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PHYSICAL AND CHEMICAL PROPERTIES OF SOIL INFLUENCED BY *PARAQUAT* HERBICIDE APPLICATION IN GWAGWALADA AREA COUNCIL, ABUJA, NIGERIA

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ABSTRACT
The study was conducted with the purpose of determining the effects of herbicide (*paraquat*) on some important physico-chemical properties of soils of University of Abuja Teaching and Research Farmland. A portion of land in the school farm was mapped out for this experiment. Samples of soil from the land were collected for analysis in which the physico-chemical properties of soil were determined. Thereafter, the field was laid out using RCBD (Randomized Complete Block Design) which had four treatments with three replicates. The four (4) treatments used were 0ml/L which involves no *paraquat* application and called the control. The second treatment was 5ml/L which involved the use of 5ml/L of *paraquat.* The third treatment was 15ml/L, in which 15ml/L of *paraquat* was applied. The fourth treatment used was 30ml/L, which involved the application of 30ml/L of *paraquat*. From the result of the soil analysis, the soil's textural class was sandy loam. The soil was acidic with a pH of 5.2 and has an average electrical conductivity of 0.060mg/kg. Its content of organic matter, organic carbon and total nitrogen was 0.87 mg/kg, 1.08mg/kg and 0.175mg/kg respectively. Cation Exchange Capacity of the soil was low with the value 8.60cmol/kg and Effective Cation Exchange Capacity of 8.12cmol/kg. The soil was high in micro-nutrients (iron-Fe, manganese-Mn, zinc-Zn and copper-Cu). The result of the experiment showed that *paraquat* does not have negative effect on the properties of the soil and therefore is reliable for use within this ecological zone.

Keywords: Application, Herbicide, *Paraquat*, Physico-chemical Properties, Soil, Treatment.

INTRODUCTION
In recent times, there has been an arising need for the increase and improvement of Agricultural production due to the fast growth or increase in the population overtime by the use of herbicides to control weeds. Weeds reduce crop yield and quality, interfere with cultivation and harvest operation and seem to be the most economically important of all pests with respect to sales of pesticides world-wide source (Agyakwa and Akobundu, 1987).

Herbicides, commonly known as weed killers, are pesticides used to kill unwanted plants. Herbicides have been in use since the late 1940's. Herbicides can be classified in multi-various ways, such as by chemical structure, method of use, mode of action etc.

Prior to the widespread use of chemical herbicides, cultural controls, such as altering soil pH, salinity, or fertility levels were used to control weeds and mechanical control (including tillage) was also (and still is) used to control weeds. Herbicides use is not limited to crop production alone, its use in animal production include antibiotics administered either by injection *or* combined with feed; to control infectious diseases and parasites that often arise when animals are raised under extremely crowded conditions. The rapid development of modern herbicides, experienced over the last 50 years, was stimulated by the need for increasing food production during World War II *(*George and David, 2004*).*

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Paraquat is used as a quaternary ammonium herbicide, one of the most widely used herbicides in the world (Hood, 1965). As pure salt *paraquat* is a white, crystalline powder which is odourless and hygroscopic. Commonly, *paraquat* is formulated as a dichloride salt which is stable to acid and heat, but can be hydrolyzed by alkaline solutions. *Paraquat* dichloride reacts with strong oxidizers, is light-sensitive and decomposes at high temperatures to form poisonous vapours. *Paraquat* was first manufactured and sold by ICI in early 1962, and is today among the most commonly used herbicides and its use was approved by European Union in 2004. *Paraquat* is a total contact herbicide used to control broad-leaved and grassy weeds. It should be sprayed when the weeds are young and less than 30 cm high. It kills all green tissues, but does not harm the mature bark. *Paraquat* is used for plantation crops (banana. cocoa-palm, oil-palm, rubber, etc.) and for citrus fruits, apples, plums, vines and tea. On certain crops (potato, pineapple, sugar-cane, sunflower), it is used as a desiccant; it is also used as a cotton defoliant. It is applied around the trees in orchards and between the rows of crops. Uncropped land on industrial sites, railways, roadsides, etc., can be cleared of weeds by applying *paraquat* at higher concentrations (Yaohua *et al.* (2019).

It is a non-selective herbicide used for no-till burn down and in aerial destruction of marijuana and cocoa plantings. It is more acutely toxic to people than any other herbicide in widespread commercial use (Maryke *et al.,* 2018). The key characteristics that distinguish the non-selective contact herbicide *paraquat* from other active ingredients used in plant protection products are:

i. It is non-selective, which means it kills a wide range of annual grasses and broad-leaved weeds and the tops of established perennial weeds.
ii. It is very fast-acting.
iii. It is rain-fast within minutes of application.
iv. It becomes biologically inactive upon contact with soil.

