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# Effect of pH on Soil Chemical Properties and Maize Performance in Abakaliki, Nigeria

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## ABSTRACT

**Background:** Low soil productivity in Nigeria and Africa sub sahara is considered as one of the major causes of food insecurity and under nutrition. This area is considered among the most regions affected by acidity on soil nutrients optimization. Despite of its severity, there is limited knowledge about limiting effect of pH on nutrients availability and maize yield in the state. Evolving a technology that does not depend on traditional system of amendment for pH assessment for increased soil productivity must first of all go through a good knowledge of the nature and distribution of soil studied. The present study aimed to evaluate three pH (4, 7 and 9) values on soil chemical properties in the state and assess maize performance under these conditions in order to control and manage pH related problems.

**Methods:** In the field-laboratory investigation during 2018-2019 at different localities of Ebonyi State were surveyed. Three sampling localities were selected based on geographical situation, climate and local condition. In the laboratory, the soil samples of natural stock collected were processed for mean pH values and confirmed with pH meter using standard laboratory method. Maize was used as test crop to assess effect of pH on its performance.

**Result:** Our investigations in Ebonyi State have allowed us to inventory three pH values. Among the inventoried pH values, some are regarded adverse for soil productivity. The implication of soil pH on nutrients availability and maize performance was discussed. The current work will be a complementary contribution of detailed study of effect of pH on soil productivity.


**Key words:** Chemical properties, Evaluate, pH, Soil, Yield.

## INTRODUCTION

Maize is one of the world's leading cereal crops. It is the second largest grown cereal in Nigeria, after rice as a result of its wide adaptability and sturdiness more than sorghum and millet. It is the choice of many people in the country as it contains more protein, vitamins and minerals like legumes (Pingoliya *et al.,* 2013) than rice. Many people suffering from health challenge such as diabetes prefer its meal as it has low carbohydrate content (NPAFS, 2010). The crop performs well if planted in April or August for late cropping in Abakaliki. Optimal yields were obtained from sandy loam or sandy clay loam with good supply of nutrients. The crop needs adequate supply of N, P, K, Ca, Mg and organic carbon for yield optimization. As a heavy feeder, it is not a good fit for continuous cropping but can be integrated in mixed cropping system. Optimum moisture, ideal temperature and adequate sunshine are requisite for highest yields. Generally, with good agronomic management practices and use of good high yielding varieties (Kumbhare *et al.,* 2014) higher yields are obtained in maize compared to pulses. The crop does not tolerate soils that are strongly acidic or alkaline (<pH 5 or >8), loose or impermeable and lateritic (Biswas and Murkherjee, 2008) as they tend to reduce yields. Despite its high agricultural value chain, suitable soil for its profitable production is posing a problem. This is because almost >75% arable land area accounting for >45% in the dominant maize production ecology is lateritic or gravelly and predominantly acidic with <35% being alkaline. Therefore, pH which underlies its successful and sustainable production is pivotal to develop good management practices for increased yield in maize.

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Soil pH largely determines a lot of chemical processes taking place in the soil medium, such as nutrients sorption and desorption as well as microbial activities (Nweke and Nsoanya 2013). Changes in soil pH control immediate environment (Aruna, 2017) such as soil productivity. Soil pH is essential in fertility evaluation as it functions as a medium for crop growth and yield (Dora, 2019) necessitating study of its direct contribution to soil productivity. In acid soils, macronutrients (N, P, S) and basic cations (Ca, Mg, K and Na) are not available to plants as in neutral-alkaline soils (Loncaric *et al.,* 2008) due to predominance of micronutrients. Micronutrients at large concentrations endanger phosphorus availability through fixation (Rodolfo *et al.,* 2018). Mbah *et al.* (2010) reported that soil acidity accounted for 159% loss in grain yield of maize in Southeast

Nigeria. In addition, Rodolfo *et al.* (2018) noted that plant height and their yield traits were superior at pH 6 and 8. Many crop characteristic traits such as height and yield parameters are influenced by soil pH (Jiana *et al.,* 2017). Nweke and Nsoanya (2013) further reported that low pH retarded maize growth, stifled root proliferation, chlorosis and reduced water and nutrients absorption. Additionally, pH is strategic and major variable that influences soil properties and crop adaptability (Rodolfo *et al.,* 2018).

Studies on pH in the area are often poorly investigated and lack specific or direct contribution on soil productivity. Conventional agriculture which makes extensive use of inorganic and organic input can no longer be relied upon in this 21st century for economical production due to increasing cost, scarcity and environmental pollution. Information available is only on inputs amendment on pH and their corresponding effect on availability of nutrients such as N, P, OC and Ca, Mg, K, Na as well as maize yield (Okonkwo *et al.,* 2011; Mbah *et al.,*2001). These reports seem to be vague and cannot be basis for effective policy formulation and planning for breakeven maize production as population is projected to be more than 1.5 billion by 2050. Innovative approach such as a strategy or technology in form of precision tester for rapid assessment of soil condition for optimal performance is imperative. For these reasons, even though, there may be other important environmental conditions, focus was on soil reaction (pH) in order to understand its specific contribution to soil productivity. The study was carried out during 2018/2019 rainy season with maize as test crop in plant and screen house with the objectives to find effects of three pH values of natural soil stock on chemical properties as well as performance of maize (*Zea mays* L.) under controlled condition.

