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Studies on Heavy Metal Accumulation and Quality of Irish Potato (*Solanum Tuberosum*) Tubers Grown with Inorganic and Organic Fertilizers in Jos, Plateau State, Nigeria

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ABSTRACT: The aim of this work was to determine the nutritional quality and heavy metal concentration of irish potato tubers grown with inorganic and organic fertilizer. Forty five (45) tubers obtained from the National Root Crop Research Institute (NRCRI) Kuru were planted in a randomized complete block experimental design (RCBD). Three treatments were applied namely: inorganic fertilizer, poultry dung (positive control) and without treatment (negative control). Each treatment was replicated thrice in three different plots. At maturity, tubers were investigated for protein, lipid and calcium level while heavy metal contents were determined using the Atomic Absorption Spectrophotometer. Statistical analysis was carried out using ANOVA while mean separation was done using the LSD method at 95% confidence limit. Levels of three heavy metals (Cd, Zn and Co) in Irish potato tubers were higher than their respective permissible limits of 0.02, 1.3 and 0.06 in all samples. Fertilizer application (organic and inorganic) had no significant effect on the concentration of Pb, Cd, Cr, Zn, Co and Cu. Both organic and inorganic fertilizers had significant influence on Ni, As and Mn. Inorganic fertilizer significantly lowered the crude protein, lipid and calcium level in Irish potato tubers when compared with other treatments. This research has provided useful information to stakeholders in the Environmental and Health Science sectors to enlighten growers of Irish potato on the need to limit the use inorganic fertilizer and seek alternative yield enhancers that are effective and safer to the environment and human health.

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INTRODUCTION

Agriculture production contributes significantly to economic development in Nigeria. Among crops Irish potato (*Solanum tuberosum L.*) ranks fourth in the world in terms of economic importance (Harris *et al.,* 2017). Developing countries account for 25% of the world potato production. Potato is indigenous to South America and is believed to have been brought to England in 1586. It first become an important food crop in Ireland and was reintroduced into South America from that country, hence the name Irish Potato. It is now grown extensively throughout the world and is one of the important agricultural crops, world production reached a record of 320 million tonnes in 2007 and production in the developing countries has almost doubled since 1991, with a corresponding increase in consumption (Ugonna *et al.,* 2013; Hawkes, 2015 and FAO, 2008). Potato requires high altitude about 1000-1800 meters above sea level, and low temperature of 15°C or less. In Nigeria the crop is grown in Jos and Mambilla Plateau, with altitude of at least 1400 meters above sea level and a temperature about 10-20°C. Alabi *et al.,* (2013) reported that potato is produced in several northern states such as in Borno, Kaduna, Kano and Sokoto during the colds and dry periods.

Heavy metal contamination is one of the serious environmental problems limiting plant productivity and threatening human health. Inputs of heavy metals to agricultural soils can occur from a variety of sources. These include the application of biosolids, fertilisers, livestock manure, agrochemicals, and irrigation water and from atmospheric deposition (Timsina, 2018; Abdullahi *et al.,* 2019). Some of the concerns about accumulation of heavy metals in agricultural soils stem from their possible negative impacts on soil fertility and in some case their potential to accumulate in the human chain (Adediran. and Banjoko, 2017). Among the substances that contribute

to pollution of the biosphere, trace elements are the most toxic. Lead, Zinc and Cadmium are toxic metals of increasing environmental concern as they enter the food chain in significant amounts. Farm inputs like fertilizers are also used in the farming of Irish potatoes and all these might contain Cd, Zn and Pb metals, for Irish potato crops intake on the farms. There is therefore the need for studies to establish the level of these metals in the Irish potato crop. Farms heavy metal contamination is one of the serious environmental problems limiting plant productivity and threatening human health (Gall *et al.*, 2015). Low crop yield as a result of nutrient deficiency has made it mandatory for farmers in Jos South Local Government area to use organic/inorganic fertilizer in order to increase crop yield. Nevertheless organic/inorganic fertilizers are costly, inadequate and their continuous use may results to soil acidity and heavy metals in humans (Oguike and Mbagwu 2009).