Paraquat's distinctive behaviour in soil means that farmers around the world confidently use it to protect their crops. *Paraquat* provides fast broad-spectrum weed control only through foliar contact action. There is no crop damage via the roots or any effect on seed germination (Summers, 1980). Soil fauna and microorganisms are not affected and there is no leaching or run-off from the degrading *paraquat* residues reaching the soil. Two inter-linked processes are fundamental to the overall fate of *paraquat* in soil: how it binds (adsorbs) to soil and how it degrades in soil.

The objective of the study was to determine the various effects of herbicide (*paraquat*) on the soil physico-chemical properties.

MATERIALS AND METHODS

The Study Area

The Farm of Faculty of Agriculture, University of Abuja. The landscape of the farm was relatively undulating with short slope length. The gradient of the slope was between 10-20% and the slope was oriented towards the South, North, South-east and North-east. These slopes terminate in a deep drainage channel which flows seasonally. The drainage channel cuts across the farmland dividing it into Northern and Southern parts. The Northern part of the farm has a gentle slope while the Southern part of the farmland has a steep slope.

Farming is the most dominant human activity carried out in this area. Food crops grown in this area by farmers are; yam, maize, groundnut, sorghum, cowpea, garden egg and okra. The farmers in this area practice mixed cropping and crop rotation system of farming.

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The climate of Abuja falls within the sub-humid climate in the Northern Guinea Savannah, ecological zone of West African. The area is characterized by two distinct seasons which are the wet and dry season. The dry season is experienced around November to April and it's often warm, ushering in the wet season, also known as the rainy season, which is experienced from April to October (Alhassan, 2001). The mean annual rainfall is 1100mm – 1600mm with its peak mostly around August and September. The temperature by day ranges between 28 to 38 ^{o}C in the rainy season and can even go as high as 40 ^{o}C. The relative humidity of this area rises rapidly during the wet season and also falls sharply with the end of the rains.

Human activity figures are based on the 2006 census which says that the population of Abuja is about 776,298 people with a density of 1,088s per km. The predominant primary occupation of the indigenous habitat which is the Gbagyi people, Bassa people and Gaide people is Agricultural trade and local craft especially the production of earthen pots (clay pots), charcoal is also produced by the people.

The geology of the University of Abuja and its environs predominantly consists of granitic basement complex. The basement complex rocks are subdivided into the magnetite-gneiss complex; the older meta-sediments, the younger meta-sediments, the older granite and the younger granite alkaline ring complexes and volcanic rocks. The magnetite-gneiss is the commonest rock type in the Nigerian basement. It is made up of two main types of gneiss; the biotite gneiss and the banded gneiss which is widespread. The biotite gneiss is normally fine grained with strong foliation caused by the parallel arrangement of alternating dark and light minerals (Nwaka, 1997).

Field Work (Reconnaissance Survey)

A reconnaissance survey was carried out on study area, after which a site was selected for seedbeds. An experiment plot of about 4m by 7m was marked out and laid in Randomized Complete Block Design (RCBD).

Preparation of seedbeds

In the study area, 12 seedbeds measuring 4m by 7m were prepared in the selected plot which was marked out for the experiment.

Sampling Process

There were four (4) beds in three replicates and soil sampling was carried out using a soil auger to collect soil randomly at a depth of 0cm – 30cm. After which samples collected were mixed and air dried. The samples collected from the study area were carefully labelled. Samples were air dried at room temperature. The air dried samples were put in a mortar and using a pistle, the samples were crushed into finer particles and sieved with a 2.00mm sieve, repacked and sent to the laboratory for analysis.

Experimental Plot

The experimental plot was designed using Randomized Complete Block Design (RCBD). A design of four treatments having three replicates.

TRT 1 = 0ml/L (Control)
TRT 2 = 5ml/L (Low)
TRT 3 = 15ml/L (Medium)
TRT 4 = 30ml/L (High)

Laboratory Analytical Techniques

Particle size Analysis

The particle size distribution of the soil (percentage of sand, silt and clay fractions in the soil) was determined, in which the method used for the analysis was Bouyoucos (1962) hydrometer method. Using distilled water and neutral sodium hexametaphosphate (calgon), 50g of air-dried sieved soil was weighed after which calgon was added as a dispersant and stirred for 15 minutes. The stirred suspension was then transferred into a 1000ml cylinder half filled with distilled water.