## MATERIALS AND METHODS

The research was carried out in 2018-2019 rainy season at plant and screen house of demonstration farm, Ebonyi State University, Abakaliki located at latitude 06° 4′ N and longitude 08° 65′ E in the savannah of Southeast agro zone of Nigeria. The area has tropical climate. The rainfall is bimodal with dry spell in August with annual mean of 2000 mm. Minimum and maximum temperatures are 27°C and 31°C while relative humidity ranges from 80-60% for rainy and dry seasons (Nimet, 2016). The soil is formed from shale residuum with 75% of the land area having sandy or lateritic characteristic on the surface. The soil is generally of clayey texture, brown to black rich in kaolinitic to montmorrillonitic especially at lower horizon with shallow depth below 0-20 cm, although most of the places are sandy loam except in some places with limestone deposition that have silty loam texture. The soil belongs to ultisol order, classified as typic haplustult, hyperthermic with udic moisture regime (Akamigbo, 2010) and associated with Nsukka series. The pH treatments were selected from soil samples collected randomly from natural soil stock at ten spots from Ikwo, Izzi and Nkalagu based on geographical situation, climate and local conditions with seven replicates. The soil sample collected from Ikwo is sandy or lateritic and with rapid drainage; at Izzi, an alluvial deposit at foot toe of an urban hill characterized by black to dark brown in colour and loamy; and Nkalagu from rich deposit of limestone showing sandy or silty fluffy texture. The samples from these locations were composited and processed using standard laboratory method (Peech, 1965) to obtain mean pH values used for treatment. Then 30 kg of soil samples was transferred to perforated plastic pots approximately 30 $cm^3$ replicated seven times with Oba super II hybrid maize variety arranged in completely randomized design (CRD). The initial soil samples from natural stock from selected locations were analyzed for major nutrients such as nitrogen (N), phosphorus (P), organic carbon (OC), calcium (Ca), magnesium (Mg), potassium (K) and minor nutrient-sodium (Na), soil capacity to fix nutrients (CEC) and presence of acid forming ions ($H^+$ and $Al^{3+}$). The status of these elements in each location is shown in Table 1. Ten maize plants were randomly selected from each replication and tagged for their agronomic characteristics of plant height, stover and root weights all determined on biweekly basis. Grain yield was taken after removing the grains from cobs and air dried to 14% moisture content. Air dried and sieved soil samples (<2 mm) were used for laboratory determinations. Soil pH was obtained using 1:2.5 soil and water solution ratio and values read off with glass electrode pH meter using 10 g of sieved soil and 25 ml of distilled water in a glass tube (Peech, 1965). Total nitrogen determined with use of semi-microkjedahl digestion procedure as described by Bremner and Mulvaney (1982). Available phosphorus was extracted out using Bray-2 method as described in Page *et al.* (1982) and organic carbon obtained as described by Nelson and Sommer (1982). Exchangeable cations of calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na), cation exchange capacity (CEC) and exchangeable acidity (EA) were extracted with ammonium acetate solution ($NH_4OAC$). Amounts of exchangeable cations were determined using perkin Elmer absorption spectrophotometer (Rao and Tel, 1982). The data generated from various characters under study were subjected to analysis of variance (ANOVA) and treatment effect assessed using Fisher's least significant difference (SAS, 1985).

## RESULTS AND DISCUSSION

### Available soil nutrients

Post-harvest sol analysis was carried out for available soil nutrients and data were analyzed and tabulated in Table 2. The available P (20.00 mg $kg^{-1}$) and organic carbon (2.56 g $kg^{-1}$) in soil were found maximum under pH 7. Studying effect of pH in bacterial distribution Iyere-Usiahon and Jayeoba (2018) reported that neutral to near neutral soil condition of pH 7.16 increased availability of P, N and OC in soil compared to lower or higher *i.e.* 3 and >8 pH levels. Significant concentrations of macronutrients of P, N and OC at pH 7

**Table 1:** Initial soil chemical properties.

| Treatment | P (mg kg$^{-1}$) | N (g kg$^{-1}$) | OC (g kg$^{-1}$) | Ca | Mg | K | Na | EA | CEC |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ----- | ----- | -----cmol/kg----- | ----- | ----- | ----- |
| pH 4 | 1.80 | 0.10 | 0.17 | 2.50 | 0.20 | 0.03 | 0.07 | 3.00 | 6.00 |
| pH 7 | 21.60 | 1.00 | 1.72 | 8.00 | 5.80 | 3.09 | 0.10 | 0.16 | 17.00 |
| pH 9 | 3.20 | 0.20 | 0.35 | 10.20 | 8.20 | 3.00 | 2.00 | 1.20 | 25.00 |

EA- Exchangeable acidity.

