EFFECT OF AGRICULTURAL PRACTICES ON THE HEAVY METAL LEVELS IN CEREALS (MAIZE AND MILLET) GROWN WITHIN AYAMELU L.G.A. ANAMBRA STATE

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Abstract

Studies were carried out to determine the effect of agricultural practices on the heavy metal levels in cereals (maize and millet) grown in farms within Ayamelu L.G.A., Anambra State, using relevant analytical procedures and instrumentation. The mean levels of the physicochemical properties (pH, electrical conductivity, bulk density, organic carbon, moisture content, nitrogen content, pore space and organic matter) of the soil samples applied inorganic fertilizer, inorganic manure and the control were statistically significant ($p < 0.05$). The levels of the heavy metals (Pb, Zn, Cu, Cd, and Cr) were statistically significant in the maize and millet grains grown in the different soil applications. The cereals haboured the heavy metals in the following decreasing order: cereals grown in soil applied inorganic fertilizer > cereals grown in soil applied animal manure > cereals grown in control soil. The heavy metals were present in the cereals grown in the different soil samples at non-toxic levels.

Key words: Cereals, Heavy metals and Agricultural practices

Introduction

Cereals are grasses (members of the monocot family – *poaceae*), cultivated for their edible components or their fruit seeds [7]. Cereal crops are mostly grown in the temperate and tropical regions of the world and provide more energy worldwide than any other type of crop and are therefore called staple crops [16].

In their natural form (as in whole grain), cereals are a rich source of vitamins, minerals, carbohydrates, fats, oils and protein [25]. The principal cereal crops are; maize, rice, wheat, barley, oat, sorghum, millet and rye [24]. Cereals grains are the staple food of the people of the tropics providing them with about 75% of their caloric intake and 67% of their protein intake [7]. Hence, in most developing countries, grain in the form of rice, wheat, millet and maize constitutes a majority of daily sustenance. Food safety simply means the absence or presence of safe levels of contaminants, adulterants, naturally occurring toxins or any other substance that may make food injurious to health on acute or chronic basis. The increasing demand for food safety stimulated research regarding the risk associated with consumption of food stuffs contaminated by pesticides, heavy metals [27]. Soil serves many vital functions in our society, particularly for food production. Conventional open field farming has played a significant role in improving food and fiber productivity to meet human consumption demands, but has led to soil erosion, nutrient depletion and contamination [22]. According to research,application of livestock manure and inorganic fertilizers accounted for approximately 51 – 69% of the total heavy metal contents in cultivated soils [28].

Temporary changes in the physicochemical propensities and heavy metal levels of cultivated soils have been attributed to agricultural practices [18]. Research has shown that the sources of soil contamination with heavy metals include application of fertilizers, pesticides, animal manure, automobile exhaust, waste combustion, and irrigation water and effluent discharges [30].

The distribution of heavy metals in the soil and their availability to plants are regulated by several factors, including soil characteristics, plant species, fertilization and irrigation characteristics and the interrelationships between these factors [13].Metal distribution in plants depends on plant species, genetics, types of soils, soil conditions, weather, environment, stage of maturity and supply route to the market [15]. The contamination of vegetables and crops with heavy metals due to soil and atmospheric contamination poses a threat to its quality and safety.

Vegetables and crops cultivated in soils polluted with toxic and heavy metals take up such metals and accumulate them in their edible and non-edible parts in quantities high enough to cause chemical problems both to animals and human beings consuming these metal-rich plants as there is no good mechanism for their elimination from the body [4]. Toxic metals are mostly geochemically mobile where they are readily taken up by plant roots and translocated to aerial parts [20].

Soil pollution with heavy metals has become a critical environmental concern due to its potential adverse ecological effects. Environmental risks due to soil pollution is of particular importance for agricultural areas, as extensive agricultural practices for enhanced agricultural production have immensely resulted in the accumulation of various heavy metals in the soils leading to serious consequence [18].