Commercial phosphate fertilizers contain small amounts of heavy metal contaminants (Bationo and Mokwunye, 2013). Animal manure and sewage sledges are the main organic fertilizers and this may also contain heavy metals contaminants (Diacono and Montemurro, 2011; Timsina, 2018). These heavy metals may accumulate in soil, and consequently the tubers of Irish potatoes. Toxic heavy metals have no function in the body and can be highly toxic. Heavy metals are taken into the body via inhalation, ingestion, and skin absorption. If heavy metals enter and accumulate in body tissue faster than the body's detoxification pathways can dispose of them, a gradual build-up of these toxins will occur. High-concentration exposure is not necessary to produce a state of toxicity in the body tissues and, over time, can reach toxic concentration levels (Mohajer *et al.*, 2012). The aim of this work was to determine the nutritional quality and heavy metal concentration of irish potato tubers grown with inorganic and organic fertilizer.in Jos south L.G.A Plateau state, Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted in Jos south local government Area of Plateau state; it is one of the seventeen local government areas of the state. It has an area of about 400 square kilometer (km^2) and lies at an altitude of about 1300m. It is surrounded by high plains with elevation of between 600m and 900mm above sea level. The area shares boundry with Jos north local government by the north, Riyom LGA to the east and Barkinladi LGA to the west (Ifenkwe and Okonkwo, 2009)

Experimental Site

An experimental farm located at the Substation of the National Root Crop Research Institute (NRCRI) Potato Program Kuru in Jos-South area of Plateau state were serve as source of data for the study. The site lies on latitude $09^0$44 43'N and Longitude 08^0 47'E with an altitude of 400m above sea level.

Preliminary Investigation of Soil Heavy Metal Contents

Data was obtained on previous heavy metal report of the experimental site from the management of the National Root Crop Research Institute (NRCRI) Potato Program Kuru in Jos-South area of Plateau State.

Experimental Design

The experimental design used were randomized complete block design (RCBD) with three treatments and three replicates. A table of random numbers were employed in assigning treatments to each block. This (RCBD) is a two-way classification method comprising the block and treatments in columns and rows respectively.

The treatments used are as follows:

T0: Irish potato without organic or inorganic fertilizer (as control).

T1: Irish potato with organic fertilizer

T2: Irish potato with inorganic fertilizer

The three blocks tagged BI, BII and BIII and plot size was 3 m x 2 m (6 m^2) which will inform of flat bed.

Analysis of Nutritional Quality

Five tubers were randomly selected from each plot and chopped into small cubes (1-2cm pieces), and mixed thoroughly. Crude protein and lipids were determined by standard analytical method (AOAC, 1984). Wet ashing method of AOAC (2012) was used for the estimation of calcium level using Atomic Absorption Spectrophotometer (AAS) (PERKIN ELMER Analyst 200; Germany)

Heavy metal Analysis of Irish Potato Tubers

Sampling

A total of nine tubers of Irish potatoes (*Solanum tuberosum*) were picked from the experimental farm located at the Substation of the National Root Crop Research Institute (NRCRI) Potato Program Kuru were analysed for heavy metal content .Nine heavy

metals each were analysed in Irish potatoes samples. They were: Lead, Zinc, Cobalt, Copper, Cadmium, Chromium, Nickel, magnesium and Arsenic. Concentrations were obtained in mg/kg. A total of nine Irish potato samples were analysed for heavy metal contents.

Chemical Reagents, Sample Digestion and Analysis

All chemicals and reagents were of analytical grade and were obtained from BDH Chemicals Ltd, UK. Concentrated Aqua Regia (mixture of Conc. HNO_3) and Conc. HCL in the ratio 1:3) was used for digestion of the samples while corresponding metal salts (namely $CdCl_2.H_20$, $Pb(NO_3)_2$ and $NiCl_2.6H_20$) were used as standard. To obtain the heavy metals of interest acid digestion using 2.5ml of nitric acid (HNO_3) was added to each tissue and peel sample in a beaker and placed on electric hot plate and adjusted heating was done to prevent evaporation. The digestion was completed with a colourless solution obtained. Each solution was concentrated to about 2ml solution, cooled and made up to 10ml with demonized water and filtered using filter paper. The filtrates were made up to 100ml with distilled water and stored under room temperature. The Atomic Absorption Spectrophotometer (PERKIN ELMER A. Analyst 200; Germany) was used for heavy metal analysis**.** Prepared stock standard was used to generate standard calibration curves. The absorbance for each sample was compared with those of the corresponding standards. The atomized blank (ppm) standard was set to zero display and atomization of standard solutions carried out in order of increasing concentrations and the absorbance read off, with the sample solutions aspirated under the same conditions as the standard.

