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EFFECT OF pH VARIATION ON SOIL PHYSICO-CHEMICAL PROPERTIES AND THE GROWTH AND DEVELOPMENT OF MAIZE (ZEA MAYS L.)

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ABSTRACT

This study aimed at assessing the effect of soil pH variation on the physical and chemical properties of the soil and the root growth and development of maize. To achieve this, samples were collected from the University of Abuja teaching and research farm. The pH values for specific pH classes was gotten after several trials and mixing; 1 ml of hydrochloric acid was diluted in 12,000 ml (12 Litres) of water to get a pH of 3.56 - 4.0 (strongly acidic), 0.1ml of hydrochloric acid was diluted in 10,000ml (10 Litres) of water to get a pH of 5.86 - 6.5 (slightly acidic), 0.5g of Calcium hydro oxide $Ca(OH)_2$ was diluted in 10,000ml (10 Litres) of water to get a pH of 7.5 - 8.5 (Slightly alkaline), 2g of Calcium hydro oxide $Ca(OH)_2$ was diluted in 10,000ml (10 Litres) of water to get a pH of 9.8 - 1.0 (Strongly alkaline) and the 'neutral class' (7.0) of pH was gotten by the use of pure distilled water. The rate of germination in each treatment was noted and after sometime, the maize seedlings were uprooted and the root growth and development was observed. The pre-treatment sample and post- treated samples were analysed in the laboratory to determine their physical and chemical properties. The pre-treatment sample had a pH(H_2O) of 7.5, very low nitrogen ;0.03gkg^{-1} and high sodium; 0.62Cmolkg^{-1}. Soil pH variation influenced the ECEC, nitrogen, phosphorus and potassium content of the soil.

Keywords: Variation, Soil, pH, Physico-Chemical, *Zea Mays*

Introduction

Soil is the foot hold of life on earth. It is the ground on which most activities, both agricultural and non-agricultural are carried out. Soil can be defined as "a dynamic natural body on the surface of the earth on which plant grow, composed of mineral and organic materials and living forms" (Brady, 1974). The soil is a dynamic living system with a variety of micro and macro flora and fauna. They play a dynamic role in the degradation of plant and animal residues and other organic matter in the environment as well as in nitrification, cycling of nutrients, energy and elemental fixation, soil metabolism and overall soil health and even in the release of nutrients from soil minerals. Soils are populated by a multitude of microorganisms and invertebrates. Among the organisms found in the soil are Bacteria, Fungi, Actinomycetes, Worms such as Earthworms, Nematodes, and other invertebrates (mostly arthropods) (Dindal, 1990).

Soils were literally and figuratively all of the processes that support human societies and economies and, indeed, all other terrestrial life on earth. The overwhelming focus of both ecology and agricultural sciences has been on what happens above ground, which can be seen and experienced directly by humans. Soils play physical roles in supporting plants and structures, including those created by humans. They contain a vast diversity of living organisms and non-living elements that interact to mediate processes as diverse as provision of raw materials, water filtration, breakdown of wastes, pest control, regulation of atmospheric composition, regulation of water and wind flows across landscapes, and maintenance of hydrological cycles (Bardget, *et al.,* 2001; Nelson and Mele 2006; Barrios 2007; Mele and Crowley 2008; McAlpine and Wotton 2009; Colloff, *et al.,* 2010; Dominati, *et al.,* 2010; Robinson, *et al.,* 2012). Soil can also be defined as the weathered and fragmented outer layer of the earth's terrestrial surface Hillel (1980). The physical properties of soil such as particle size and mineral composition are important in its differentiation and condition. Soil pH is one of the abiotic factors susceptible to influence biology and activity of biological regulators (Tube, *et al.,* 2010). In every sense, the term living soils is a reminder that soils too have a lifespan that can either be cut short through inappropriate interaction or sustained by appropriate nurturing or remedial attention. Soil is a heterogeneous mixture of mineral particles and organic matter that is found in the uppermost layer of Earth's crust. The soil is formed as a product of the continual interactions among the biotic (faunal and floral), climatic (atmospheric and hydrologic), topographic, and geologic features of the environment over long periods Jenny (1941), (Singer and Munns 1996). Soils were important components of ecosystem sustainability because they supply air and water, nutrients, and mechanical support for the sustenance of plants. Soils also absorb water during infiltration. By doing so, they provide storage for water as well as acting as a conduit that delivers water slowly from upstream slopes to channels where it contributes to stream flow. There is also an active and on-going exchange of gases between the soil and the surrounding atmosphere. When the infiltration capacity of the soil is exceeded, organic and inorganic soil materials are eroded and become major sources of sediment, nutrients, and pollutants in streams.