Heavy metals are the most dangerous substances in the environment due to their high level of durability and toxicity to the biota [2]. Heavy metals are persistent and non-biodegradable, having long biological half-lives and they can be bioaccumulated through the food chains. The prolonged consumption of unsafe concentrations of heavy metals through food stuffs may lead to its chronic accumulation in the liver and kidney of humans, thereby causing disruption of numerous biochemical processes [19].

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Elements such as Cd, Cr, Pb and As are considered carcinogenic, while Fe, Cu, Pb, Ni and Mn are considered as essential metals, however if the concentration of the later elements are higher than their permissible limits, they may create toxic effects in humans [12].

Since application of inorganic fertilizers and animal manure (poultry droppings) are common agricultural practices commonly adopted by farmers especially in developing countries like Nigeria, studies were carried out to assess its effects on the heavy metals levels in cereals (maize and millet) grown in Ayamelu Local Government Area of Anambra State, Nigeria.

Materials and Method

Sample Collection

The soil samples were collected after the cereals were harvested in selected farms in Ayamelu Local Government Area of Anambra State. A total of 30 soil samples comprising of 10 samples of soil control, soil applied animal dung (chicken droppings) and soil applied inorganic fertilizer were respectively used for the study. A total of 60 cereal samples comprising of 30 maize grain samples and 30 millet grain samples were respectively used for the study. The grains were harvested at maturity and used for the study. Both the soil and cereal (maize and millet) samples were collected in clean polyethene bags and taken to the laboratory for analysis.

Sample preparation

The cereal samples were placed in clean acid-washed porcelain crucible and oven dried at 105^oC for 24hrs. The dried samples were then ground into fine powder form using acid-washed mortar and pestle and passed through a 2.00mm sieve. The soil samples were equally air dried at room temperature in a well-ventilated environment until constant weight were obtained. They were ground separately using an acid pre washed porcelain mortar and pestle and then passed through a 2.00mm plastic sieve. The powdered samples (soil and cereals) were kept in polyethene bags for further analysis.

Sample analysis

Analysis of the physicochemical properties of the soil samples were determined using the approved specific standard methods for each of them [97], [10].

Cereal sample analysis

2.0g of ground powder samples were weighted and transferred into a clean crucible which was labelled according to the sample number and dry-ashing process carried out in a muffle – furnace by step wise increase in temperature up to 550^oC and then left to ash at this temperature for 6hrs. The samples were removed from the furnace and allowed to cold. The ashes were wetted with de-ionized water and 5ml of 65% HNO_3 and 70% $HClO_4$ were added in the ratio of 2:3. The crucible was covered with watch glass and placed in hot plate. The digestion was performed at a temperature of 90 – 95^oC for 1hr until a transparent solution was obtained.

After cooling, 20ml of distilled water was added and filtered using whatmann filter paper no. 42. The filtered sample was then diluted with de-ionized water up to the mark of 50ml of standard volumetric flask and stored in polyethylene container until analysis. All samples were prepared identically in triplicates [5].

Blanks were prepared to check for background contamination by the reagents used. Working standard solutions of copper (Cu), zinc (Zn), lead (Pb), chromium (Cr) and cadmium (Cd) were prepared from the standard solution containing 1000ppm of each element in 2M HNO_3. The metals (Zn, Cu, Cr, Pb and Cd) were determined in the cereal samples digests using atomic absorption spectrometer (AAS) (model: ElicoSl – 194).

Statistical analysis: All the samples analysis in this study was carried out in triplicate and the results reported in mean and standard deviation. Statistical analysis of the data was carried out using SPSS software version 18.0. The data on the physicochemical properties of the soil samples and the metallic contents of the cereal samples were subjected to one way analysis of variance (ANOVA) at 95% level of confidence.

Results and Discussion

Table 1: Mean values of the physicochemical properties of the cultivated soil samples.