**Table 2:** Effect of pH on soil chemical properties.

| Treatment | P (mg kg$^{-1}$) | N (g kg$^{-1}$) | OC (g kg$^{-1}$) | Ca | Mg | K | Na | EA | CEC |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ----- | ----- | -----cmol/kg----- | ----- | ----- | ----- |
| pH 4 | 0.05 | 0.09 | 0.16 | 2.40 | 0.02 | 0.02 | 0.14 | 2.50 | 9.10 |
| pH 7 | 20.00 | 1.20 | 2.56 | 4.50 | 4.60 | 0.23 | 0.23 | 0.18 | 13.39 |
| pH 9 | 2.10 | 0.10 | 0.17 | 8.80 | 6.80 | 2.03 | 2.00 | 1.30 | 16.91 |
| LSD (P<0.05) | 5.00 | NS | 2.03 | 1.80 | 0.07 | 0.06 | 0.20 | NS | NS |

P- Available phosphorus, N- Nitrogen, OC- Organic carbon, EA- Exchangeable acidity, CEC- Cation exchange capacity.

are due to increased mineralization (Dora, 2019). There was no significant change in level of total N in soil after pH treatment. In contrast, exchangeable Ca (8.80 cmol kg$^{-1}$) and Mg (2.00 cmol kg$^{-1}$) were maximum under pH 9. Maximum values of Ca (4.33 cmol kg$^{-1}$), Mg (0.24 coml kg$^{-1}$) and Na (0.23 cmol kg$^{-1}$) were noted by IyereUsiahon and Jayeoba (2018) under alkaline condition. Even though, maximum EA (1.30 cmol kg$^{-1}$) and CEC (16.91 cmol kg$^{-1}$) were recorded under pH 9, there was no significant change when the two parameters are compared to their counterparts under other pH values.

The data showed post-soil test status in relation to effect of different treatments of pH values. The results show that changes in soil test values with respect to available macronutrients had significant effect except N in relation to different pH treatments. Since maize crop requires high dosage of N, P and K, uptake of these nutrients resulted to limiting values after harvest. It is even possible that anticipated removal of nutrients by the crop could have been due to leaching of cations and reduction of major nutrients under acidic or alkaline condition (Dora, 2019). Ammal *et al.* (2001) reported nutrients mobilization in soil. Available P and OC were significantly increased at pH 7 relative to their values at other pH treatments. Exchangeable Ca, Mg, K and Na appreciated significantly at pH 9 compared to their counterparts under pH 7 and 4. The levels of N, CEC and EA did not show any significant variation due to treatments indicating severity of pH on their expressions.

### Agronomic yield

The data was recorded and analyzed for agronomic yield of maize (Table 3). Compared to other treatments, minimum plant height (105.54 cm plot$^{-1}$) was observed under pH 4 which was found to be at par with pH 7 and 9. The minimum root weight (5.38 kg plot$^{-1}$) was also recorded under pH 4. The same trend of minimum stover weight (1.14 kg plot$^{-1}$) and grain yield (4.1 kg plot$^{-1}$) were noted under pH 4. Similar findings of shortest maize plant (134 cm plot$^{-1}$) and grain yield (1.2 t ha$^{-1}$) were reported (Mbah *et al.,* 2010) at low pH in Southeast Nigeria and supported (Minasny *et al.,* 2016). Data in Table 3 also show that treatments had no significant effect on agronomic yield of maize. Nevertheless, yield attributing characters indicated superior effect of pH 7 with respect to others. The assessed yield characters though identical implied greater response to neutral soil condition. Turner (1928) reported 50% taller plant under neutral (pH 7) condition than at acidic or alkaline conditions. Aluminium or mangnese toxicities suspected could have reduced root proliferation and stunted maize growth (Nweke and Nsoanya, 2013; Hao *et al.,* 2017) at pH 4. This reduced photosynthetic efficiency of the crop (Tessmer *et al.,* 2013). Rodolfo *et al.* (2018) reported maximum yield attributes under pH7 or near neutral soil condition in support of the findings.

**Table 3:** Effect of pH on maize growth and yield.

| Treatment | Plant height (cm plot$^{-1}$) | Root weight (kg plot$^{-1}$) | Stover weight (kg plot$^{-1}$) | Grain yield (kg plot$^{-1}$) |
|---|---|---|---|---|
| pH 4 | 105.54 | 5.38 | 1.14 | 4.1 |
| pH 7 | 124.94 | 13.04 | 1.98 | 7.7 |
| pH 9 | 106.55 | 7.50 | 1.63 | 4.4 |
| LSD (P<0.005) | NS | NS | NS | NS |

## Conclusion

Increase in Nigerian population would enhance demand of more cereals. The high human population needs correspondingly higher cereal production for satisfying the nutritive protein intakes. The study showed that pH had influence on degree of availability or otherwise of nutrients under controlled soil environment and maize performance. Findings strongly demonstrated that concentrations of nutrients in soil and their uptake by maize crop are pH dependent. Thus, the use of soil with high pH improved soil fertility and increased productivity. Use of soil testing technology has to be adopted in Nigeria as a practice that optimizes pH condition of soil for effective and efficient nutrient management and to get maximum yield of maize. We have a duty to develop maize with new traits such as high yielding variety (HYV) and adaptable to local conditions.

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