Plant roots absorb mineral nutrients such as nitrogen and iron when they were dissolved in water. If the soil solution (the mixture of water and nutrients in the soil) is too acidic or alkaline, some nutrients won't dissolve easily, so they won't be available for uptake by roots. Unfavourable soil pH has caused poor root development and this had led to poor yield of crop produce. The researcher therefore, sees the need to know the relationship between soil pH and plant roots growth and development in Maize and to be certain on the ideal pH that will promote a good root growth and development in Maize. Also, Maize is one of the major crop sources of food in Nigeria and most farmers are ignorant of the implication of the soil pH on maize crops growth. This has led to unstable maize crop production in Agriculture. Lack of proper knowledge on the soil pH suitable for the root growth and development of maize have reduced the yield of maize in most part of the Country. A careful study of the relationship between soil pH and some of the physical and chemical properties of the soil on the teaching and research farm of Faculty of Agriculture, University of Abuja, Nigeria is important. This research will provide an update of the average pH and physico-chemical properties of the soil on the research and training farm of the Faculty of Agriculture, University of Abuja and this is of huge benefit for the commencement and development of projects on the farm. This report will provide up-to-date information for the staff and upcoming students of Faculty of Agriculture, University of Abuja. This study will discuss and enlighten farmers and agriculturist on the influence of soil pH on Maize root growth which is essential for proper and continuous crop production. This study will serve as a guide, reference, document and data book that provides useful information to any soil scientist that wants to make further research on the Faculty of Abuja, University of Abuja teaching and research farm. This project builds upon previous projects undertaken by various researchers on the effect of soil pH on Maize root growth and development and the physic-chemical properties of the soil.

2.0 MATERIALS AND METHODS

The materials that were used include plastic buckets (pots), Hydrochloric acid, Sodium hydroxide, selected maize seeds, shovel, measuring tape, scissors etc.

2.1 Study Area

2.1.1 Location

The study was conducted in a screen house of the Teaching and Research Farm of the Faculty of Agriculture, University of Abuja. The farm where the soil samples were collected is located within the permanent site of the University close to the Faculty of Agriculture, West of the road. The main gate of the permanent site can be seen along the Giri Junction and the Abuja International Airport of (Nnamdi Azikiwe International Airport) road. The landscape gradient of 10 - 20 scope aspect are oriented Southwards, Northwards, South east wards and Northeast wards. This scope terminates into a deep drainage line with seasonal flows. This drainage line divides the farm into southern and northern portions. The scope aspects are more gentle on the northern portion while the southern portion is more steep.

2.2 Methodology

2.2.1 Sample collection

Surface samples (0 – 15cm depth) were collected from the teaching and research farm of Faculty of Agriculture, University of Abuja. The samples were mixed well using a shovel and were placed in fifteen clean plastic buckets (pot experiment).

