume of 25ml.

Preparation of Standard working solution (Na, Fe, K, Mg, Ca and Zn)

100ppm was prepared as working solution from the 1000ppm obtained from manufacturers (Buck Scientific, USA). A simple dilution formula ($C_1V_1 = C_2V_2$) was used to calculate the volume of the stock solution to be diluted to the new desired concentration. To prepare 100ppm, 10ml of the standard stock solutions were pipetted and added in to 100 ml calibrated flasks finally diluted with deionized water and the solution was mixed thoroughly. The other standard working solutions were prepared from the 100ppm by pipetting out appropriate volume in to calibrated flasks and made up to volume with deionized water.

Determination of metal content by AAS

Preparation of calibration curve

Calibration curves were prepared to determine the concentration of the metals in the sample solution. The instrument was calibrated using series of working standards. The working standard solutions of each metal were prepared from standard solutions of their respective metals and their absorbencies were taken using the Atomic Absorption Spectrometry (AAS). Calibration curve for each metal ion to be analyzed was prepared by plotting the absorbance as a function of metal standard concentration.

Determination of metal contents of each sample

Concentrations of the metal present in the sample were determined by reading their absorbance and comparing it on the respective standard calibration curve. Three replicate determinations were carried out on each sample. The metals were determined by absorption /concentration mode and the instrument readout was recorded for each solution manually. The same analytical procedure was employed for the determination of metal in digested blank solutions and for the spiked samples.

Data Analysis

Data was analyzed using Microsoft Office Excel. The data were expressed in term of descriptive statistics while the figures were presented with Mean values as (Mean±SD). The analytes determined include magnesium (Mg), Calcium (Ca), Copper (Cu), Sodium (Na), Potassium (K), Iron (Fe), Manganese (Mn), Zinc (Zn),

DATA ANALYSIS AND STRATEGIES

Results were expressed as mean + standard deviation.

RESULTS AND DISCUSSION

This research work examined the nutrient and heavy metal accumulation capacity of three different species of *Striga* plant from two different locations (western and eastern Yobe) in Yobe State; Kukar Gadu and Damaturu towns respectively. The nutrients were classified as mobile nutrients such as Nitrogen, Phosphorus, Potassium (Srivastava & Shyam, 2004) and non mobile nutrients such as Calcium, Copper, Iron, Manganese, Nickel and Zinc (Agustin, John, & Antonio, 2015).

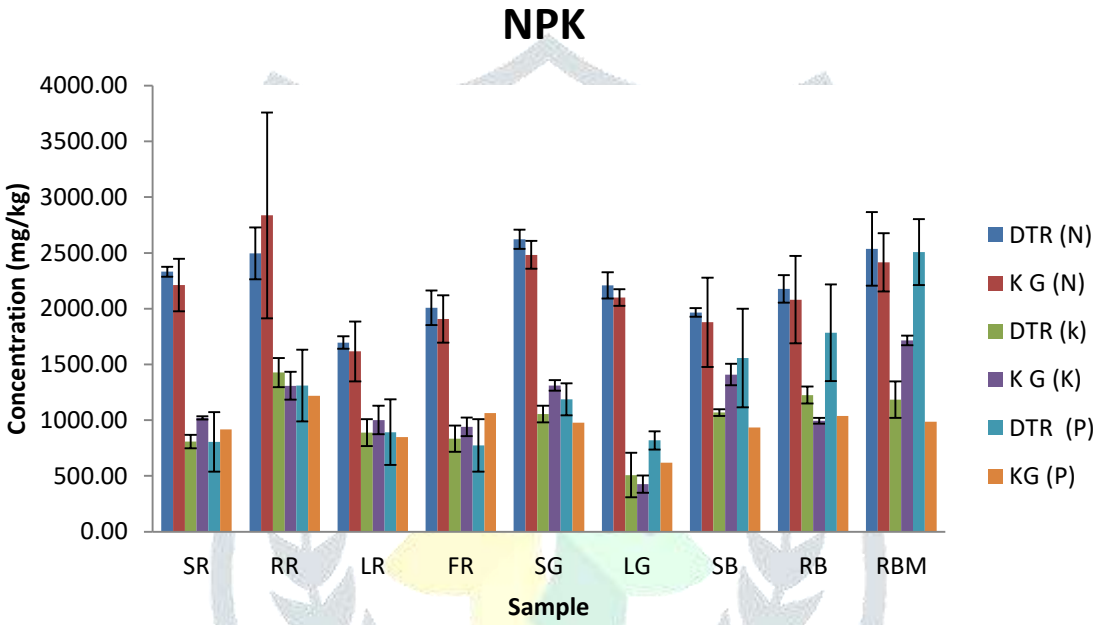

Figure 3: Concentrations of Nitrogen, Phosphorus and Potassium in Damaturu and Kukar Gadu Samples