The first hydrometer and temperature readings were taken within the first 1 minute. The second readings were taken two (2) hours later. The recorded results were calculated to give the percentage of sand, silt and clay. The USDA soil textural triangle was used to determine the textural class of the analysed soil.

Determination of Soil pH

Soil pH determination was carried out using distilled water and $CaCl_2$. Using distilled water, a 1:5 suspension was shaken for 30 minutes and then measured with a pH electrode. Using the $CaCl_2$, a 1:2.5 suspension of soil and 0.01M $CaCl_2$ was stirred vigorously and then left to stand overnight before the measurement with a pH electrode.

Determination of Micronutrients

Micronutrients (manganese Mn, iron Fe, copper Cu and Zinc Zn) were determined by calometric method using Concentrated HCl (0.1N. HCl) and read using Atomic Absorptive Spectrophotometer (AAS).

Determination of other Properties

Organic carbon was determined by Walkey and Black wet oxidation method. Effective Cation Exchange Capacity (ECEC) was determined by using the values obtained for exchangeable bases from the soil analysis to calculate for the ECEC.

RESULTS AND DISCUSSION

Physico-chemical Properties of Soil of the Experimental Site

The data of the physical and chemical properties of the soil of the experimental site is presented in Table 1. The results of the soil texture (particle size analysis) as indicated in the Table 1 shows that, the soil belongs to the textural class of sandy loam. It is mainly dominated by sand having a percentage of 70%, while silt and clay had a percentage of 18% and 12%, respectively. This result is similar to that of Sylvia (2013) and Nusa (2011) who studied the same soil. The soil's water holding capacity was low and nutrients were easily leached from the soil (Hodnett and Tomasella, 2002).

Table 1: Physical Properties

Physical properties	Value %
Sand	70
Silt	18
Clay	12
Textural class	Sandy loam

Soil pH

The soil of the **experimental site** as presented in Table 2 was strongly acidic with a pH of 5.2. Soils tend to become acidic as a result of rain water leaching away basic ions (calcium, magnesium, potassium and sodium); carbon dioxide from decomposition of organic matter and root respiration dissolving in soil water to form a weak organic acid; formation of strong organic and inorganic acids, such as nitric and sulphuric acid, from decaying organic matter and oxidation of ammonium and sulphur fertilizers (Donald, 2014).

Electrical Conductivity (EC)

The electrical conductivity of the soil of the study area ranges from 0.05- 0.08dS/m with an average of 0.06dS/m (Table 2). The electrical conductivity of a soil is the measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electrical current through it (Wiatrak *et al*., 2009).

Organic Matter

The organic matter content of the soil ranges (Table 2) from moderate to high (1.1-2.28g/kg), with an average of 1.87g/kg in the study area. The high level of organic matter contained in the soil of the study area is attributed to the accumulation of residues and leaching of nutrients from the higher slopes down to the lower slope (Sanni, 2012).

Table 2: Chemical Properties

Chemical Properties	Value
pH (H_2O)	5.20
pH ($CaCl_2$)	5.00
EC (dS/m)	0.06
OC (g/kg)	1.08
OM (g/kg)	1.87
TN (%)	0.18
AP (mg/kg)	13.13
Ca (cmol/kg)	4.50
Mg (cmol/kg)	0.72
K (cmol/kg)	0.27
Na (cmol/kg)	0.18
H + Al (cmol/kg)	0.80
CEC (cmol/kg)	8.60
ECEC (cmol/kg)	8.12
TEB (cmol/kg)	7.32
ESP (%)	2.13
PBS (%)	85.12
Zn (mg/kg)	3.16
Mn (mg/kg)	109.54
Cu (mg/kg)	1.57
Fe (mg/kg)	46.80

Organic Carbon

The amount of organic carbon contained in the soil of the study area ranges from moderate to high with a value of 1.08g/kg (Table 2). It is the main source of energy for microorganisms (Edward *et al*., 1999).

Total Nitrogen, Available Phosphorus and Potassium

The content of total nitrogen (TN), phosphorus (P) and potassium (K) in the soil of the study area as gotten from the result of the soil analysis were 0.18%, 13.13mg/kg and 0.27cmol/kg, respectively.

Cation Exchange Capacity (CEC) of the soil was low with the value 8.60cmol/kg and with a low Effective Cation Exchange Capacity of 8.12cmol/kg. The main ions associated with CEC are calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}) (Rayment and Higgingson, 1992).