Parameter	Soil cultivated with inorganic fertilizer	Soil with animal dung (chicken droppings)	Control soil	T – Test P – value
pH	5.84 ± 0.28	6.12 ± 0.09	6.43 ± 0.112	0.03
Electrical conductivity (µS/cm)	0.97 ± 0.31	0.84 ± 0.20	0.55 ± 0.009	0.02
Bulk density (%)	1.436 ± 0.32	1.207 ± 0.44	0.82 ± 0.210	0.02
Organic Carbon (%)	1.206 ± 0.270	1.04 ± 0.152	0.766 ± 0.213	0.03
Moisture content (%)	2.170 ± 0.42	1.88 ± 0.304	1.563 ± 0.106	0.02
Nitrogen content (%)	0.264 ± 0.08	0.177 ± 0.05	0.115 ± 0.04	0.01
Pore space (cm)	0.114 ± 0.03	0.08 ± 0.02	0.04 ± 0.02	0.02
Organic matter (%)	2.781 ± 0.226	2.265 ± 0.183	1.842 ± 0.174	0.02

pH:

Table 1 shows that the mean pH values of the soil samples cultivated with inorganic fertilizer, soil samples cultivated with animal manure (chicken droppings) and control soil were 5.84, 6.12 and 6.43 respectively. The order of the increase of the mean pH values of the samples were: soil cultivated with inorganic fertilizer < soil cultivated with animal manure < control soil. The mean pH values of the soil samples were statistically significant at $p < 0.05$.

According to [19], soil pH and other soil properties are especially important in soil processes responsible for solubility of heavy metals in soil and their transportation. At high pH, metals tend to form metal mineral phosphates and carbonates which are insoluble while at low pH, they tend to be found as free ionic species or as soluble organo metals and are more bioavailable. The results shows that the pH values in the soil cultivated with inorganic fertilizers will favour more plant uptake of heavy metals than other soil samples. The results of this study was slightly higher than 4.7 – 5.7 obtained by [23], in soil in major high ways in Delta State, Nigeria.

Electrical conductivity:

Table 1 shows that the mean values of the electrical conductivity of the soil samples applied with inorganic fertilizer, soil samples with animal manure and control soil samples were 0.97, 0.84 and 0.55µS/cm respectively. The values of electrical conductivity in the soil samples were statistically significant at $p < 0.05$. Research has shown that higher values of electrical conductivity in a soil indicate significance presence of trace metal ions or consumables materials in the soil [13]. The order of decrease in the mean values of electrical conductivity in the soil samples were: soil cultivated with inorganic fertilizer > soil cultivated with animal manure > soil control. The values obtained in the soil samples cultivated with inorganic fertilizer in this study compared very well with 0.91μS/cm reported by [21] in dumpsites along Enugu – Port Harcourt expressways – South East, Nigeria.

Bulk density:

The mean values of the bulk density of soil samples cultivated with inorganic fertilizer (1.436%) were significantly higher than soil samples cultivated with animal manure (1.207%) and control soil samples (0.82%) as shown in Table 1.

Organic carbon:

Table 1 shows that the mean values of the organic carbon contents of the soil samples decreased in the following order: soil cultivated with inorganic fertilizer > soil sample cultivated with animal manure > control soil, with values of 1.206, 1.04 and 0.766% respectively. The values of the organic carbon contents in the soil samples were found to have significant difference at $p < 0.05$.

According to [28], total organic carbon is a measure of organic content in soil and contributes significantly to the acidity of soil through organic acid and biological activities through complexion of metals. [20], observed that high total organic carbon content entails larger adsorption surfaces and more metals are absorbed to the organic material.The results of this study was lower than 2.08% reported by Osakwe and Okolie, (2018) in soils in farmlands along major highway in Delta State, Nigeria.

Moisture content:

The mean values of the moisture content of the soil samples were 2.170% for soil applied with inorganic fertilizer, 1.88% for soil applied animal manure and 1.563% for control soil sample. The levels of the moisture content in the soil samples showed significant difference at $p < 0.05$. [6] reported that increase in moisture contents in the soil increases the bioavailability of metals for plant uptake in that soil. The order of decrease in the levels of moisture content in the soil samples were; soil applied inorganic fertilizer > soil applied animal manure > control soil.