2.2.2 Soil Treatments

Five soil pH levels was administered on the soil samples in the buckets. The pH values for specific pH classes was gotten after several trials and mixing; 1 ml of hydrochloric acid was diluted in 12,000 ml (12 Litres) of water to get a pH of 3.56-4.0 (strongly acidic), 0.1ml of hydrochloric acid was diluted in 10,000ml (10 Litres) of water to get a pH of 5.86-6.5 (slightly acidic), 0.5g of Calcium hydro oxide $Ca(OH)_2$ was diluted in 10,000ml (10 Litres) of water to get a pH of 7.5-8.5 (Slightly alkaline), 2g of Calcium hydro oxide $Ca(OH)_2$ was diluted in 10,000ml (10 Litres) of water to get a pH of 9.8-1.0 (Strongly alkaline) and the 'neutral class' (7.0) of pH was gotten by the use of pure distilled water. These different pH classes formed five different pH treatments replicated three times thus giving a total of fifteen buckets (fifteen samples). All the 5 treatments above were mixed in 5kg of soil. Each treatment in the plastic bucket (pot experiment) had a specific pH range. The treatment was laid out in a completely randomized design (CRD). The quantity of calcium hydro oxide in (g) was gotten by first setting the weighing balance at 0.0g to avoid errors. A sharp instrument was used to bore holes on the plastic buckets to allow optimal aeration. Selected maize seeds was planted in each treatment, two seeds per pot. The pots were watered occasionally with their specific treatment. The rate of germination in each treatment was noted and after sometime, the maize seedlings were uprooted and the root growth and development was observed. The buckets were turned with time to optimize their response to the sun. The treatments were watered occasionally strictly by the use of each of their specific treatment that was prepared previously. The pots were watered occasionally with their specific treatment. The soils from each treatment was also analysed to determine their physico-chemical properties before and after the administration of the pH treatments. The soil samples were air dried, grounded, sieved using a 2mm sieve and labelled properly before they were taken for analysis.

2.3 Laboratory analysis

2.2.1 Soil pH determination

The soil pH was determined using a glass electrode in a soil/water ratio of 1:2.5. This was done in duplicate in H_2O and in 0.01M KCl and $CaCl_2$ (McLean, 1982). The proliferation of pH meters in recent years precludes as in-depth discussion of meter operation; specific instructions are provided with individual units (Eckert and Sims, 2009). 10g of 2mm sieved air-dried soil was weighed and placed in a 50ml beaker. To the soil in the beaker, 25ml of distilled water was added. The soil suspension was then left to stand for 30 minutes with intermittent stirring using a glass rod. The pH meter was calibrated in a buffer solution of pH 7 before being immersed into the solution. The reading was taken when it became stable. Between readings, the electrode was rinsed and wiped dry and dropped into distilled water.

3.0 RESULTS AND DISCUSSION

3.1 Physico-chemical properties of pre-treatment sample

3.1.1 Physical properties of pre-treatment sample

Table 3.1: sand, silt and clay content; textural class of pre-treatment sample

Physical properties	Value
Sand	59 %
Silt	13 %
Clay	28 %
Textural class	Sandy clay

Table 3.2: Some chemical properties of pre-treatment sample

Chemical properties	Value
pH (H_2O)	7.5
pH $CaCl_2$	6.6
Organic Carbon gkg^{-1}	2.8
Total Nitrogen gkg^{-1}	0.03
Available Phosphorus $mgkg^{-1}$	15
Na^+ $cmolkg^{-1}$	0.84
K^+ $cmolkg^{-1}$	0.62
Mg^{2+} $cmolkg^{-1}$	2.11
Ca^{2+} $cmolkg^{-1}$	3.5
Exchangeable acidity $cmolkg^{-1}$	1.56
ECEC $cmolkg^{-1}$	8.63
TEB $cmolkg^{-1}$	7.07

3.1.2 Particle Size Distribution of pre-treatment samples

The result of the analysis as shown in table 3.1 tells us that the soil belongs to the textural class of sandy clay. It is dominated by sand having a percentage of 59%, followed by clay with a percentage of 28% and lastly, silt with a percentage of 13%. This is the top 15cm of the soil before treatment. High and intense rainfall in the area might have resulted in clay illuviation down the profile (Onyeakanne, *et al*., 2012).

3.1.3 Chemical properties of the pre-treatment sample

3.1.4 Soil pH of pre-treatment samples

The pH of the soil in water is slightly alkaline as seen on the result in table 3.2. Soil pH in water is always higher than its pH in calcium chloride. In strongly acidic soils, Al_3^+ becomes soluble and increase soil acidity while in alkaline soils, exchangeable basic cations tend to occupy the exchange sites of the soils by replacing exchangeable Hydrogen and Aluminium ions (Miller and Donahue, 1995). Most nutrients that plants need can dissolve easily when the pH of the soil ranges from 6.0-7.5 hence, the pH of the soil from table 3.2 is favourable for nutrient availability to plants and subsequently, plant growth and development.