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The Exchangeable Sodium Percentage of the soil of the study area was 2.13%. The amount of zinc (Zn) in the soil of the study area was 3.16mg/kg. Zinc in minute quantity is essential for healthy plant growth and development (Wild, 1994).

The manganese concentration (Mn) of the study area was 109.54mg/kg. Lack of manganese is dangerous to plants (Buchanan, 2001) and in excess, it is particularly damaging to plants (Mukhopadhyay and Sharma, 1991).

The quantity of copper (Cu) in the study area was 1.57mg/kg. Copper in very low concentration is essential for survival of plants (Wild, 1994).

Table 2 further shows the amount of iron **(Fe)** contained in the soil. Iron is a micro nutrient taken up by plant in form of Fe^{2+} (ferrous cation) or Fe^{3+} (ferric cation).
It is involved in photosynthesis, respiration, chlorophyll formation and enzymatic reactions (Brail, 2005).

Effect of *Paraquat* on Physico-chemical Properties of Soil of the Experimental Site

The effect of *paraquat* on the physical properties of the soil is indicated in Table 3. The percentage of clay showed a significant difference on the different levels of *paraquat* applied to the soil. There was no significant difference on the percentage of sand and silt on the different levels of treatment applied in the soil. This may be due to the fact that soil texture is the only soil property that is not affected by any farming system. Nwaka (1997) stated that soil texture is a permanent soil physical property, hence not easily affected by man's manipulations.

Table 3: Effect of *Paraquat* on the Physical Properties of the Soil

Treatment	Sand %	Silt %	Clay %
0ml/L	72.67	15.33	15.33[a]
5ml/L	72.00	14.67	14.00[ab]
15ml/L	71.33	14.67	14.00[ab]
30ml/L	70.67	14.00	12.00[b]
	NS	NS	*

*Significant, NS= Not significant.

Effect of *Paraquat* on the Chemical Properties

The data in Table 4 shows the effect of *paraquat* on the chemical properties (pH) in water and in calcium chloride ($CaCl_2$), Effective Cation Exchange Capacity (ECEC), and organic carbon in the soil. The different rates of *paraquat* added to the soil had a significant effect on the Effective Cation Exchange Capacity (ECEC), while the organic carbon and pH (in water – H_2O and calcium chloride – $CaCl_2$) of the soil showed no significant difference on the application of different rates of *paraquat* to the soil.

Table 4: Effect of *Paraquat* on the Chemical Properties of the Soil

Treatment	pH in H_2O	pH in $CaCl_2$	ECEC	OC
1	6.33	5.73	7.97[a]	0.98
2	6.50	5.67	8.13[a]	0.66
3	6.63	5.73	6.80[b]	0.71
4	6.53	5.73	8.10[a]	1.00
SE+	14.00	0.05	0.44	0.15
	NS	**NS**	*	**NS**

*Significant, NS= Not significant

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Effect of *Paraquat* on the Available Soil Micronutrients

The effect of *paraquat* on the Available Soil Micronutrients (zinc Zn, manganese Mn, copper Cu and iron Fe) is presented in Table 5. There was no significant difference on the available manganese, copper and iron in the soil on the application of different rates of *paraquat* to the soil. Available zinc in the soil showed a significant effect in the control but had no significant difference on treatment in the soil. As such, doesn't have much effect on the distribution of some heavy metals especially Copper and Iron. Mirjana *et al*. (2009) also observed similar trend in their work carried out on Sebian Soils.

Table 5: Effect of *Paraquat* on the Available Soil Micronutrients (zinc Zn, manganese Mn, copper Cu and iron Fe)

Treatment	Zn	Mn	Cu	Fe
1	8.77^{a}	87.33	6.39	169.37
2	7.44^{ab}	84.85	7.01	182.07
3	7.83^{ab}	83.89	7.56	246.06
4	7.83^{ab}	83.89	7.56	246.06
	*	NS	NS	NS

*Significant, NS = Not significant.

CONCLUSION AND RECOMMENDATIONS

The result obtained from the soil analysis showed that the soil texture of the study area was sandy loam. The soil was strongly acidic with high organic matter content. The level of percentage total nitrogen (TN) and available phosphorus (P) contained in the soil were medium. The soil was low in CEC and ECEC. Trace elements (micronutrients) in the soil were abundant. Based on the findings of this research, the following recommendations were made:

1. Farmers should be educated more on the use of herbicide (*paraquat*) in other to avoid unwanted effect.
2. In order to prevent spray drift and its effect on humans and animals, it should not be sprayed when the wind speed exceed 10 km/hour.
3. The use of *paraquat* herbicide should be promoted to improve Agricultural production

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