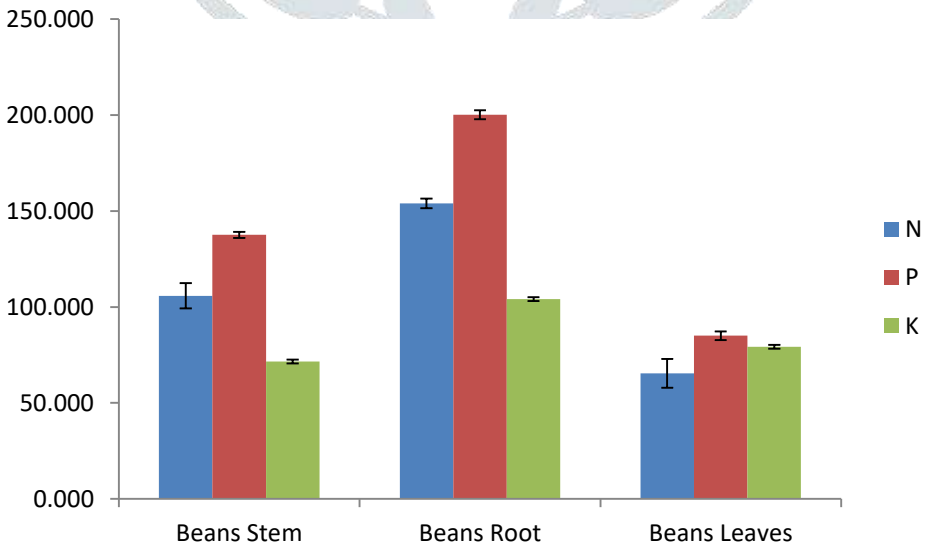

Figure 4: Concentrations of Nitrogen, Phosphorus and Potassium some affected beans Samples

The concentration of nitrogen analysis in the three (3) species revealed a range between 479.75- 826.91 mg/kg in stem, 145.60-532.09mg/kg in leaves and 701.33 – 859.06mg/kg in root while the root-bulb of *S. gesneriodes* as indicated in figure 3 above. According to Jorgenson and Price (1978) as adopted by (Srivastava & Shyam, 2004), the recommended optimum limits of Nitrogen (N) in plant is between 2.4-2.6% (24,000-26,000mg/kg). This results shows

that the nitrogen analyzed in the *Striga* species were all below the recommended level; indicating deficiency in the nitrogen content in all the study area.

Concentration of phosphorus in the analysis results of the three (3) species ranged between 18.83+ - 202.76 mg/kg in stem, 17.40-176mg/kg in leaves and 49.28 – 275.27mg/kg in root while the root-bulb of *S. gesneriodes* has capacity between 56.75-265.49mg/kg, slightly lower than the roots of *S. hermontheca.* In each case, the levels of Phosphorus in all parts of the plants are lower than the optimum requirement of 0.140.16% (Srivastava & Shyam, 2004).

From the analysis results of potassium in the three (3) species, the range is between 335.55+ to 1360.54 mg/kg in stem, 115.61-956.64mg/kg in leaves and 634 – 1245.18mg/kg in root while the root-bulb of *S. gesneriodes* has capacity between 664.05-1689.66mg/kg, indicating a higher accumulation level than the roots. In each case, the levels of Potassium in all parts of the plants are within the optimum requirement of 0.9-1.2% (Srivastava & Shyam, 2004).
The results above were also compared with that of the affected plants (beans). The average concentrations of N, P and K in the sample beans are between 153.95 mg/kg, 200.01 mg/Kg and 104.07 mg/Kg respectively in roots which is the highest when compared to leaves. However, the results indicated a slightly lower amount of all the nutrients in the beans samples thereby confirming the assumptions as is evident from the yellowish nature of the host plant. This can also be the cause of the death of the host plant.