3.1.5 Nitrogen, Phosphorus and Potassium of pre-treatment samples

From table 4.2, the Nitrogen content is very low; $0.03gkg^{-1}$ and this value agrees with the amount of total nitrogen on cultivated soils Mengel and Kirkby (1987). Nitrogen is the most deficient nutrient in soils (Chude, *et al.*, 2011). Brady and Weil, 2002 reported that nitrogen being a very mobile element is prone to be easily lost through leaching and percolation as well as volatilization. Low amount of nitrogen in the soil causes stunted growth of maize plants and reduces the green colouration of maize leaves. The Phosphorus content is $15mgkg^{-1}$ which is rated as medium Olsen and Dean (1965) and moderate (Bray). The phosphorus content in this soil is sufficient for the growth of maize plant. The major source of phosphorus in plants is the parent material. Purple colouration of leaves is a major deficiency symptom of phosphorus in maize. The potassium content is high; $0.62cmolkg^{-1}$ hence the soil has been intensively cultivated Alemayehu (1990). A low level of potassium in the soil causes stress in maize plants because the movement of water, nutrients and carbohydrate is impeded. A major deficiency symptom of a low potassium content in maize a brown colouration of the leaf margins.

3.1.6 Effective Cation Exchange Capacity of pre-treatment samples

From table 3.2, the effective cation exchange capacity is $8.63cmolkg^{-1}$ which is low. A low cation exchange capacity implies low ability of the soil to hold cations for exchange. It therefore makes nutrient less available for the plants uptake.

Table 3.3: Effect of pH variation (treatments) on pH($CaCl_2$) and Organic carbon

Treatment	pH($CaCl_2$)	Organic carbongkg^{-1}
Strongly acidic	5.6406^{bc}	3.5200^{a}
Slightly acidic	5.2198^{c}	1.9700^{b}
Neutral	4.1531^{d}	1.8700^{b}
Slightly alkaline	6.1531^{b}	1.3033^{b}
Strongly alkaline	7.4865^{a}	1.7367^{b}
LSD	*	*

Means followed by the same superscript are significantly similar using LSD at 0.05 level of significance

Table 3.4: Effect of pH variation (treatments) on other chemical properties of the soil

Treatment	Mg^{2+}	Ca^{2+}	$E.A^{+}$	ECEC	BS%	k^{+}	Na^{+}
			cmolkg^{-1}				
Strongly acidic	0.4941^{a}	3.0956^{b}	2.2791^{bc}	1.8591^{c}	8.6488^{a}	81.700^{ab}	0.9209^{c}
Slightly acidic	0.3020^{c}	3.0348^{b}	2.4070^{abc}	2.1036^{b}	8.8371^{ab}	59.333^{c}	0.9897^{bc}
Neutral	0.2020^{d}	2.9281^{b}	1.9103^{c}	2.4570^{a}	8.4504^{b}	57.167^{c}	0.9530^{c}
Slightly alkaline	0.3586^{bc}	3.1148^{b}	3.1203^{ab}	1.9503^{bc}	9.6970^{ab}	69.467^{bc}	1.1530^{a}
Strongly alkaline	0.4186^{ab}	4.8748^{a}	3.4636^{a}	1.4703^{d}	11.3503^{ab}	88.367^{a}	1.1230^{ab}
LSD	*	*	*	*	*	*	*

3.2 Effect of Treatments on the Chemical properties of the soil

3.2.1 pH of post treated soil samples

From table 3.3, the effect of treatment on pH is significant. The variation trend in pH from table 3.3 matches with soil pH ranges of soil survey division staff (1993). The pH ($CaCl_2$) in treatment five is rated as a high pH level; iron, manganese and phosphorus are less available (Brady and Weil, 2002). There is an effective significant difference of pH in treatment two and three. Also, the effect of treatment on Organic carbon in treatment one is significant but insignificant on treatment two, three, four and five.

3.2.2 Effective Cation Exchange Capacity of post treated soil samples

The result of the analysis in table 4.4 shows that the effect of the treatment on the effective cation exchange capacity is significant. There is a high level of significance in treatment one. Variations in pH affects the effective cation exchange capacity of the soil so well. Also, the effect of the treatment in the calcium and magnesium content was significant with treatment five being most significant. The effect of the treatment on sodium was significant with treatment one being most significant. The effect of treatment on potassium is significant with treatment four being most significant; which implies that the level of potassium in a slightly alkaline soil is high and this tallies with Mesfin (1996) that the level of potassium in an acidic soil is low.