Nitrogen content:

The nitrogen content of the soil applied inorganic fertilizer (0.26%) was significantly higher than 0.177% obtained for soil samples applied animal manure and 0.115% for control soil samples. The results of the study was lower than 1.23% reported by [22] in urban garden soils in a tropical metropolitan area (Libreville), Gabon.

Pore space:

Table 1 shows that the mean levels of pore spaces of the soil samples were 0.114cm for soil applied inorganic fertilizer, 0.08cm for soil applied animal manure and 0.04cm for control soil. The mean levels of the pore spaces of the soil samples were statistically significant at $p < 0.05$.

Organic matter:

According to [23], the organic content is the most important factor after pH, that influences the bioavailability of metals and their uptake by plants.Higher value of organic matter contents in the soil has been shown to indicate equally higher bioavailability and solubility of metals for plants uptake [22].

The results of this study shows that the mean values of the organic matter content of the soil applied inorganic fertilizer (2.781%) were significantly higher than 2.265% for soil applied animal manure and 1.842% for control soil.

Table 2: Mean concentration of heavy metals in the millet grains grown in the different soil applications(ppm).

Metal	Millet grains grown in soil applied animal dung	Millet grains grown in soil applied inorganic fertilizer	Millet grains grown in control soil	T – Test p – value	WHO STD
Pb	0.304± 0.041	0.376± 0.066	0.158± 0.051	0.02	0.5
Zn	3.251± 0.32	4.012± 0.592	2.682± 0.413	0.03	100
Cu	2.440± 0.165	2.905± 0.362	1.737± 0.204	0.02	100
Cd	0.120± 0.07	0.174 ± 0.033	0.087± 0.033	0.04	0.5
Cr	0.163± 0.04	0.285± 0.07	0.092± 0.03	0.02	5