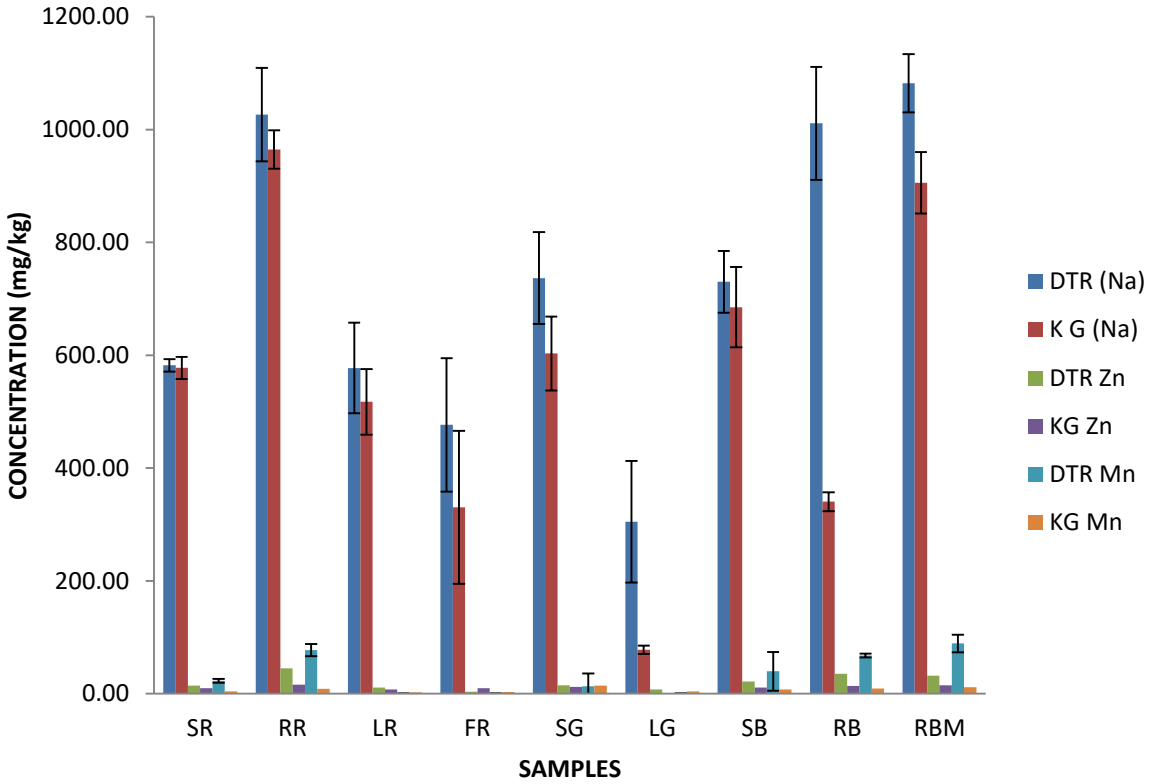

Figure 5: Concentrations of Sodium (Na, Zinc (Zn) and Manganese in Damaturu and Kukar Gadu Samples

From the analysis results of Zinc in the three (3) species, the range is between 9.750 - 21.740 mg/kg in stem, 1.42-10.83mg/kg in leaves and 13.94-45.14mg/kg in root while the root-bulb of *S. gesneriodes* has capacity between 14.91-32.16mg/kg. The levels of zinc concentration in all parts of the plants are within the optimum requirement of 25-100 ppm (Srivastava & Shyam, 2004).

The analysis results of manganese in the three (3) species revealed a range between 4.19-39.58 mg/kg in stem, 0.00-8.38 mg/kg in leaves and 9.09-77.30mg/kg in root. The root-bulb of *S. gesneriodes* had 11.58-89.106mg/kg of manganese. The levels of manganese concentration in all parts of the plants are also within the optimum requirement of 25-100 ppm (Srivastava & Shyam, 2004) and WHO limits of 500mg/kg