Statistical Analysis

The statistical models that were employed is the analysis of variance (ANOVA) The analysis of variance (ANOVA) technique were employed in analyzing the data collected in order to find out if there were significant differences among treatments and blocks with regard to the growth and yield parameters mentioned below.

RESULTS

Data on heavy metal analysis of soil samples obtained from previous records is presented in table 1 and appendix 1.Nickel, Cobalt, Cadmium, Vanadium, Chromium and Mercury were not detected (<0.001mg/kg). Magnesium had the highest concentration (4.075mg/kg) followed by Arsenic (3.655mg/kg), Iron (2.544mg/kg), Lead (1.851mg/kg) and Copper (1.267mg/kg). All heavy metals concentrations found below the recommended range of permissible limits for good soil.

Table 2 presents the concentrations of toxic heavy metals in potato tubers. The inorganic fertilizer sample had the lowest concentration of Pb (0.93ppm) while organic and control samples contained higher amount (1.44ppm) than inorganic samples. The application of inorganic fertilizers exhibited the highest amount of Cd (0.315ppm), followed by Irish potato treated without application of any fertilizer that had 0.276ppm and the least was revealed by Irish potato treated with the application of organic fertilizers that had 0.20ppm Cd. All Cd levels were higher than the permissible limit of 0.02.Irish potato treated with the application of organic and inorganic fertilizers showed higher amount of Cr (0.57ppm) than the control sample (0.284ppm). The application of inorganic fertilizer significantly influenced the amount of Ni in the potato tubers with the highest concentration of 0.66 ppm ($P<0.05$) while the organic treated and control samples had values of 0.61ppm and 0.26ppm respectively. Level of As was highest in tubers treated with inorganic fertilizers (1.89pmm) followed by organic and control samples with As values of 1.71ppm and 1.34ppm respectively with statistically significant differences (P,0.05).

Table 3 presents the concentrations of essential and less toxic heavy metals in potato tubers. Zinc level was higher in control samples (3.63 ppm) than those treated with inorganic (2.86ppm) and organic (2.41 ppm) fertilizers. All Zn levels were higher than permissible limits of 1.3 ppm. Organic treated samples had the highest amount of Cobalt (0.42 ppm) while the inorganic samples had the lowest (0.33 ppm). All samples had higher Co level than the permissible limit of 0.06 ppm. Copper was highest in control sample (0.80ppm)followed by inorganic treated tubers (0.70 ppm) while organic samples contained the least amount of Cu (0.63 ppm). Application of fertilizers (organic and inorgabic0 significantly lowered the Mn level ($P<0.05$) whereas it was higher in the control samples (1.17 ppm). In summary, Cd, Zn and Co levels were higher than their respective permissible limits of 0.02, 1.3 and 0.06 in all samples. Fertilizer application (organic and inorganic) had no significant effect on the concentration of Pb, Cd, Cr, Zn, Co and Cu. Both organic and inorganic fertilizers had significant influence on Ni, As and Mn

Table 4 gives the effects of fertilizer application on the nutritional quality of Irish potato tubers. Result showed significant differences among the treatment means ($P<0.05$) where tubers grown with inorganic fertilizer had the least mean crude protein (2.8g/100g) whereas the organic manure and control recorded significantly higher values of 3.46g/100g and 3.54g/100g respectively. Lipid composition was highest in tubers grown with inorganic fertilizer (0.96 g/100g) but lowest in organic manure (0.78 g/100g)

with significant differences (P<0.05). Calcium level was reduced with the application inorganic fertilizer to 0.17g/100g whereas tubers planted without any treatment had the highest calcium value (0.20 g/100g) although the observed differences are insignificant (P>0.05). Inorganic fertilizer significantly lowered the crude protein, lipid and calcium level in Irish potato tubers when compared with other treatments