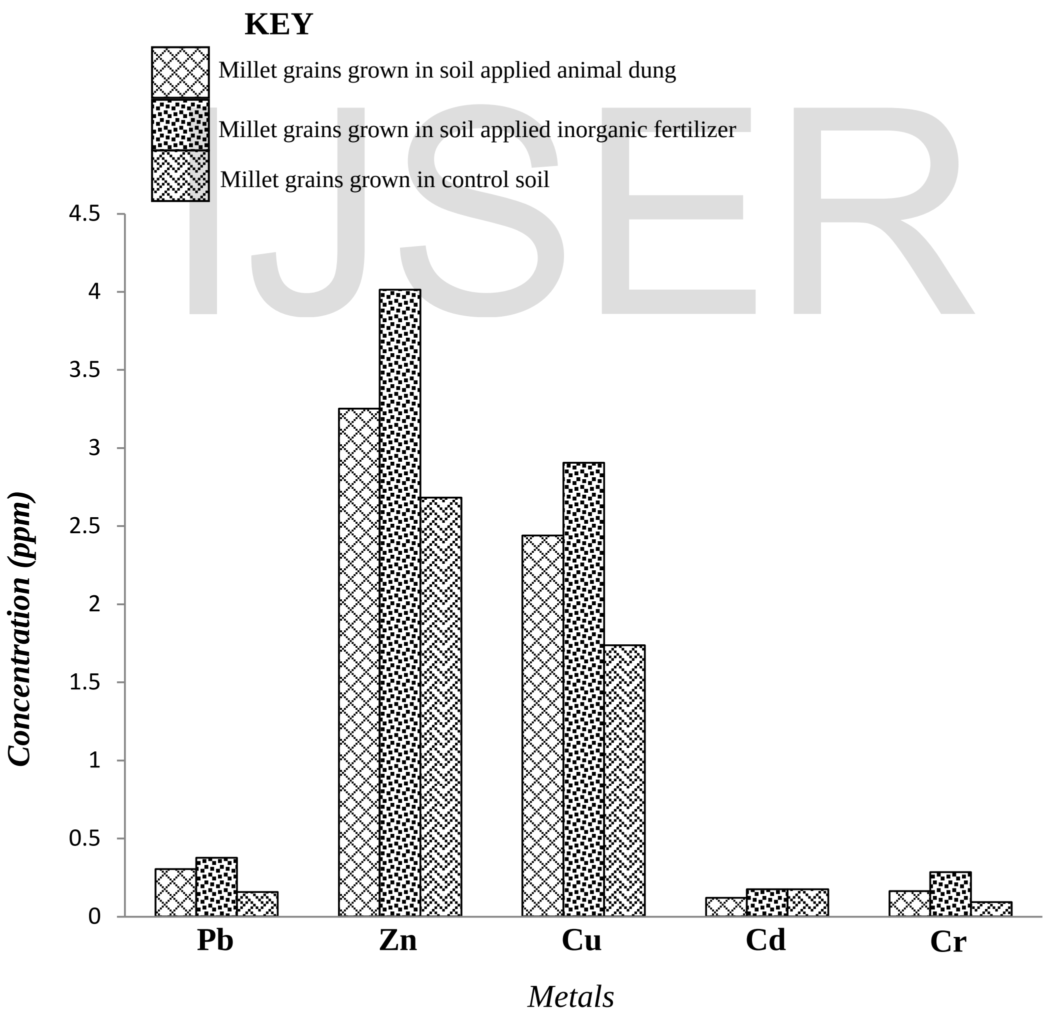

Fig 1: Bar chart representation of mean concentration of the heavy metals in the millet grains grown in the different soil applications.

Table 3: Mean concentration of heavy metals in the maize grains grown in the different soil applications(ppm).

Metal	Millet grains grown in soil applied animal dung	Millet grains grown in soil applied inorganic fertilizer	Millet grains grown in control soil	T – Test p – value	WHO STD
Pb	0.183± 0.06	0.263± 0.09	0.102± 0.04	0.03	0.5
Zn	2.072± 0.245	2.550± 0.134	1.270± 0.107	0.02	100
Cu	1.263± 0.171	1.847± 0.313	1.751± 0.082	0.02	100
Cd	0.081± 0.02	0.105± 0.06	0.04 ± 0.02	0.01	0.5
Cr	0.276± 0.05	0.489± 0.034	0.125± 0.04	0.02	5