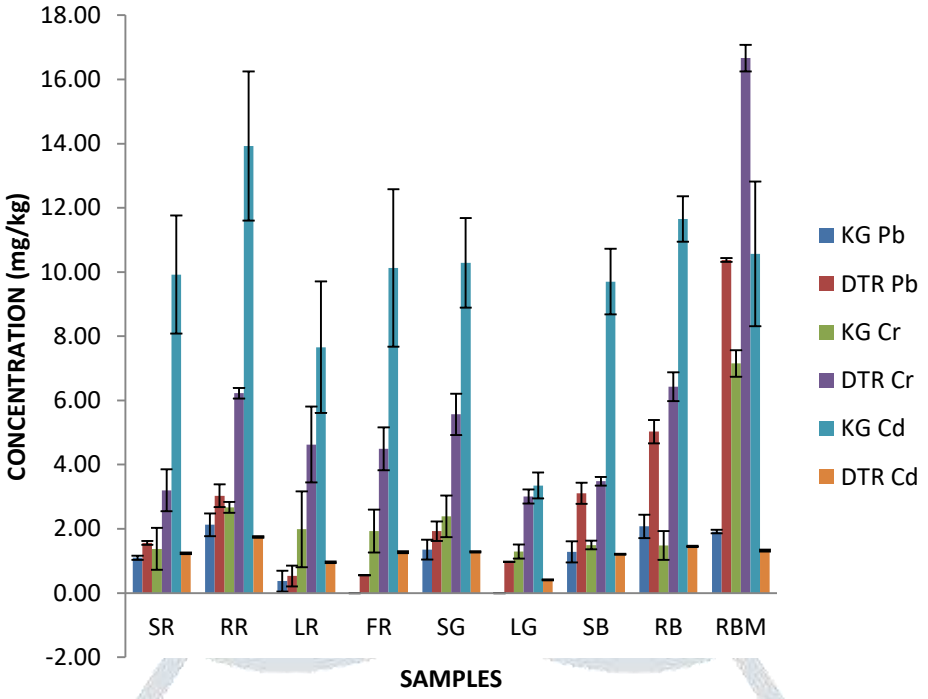

Figure 6: Concentrations of Lead (Pb), Chromium (Cr) and Cadmium (Cd) in Damaturu and Kukar Gadu Samples

The results of the research work indicated a significant amount of copper in all parts of the *Striga grasses*. The root-bulb of *S. gesnerioides* has the highest level of 41.879mg/kg, followed by its root with 17.983mg/kg. The concentration in stem ranged between 5.453-16.285mg/kg while the leaves had 3.46-5.984mg/kg. The concentration of copper in the different plant parts is higher that both WHO/FAO recommended level of 73.3mg/kg in plants (WHO/FAO, 2001).

From the experimental results obtained, lead concentration in samples ranges between 1.10-3.11mg/kg in stem, 2.08-5.03mg/kg in root and 0.37-0.98 in leaves. The root-bulb has 1.91-10.37mg/kg. The overall analysis shows that the levels of lead accumulation in all the different parts of the plants are above the set limit of 0.3mg/kg **(WHO/FAO 2001).**

The experimental results obtained shows the cadmium concentration in samples ranges between 1.21-9.92mg/kg in stem, 1.46-13.92mg/kg in root and 0.42-7.65 mg/kg in leaves. The root-bulb has 1.32-10.56mg/kg. The accumulation levels in all the different parts of the plants are above the set limit of 0.2mg/kg **(WHO/FAO 2001).**

CONCLUSION

The concentration of nitrogen analysis in the three (3) species revealed a range between 479.75- 826.91 mg/kg in stem, 145.60-532.09mg/kg in leaves and 701.33 – 859.06mg/kg in root. **Concentration of p**hosphorus **in the** three (3) species ranged between 18.83+ - 202.76 mg/kg in stem, 17.40-176mg/kg in leaves and 49.28 – 275.27mg/kg in root while the hostorium of *S. gesneriodes* has between 56.75-265.49mg/kg. Potassium concentrations in the three (3) species, the range is between 335.55+ to 1360.54 mg/kg in stem, 115.61-956.64mg/kg in leaves and 634 – 1245.18mg/kg in root while the hostorium of *S. gesneriodes* has capacity between 664.05-1689.66mg/kg.

The average concentrations of N, P and K in the roots of sample beans (host plant) are between 153.95 mg/kg, 200.01 mg/Kg and 104.07 mg/Kg respectively.

Zinc concentration in the three (3) species, the range is between 9.750 - 21.740 mg/kg in stem, 1.42-10.83mg/kg in leaves and 13.94-45.14mg/kg in root while the hostorium of *S. gesneriodes* has 14.91-32.16mg/kg. Manganese in the three (3) species revealed a range between 4.19-39.58 mg/kg in stem, 0.00-8.38 mg/kg in leaves and 9.09-77.30mg/kg in root. The root-bulb of *S. gesneriodes* had 11.58-89.106mg/kg of manganese. The levels of manganese concentration in all parts of the plants are also within the optimum requirement of 25-100 ppm (Srivastava & Shyam, 2004) and WHO limits of 500mg/kg

Lead concentration in samples ranges between 1.10-3.11mg/kg in stem, 2.08-5.03mg/kg in root and 0.37-0.98 in leaves. The hostorium has 1.91-10.37mg/kg. Cadmium concentration in samples ranges between 1.21-9.92mg/kg in stem, 1.46-13.92mg/kg in root and 0.42-7.65 mg/kg in leaves. The root-bulb has 1.32-10.56mg/kg.

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