Table 1: Preliminary Report on Heavy Metals Analysis of Soil Samples

Heavy metals	Mean Concentration of heavy metals
Nickel (Ni) (mg/kg)	<0.01
Iron (Fe)	2.544
Arsenic (As) (mg/kg)	3.655
Zinc (Zn) (mg/kg)	0.393
Cobalt (Co) (mg/kg)	<0.01
Lead (Pb) (mg/kg)	1.851
Cadmium (Cd) (mg/kg)	<0.001
Copper (Cu) (mg/kg)	1.267
Vanadium (Vd)	<0.001
Chromium (Cr) (mg/kg)	<0.01
Magnesium (Mg) (mg/kg)	4.075
Mercury (Hg)	<0.001

Table 2: Concentrations of Toxic Heavy Metals in Potato Tubers

	Pb (ppm)	Cd (ppm)	Cr (ppm)	Ni (ppm)	As (ppm)
T_0	1.437[a]	0.276[a]	0.281[a]	0.255[b]	1.342[b]
T_1	1.437[a]	0.197[a]	0.568[a]	0.612[a]	1.708[a]
T_2	0.934[a]	0.315[a]	0.568[a]	0.663[a]	1.890[a]
$LSD_{(0.05)}$	0.74	0.34	0.45	0.46	0.84
SE±	0.92	0.42	0.56	0.58	1.05
Permissible limit	2	0.02	6.0	10	30

Means in the same column with the same letters are not statistically significant at ($P \leq 0.05$) level of significant ``when compared with least significant difference (LSD)

T_0 = Irish Potato without Organic or Inorganic Fertilizer (as control)

T_1= Irish Potato with organic fertilizers

T_2 = Irish Potato with inorganic fertilizers

LSD = least significant difference (5%)

SE = Standard Error

Table 3: Concentrations of Essential Heavy Metals in Potato Tuber

	Zn (ppm)	Co (ppm)	Cu (ppm)	Mn (ppm)
T_0	3.630[a]	0.374[a]	0.799[a]	1.171[b]
T_1	2.413[a]	0.421[a]	0.625[a]	0.928[a]
T_2	2.855[a]	0.327[a]	0.695[a]	0.970[a]
$LSD_{(0.05)}$	1.13	0.40	0.55	0.66
SE±	1.41	1.65	0.69	0.83
Permissible limit	1.3	0.06	10	12.79

Means in the same column with the same letters are not statistically significant at ($P \leq 0.05$) level of significant when compared with least significant difference (LSD)

T_0 = Irish Potato without Organic or Inorganic Fertilizer (as control)

T_1= Irish Potato with organic fertilizers

T_2 = Irish Potato with inorganic fertilizers
LSD = least significant difference (5%)
SE = Standard Error

Table 4: Effects of Organic and Inorganic Fertilizers on Crude Protein, Lipids and Calcium on Irish Potato Tuber

Treatment(s)	Crude Protein	Lipids	Calcium
T_0	3.54^a	0.84^b	0.20^a
T_1	3.46^b	0.78^c	0.19^b
T_2	2.8^c	0.96^a	0.17^c
$LSD_{(0.05)}$	0.04	0.09	0.00
SE±	0.48	0.30	0.00

Means in the same column with the same letters are not statistically significant at ($P \leq 0.05$) level of significant when compared with least significant difference (LSD)

DISCUSSION

Preliminary investigation of soil samples showed the presence of Arsenic, Iron, Lead and Copper. This could be due to the nature of the soil parent rock material as these heavy metals are natural components of mineral matter such as tin ore that characterize the area. It might be responsible for the slight acidic nature of the soil, a property impacts on the cation exchange capacity of the soil as well as heavy metal uptake by the plant. This view was earlier supported by Abduljalal *et al.* (2010). Results showed that the concentrations of six heavy metals increased slightly in tubers under the influence of inorganic fertilizer. They include Pb, Zn, Cd, Ni, Cr and As. Similar report was given by some workers who found a slight increase in the level of heavy metals in soil and vegetable crops under the influence of synthetic fertilizers and pesticide applications (Abdullahi *et al.*, 2019). Although it has been reported that the availability of heavy metals usually increases as soil pH decreases, the effect of inorganic fertilizer was pronounced in escalating the heavy metal concentrations since results were compared with organic manure and samples that received no yield enhancer. Moreover, Cd, Ni, and Cr were not detected the preliminary soil analysis prior to the application of treatments, thus the observed level in the heavy metals could be solely attributed to fertilizer application.