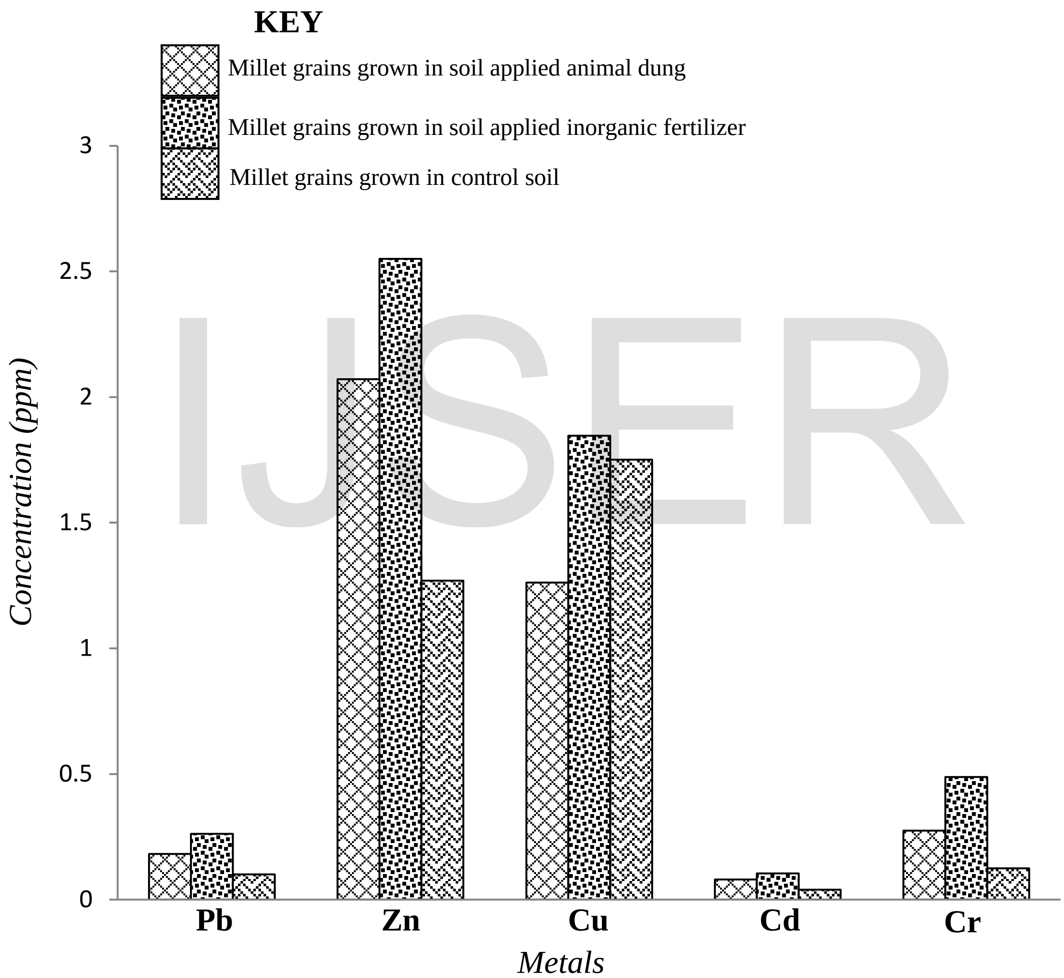

Fig 2: Bar chart representation of mean concentration of the heavy metals in the maize grains grown in the different soil applications.

Lead:

Table 2 shows that the mean values of lead in the millet grains grown in the different soil applications decreased in the following order; millet grains grown in soil applied fertilizer > millet grains grown in soil applied animal manure > millet grains grown in control soil, with values of 0.376, 0.304 and 0.158ppm respectively.

The mean values of lead in the maize grains grown in the different soil applications were; 0.183ppm for maize grown in soil applied animal dung, 0.263ppm for maize grainsgrown in soil applied inorganic fertilizer and 0.102ppm for maize grainsgrown in control soil. The order of decreased of the metal in the samples were maize grains grown in soil applied inorganic fertilizer > maize grains grown in soil applied animal manure > maize grains grown in control soil as shown in Table 3, Fig 2.

The concentrations of lead in the maize and millet grains grown in the different soil applications were statistically significant at $p < 0.05$. The concentrations of lead in maize and millet grains were within the WHO recommended permissible limits [29]. So the levels of lead obtained in this study do not present a potential health hazard to consumers. Lead toxicity is known to cause musculoskeletal, renal, ocular, neurological, immunological, reproductive and developmental effects [3]. The result of this study compared very well with 0.156mg/kg reported by [7] in millets grains sold in markets in Kaduna, North West Nigeria.

Zinc:

One of the most important metals for normal growth and development in human beings is zinc. Its deficiency may be due to inadequate dietary intake, impaired absorption, excessive excretion or inherited defects in zinc metabolism [11].

Table 2 shows that mean values of Zinc in millet grown grains soil applied fertilizer (4.012ppm) were significantly higher than millet grains grown in soil applied annual manure (3.251ppm) and millet grains grown in control soil (2.782ppm). Fig 1 shows that the order of decrease of the metal in the samples were millet grains grown in soil applied inorganic fertilizer > millet grains grown in soil applied animal manure > millet grains grown in soil control. Table 3 shows that the mean concentrations of zinc were 2.072, 2.550 and 1.220ppm for maize grains grown in soil applied animal manure, maize grains in the soil applied inorganic fertilizer and maize grains in the control soil respectively. The decrease of the metal in the maize grains grown in the different soil applications followed the same trend as millet grains in Table 2.

The levels of the metal in the millet and maize grains grown in the different soil applications were statistically significant ($p < 0.05$) and within WHO recommended permissible limits for the metal. The results of this study was higher than 0.66mg/kg reported by [27] in maize grains collected from local markets of Ambo city, Ethiopia.