4.2.3 Exchangeable acidity of post treated soil samples

Exchangeable acidity is the extent of H^+ and AL^{3+} in a soil. From table 3.4, the effect of treatment on exchangeable acidity is significant with treatment three being most significant. There is no consistent trend in the treatments.

Table 3.5: Effects of pH variation (treatments) on Nitrogen and Phosphorus

Treatment	$Ngkg^{-1}$	$Pmgkg^{-1}$
Strongly acidic	8.5184^{b}	25.168^{a}
Slightly acidic	8.5372^{a}	26.584^{a}
Neutral	8.5239^{ab}	16.584^{b}
Slightly alkaline	8.5339^{ab}	24.918^{a}
Strongly alkaline	8.5239^{ab}	23.584^{a}
LSD	*	*

Table 3.6: Effect of pH variation (treatments) on plant Height, Root Length, Root Count and Stem Diameter.

Treatment	PLHcm	RLTcm	RCNTcm	STDMcm
Strongly acidic	50.03^{b}	8.9667^{a}	12.667^{a}	1.1433^{a}
Slightly acidic	45.73^{b}	6.9000^{ab}	11.667^{a}	0.7667^{ab}
Neutral	43.43^{b}	0.7400^{c}	4.000^{b}	0.6667^{b}
Slightly alkaline	225.80^{a}	7.1667^{ab}	10.667^{ab}	0.8000^{ab}
Strongly alkaline	35.93^{b}	5.1333^{b}	7.667^{ab}	0.5000^{b}
SE±	107.34	1.5646	3.0894	0.1976
LSD	*	*	*	*

3.2.4 Nitrogen and Phosphorus of post treated soil samples

From table 3.5 above, the effect of treatment on nitrogen is significant with treatment two being most significant; the effect on other treatment, treatment three, four and five is not significant. Nitrogen is less affected directly by pH compared to other plant nutrients. Nitrogen is the most deficient element in the tropics (Sanchez, 1976). The nitrogen content was highest in treatment two; slightly acidic with a pH range of 5.8 - 6.5. The effect of treatment on phosphorus is significant. The effect on other treatment; one, two, four and five is insignificant. Phosphorus is directly affected by pH; it gets fixed with iron in acidic soils and with calcium in alkaline soils. The level of phosphorus in all the five treatments is higher when compared with the pre-treatment sample.

3.3 Effects of Treatment on Maize Growth and Development

3.3.1 Maize Height, Root Length, Root Count and Stem Diameter

The effect of treatment is significant on the maize plant height as seen in table 3.6 with treatment four (225.80^{a}) being most significant. This is to say that there is a high tendency of maize plants to grow very tall in a slightly alkaline soil. The effect of treatment on maize root length is significant with treatment one (8.9667^{a}) being most significant. The effect of treatment on the number of roots counted is significant; this is to say that there is a good rate of multiplication of maize roots in an acidic soil. The effect of treatment on the maize stem diameter is significant with treatment one (1.1433[a]) being most significant.

3.3.2 Maize Growth and development

Soil pH also affects the germination of seeds because there was a very good and fast germination rate in the pots with neutral treatment. The tolerance level of maize in treatment one (highly acidic) and treatment four (slightly alkaline) was very low. The best growth rate of the maize was seen in treatment three (neutral).

4.1 Conclusion

The pH of the soil could be attributed to the parent material with which the soil was formed, possibly agronomic practices, The effective cation exchange capacity of the soil studied indicates that the soil has a low nutrient holding capacity, this can be linked to the high quantity of the sand content in the soil. Studies on the soil from the field reveals that the soil has a high percentage of sand, medium clay quantity and a low silt content. It has a pH(H_2O) of slightly alkaline 7.5, very low nitrogen (0.03g/kg), moderate phosphorus content (15mgkg^{-1}) , high sodium (0.84cmol/kg), high potassium (0.62cmol/kg), moderate magnesium (2.11cmol/kg) and moderate calcium (3.5cmol/kg). Also, maize roots grow deeper and multiply more in a slightly acidic medium.

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