Among the heavy metals found in tubers, only Zn is known to have positive role in plant system as a micro-nutrient that is required by plant in minute quantity. Others are toxic to plant even at little concentration. However, all values appeared below the permissible limits for food crop, and this makes the Irish potato tubers healthy for consumption. There is an exception to this because Cd was detected in tubers grown with inorganic fertilizer above 0.02mg/kg limit. The elevated level of Cd in the present work is disturbing because intake of vegetable and tuber crops is an important pathway of heavy metal toxicity to human beings (Lanre-Iyanda *et al.*, 2007). Other studies have shown that Cd is easily absorbed by roots and transported to the shoots where it is uniformly distributed in plants; and that it is not known to have any biochemical function to perform, and are toxic even at low concentrations (Sekara *et al.*, 2005; Mohajer *et al*., 2012).

Literature shows that there is a strong relationship between heavy metals in soil and food crops. In general, the bioavailability of heavy metals depends on the amount of exchangeable metals in soil (Verma and Dubey, 2003; Amir *et al.*, 2013. The bioavailability of heavy metals in potato plants varies for different plant organs, and the absorption and bioaccumulation rate is highest for roots as compared to other parts (Verma and Dubey, 2003). Similarly, solubility and soil- type also affect the metal uptake by plants. The mean heavy metal uptake by potato plants increases as the contents of these metals increase in the soil environment (Gall *et al.*, 2015). The outcome of the present work was partly similar to the findings of many workers. Kihampa *et al.* (2010) investigated heavy metal presence *Ipomea batata* grown along the slopes of a closed dump site in Tanzania where the concentration of Cadmium ($1.50mg/L^{-1}$) was detected above the permissible levels ($0.1mg/L^{-1}$ - $0.3mg/L^{-1}$) of heavy metals in food crop as recommended by the WHO. Adu *et al.* (2011) worked on heavy metals concentration in garden Lettuce (*Lactuca sativa* L.) and established that Cadmium and Lead were highest in the roots. Also, Okoronkwo *et al*. (2005) reported the accumulation of heavy metals such as Lead, Nickel, Chromium, Cadmium and Arsenic in the roots, stems and leaves of Cocoyam (*Colocesia esculentus*) and Cassava (*Manihot esculentus*) grown in polluted soil, an abandoned waste dump soil in Umuahia, Abia State Nigeria.

Apart from the negative impact of inorganic fertilizer on heavy metals, it had significant effect on the nutritional quality of the tubers produced by lowering the crude protein and calcium content. This result might be due to the effect of heavy metal on protein structures. The above findings was earlier reported by some workers that fertilizer application affected the taste of yam tubers as tubers cultivated with organic fertilizers had better taste though smaller yield than yam tubers cultivated with inorganic fertilizers

(Bationo and Mokwunye, 2013; Kulkarni *et al.*,2018). The lowering of calcium content in tubers cultivated with inorganic manure may have a negative effect on the overall physical integrity and strength of the potato tuber. This is because calcium is integral to cell walls and gives the cells particularly the skin strength (Decamp, 2021). A sufficient of calcium supply will help against physical damage which can occur during harvesting and handling. In the present work, since the organic manure also helped to achieve good yield while retaining the nutritional quality (protein, lipid and calcium) and food safety (lowered heavy metal concentration), it seems to be a better choice from the environment and safety point of view. This view is widely supported as the use inorganic fertilizer has been criticized for causing injury to the environment (Diacono and Montemurro, 2011; Kulkarni *et al.*, 2018).

CONCLUSION

In conclusion, the levels of three heavy metals (Cd, Zn and Co) in Irish potato tubers were higher than their respective permissible limits of 0.02, 1.3 and 0.06 in all samples. Fertilizer application (organic and inorganic) had no significant effect on the concentration of Pb, Cd, Cr, Zn, Co and Cu. Both organic and inorganic fertilizers had significant influence on Ni, As and Mn. Inorganic fertilizer significantly lowered the crude protein, lipid and calcium level in Irish potato tubers when compared with other treatments. This research has provided useful information to stakeholders in the Environmental and Health Science sectors to enlighten growers of Irish potato on the need to limit the use inorganic fertilizer and seek alternative yield enhancers that are effective and safer to the environment and human health

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