Copper:

Copper is an essential micronutrient which functions as a biocatalyst, required for body pigmentation in addition to iron, maintain a healthy central nervous system, prevents anemia and inter-related with the function of zinc and iron in the body [17].

However, most plants contain copper in amount considered inadequate for normal growth which is usually augmented through inorganic or organic fertilizers [14]. The mean concentrations of copper as shown in Table 2 were, 2.440, 2.905 and 1,735ppm for millet grains grown in soil applied animal maize, millet grains grown in soil applied fertilizer and millet grains grown in control soil respectively. Fig 1 shows that the metal decreased as follows; millet grains grown in soil applied fertilizer > millet grains grown in soil applied animal manure > millet grains grown in control soil.

Table 3 shows that the mean concentrations of copper were 1.263, 1.847 and 0.751ppm for maize grains grown in soil applied animal manure, maize grains grown in soil applied inorganic fertilizer and maize grains grown in control soil respectively. The concentrations of the metal in the millet and maize grain grown in the different soil applications were found to have significant difference ($p < 0.05$) and within the permissible limits set for the metal. The results obtained for copper in the cereals grains grown in the different soil applications (animal dung and inorganic fertilizer) was in agreement with 1.72mg/kg reported by [27], for wheat grains sold in local markets of Ambo city, Ethiopia.

Cadmium:

Table 2 shows that the mean concentration of cadmium were; 0.120, 0.174 and 0.087ppm for millets grains grown in soil applied animal manure, millets grains grown in soil applied inorganic fertilizer and millet grains grown in control soil respectively. Millet grains grown in soil applied inorganic fertilizer gave the highest value for the metal while the least was millet grains grown in soil control. The mean concentrations of cadmium as shown in Table 3, fig 2 decreased in the following order; maize grains grown in soil applied inorganic fertilizer > maize grains grown in soil applied animal manure > maize grains grown in soil control with values of 0.105, 0.081 and 0.04ppm respectively. The mean concentrations of cadmium in the millet and maize grains grown in the respective soil applications were statistically significant ($p < 0.05$) and within the WHO recommended permissible limits. The results of this study indicates that the cadmium levels in the maize and millet grains were at non-toxic levels. Cadmium is a highly toxic, non-essential heavy metal and does not play any role in the biological process in living organisms. Thus, even at low concentrations, cadmium could be harmful to living organisms [3].

The concentrations of cadmium reported in this study were in agreement with 0.115mg/kg reported by [7] for sorghum and maize grains sold in markets in Kaduna, North West, Nigeria.

Chromium:

Chromium is an essential element required for sugar and fat metabolism [17]. Table 2 shows that the mean concentrations of chromium were significantly higher in millet grains grown in soil applied inorganic fertilizer (0.285ppm) than millet grains grown in soil applied animal manure (0.163ppm) and millet grains grown in control soil (0.092ppm). 0.403, 0.276 and 0.125ppm were respectively the mean levels of chromium in maize grains grown in soil applied inorganic fertilizer, maize grains grown in soil applied animal manure and maize grains grown in control soil. The concentrations of the metal in the millet and maize grains grown in the respective soil applications were statistically significant ($p < 0.05$) and equally within the WHO recommended permissible limits set for the metal in edible solid foods. The results of this study compared favourably with 0.43 and 0.29mg/kg obtained by [27] in wheat and barley respectively, sold in local markets of Ambo city, Ethiopia.

Conclusion

The study shows that agricultural practices like applications of animal manure and inorganic fertilizer has a significant influence on the levels of the physicochemical properties of the soil and equally on the heavy metal levels of crops grown in such soil. The concentrations of the heavy metals analyzed in the maize and millet grains grown in the different soil applications were all statistically significant ($p < 0.05$) and within the WHO recommended permissible limits set for each of the metals in edible solid foods. This results of the study shows that the heavy metals in the cereals grown in the respective soil samples were at non-toxic levels and therefore could not pose any health risk to potential consumers.

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