Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 21 Number 4 (October 2022) pp. 69 - 76
ISSN 1119-7455

COMBINED INFLUENCE OF ASH AND POULTRY MANURE ON SOIL REACTION AND PERFORMANCE OF MAIZE (*Zea mays*) IN A COARSE-TEXTURED ACID SOIL OF SOUTH-EAST, NIGERIA

***[1]Amanze C.T., [1]Amulu L.U., [1]Ukabiala M.E., [2]Kayode A.P., [3]Omatule L.A., [4]Ozomata A.S. and [5]Kolo J.**

[1]Faculty of Agriculture, University of Agriculture & Environmental Sciences, Umuagwo, Nigeria
[2]School of Agriculture & Agricultural Technology, Federal Polytechnic, Ado-Ekiti, Nigeria
[3]Department of Soil & Environmental Management, Kogi State University, Anyigba, Nigeria
[4]Department of Veterinary Epidemiology & Economics, University of Nairobi, Kenya
[5]National Drug Law Enforcement Agency, Ikoyi-Lagos, Nigeria

*Corresponding author's email: chikamneleamanze@gmail.com

ABSTRACT
Crop production can be limited by soil acidity. A two-factor factorial experiment involving three levels each of ash and poultry manure (PM) was conducted to determine the effects of ash and PM on soil reaction and performance of maize in an acid soil. The ash comprised of mixture of ash from wood, cocoa husk and palm bunch. The levels of ash (0.00, 3.00, 6.00 t ha^{-1}) and PM (0.00, 4.00, 8.00 t ha^{-1}) were combined to obtain nine treatment combinations (control, 3.00 ash and 0.00 PM, 3.00 ash and 4.00 PM, 3.00 ash and 8.00 PM, 0.00 ash and 4.00 PM, 3.00 ash and 0.00 PM) which were replicated thrice. The experiment was laid out in a randomized complete block design. Soil samples were collected at 3, 6, 9 and 12 weeks after planting (WAP), plant height measured at 3, 5, 7, and 9 WAP while cob oven-dry weight was measured after oven-drying harvested cobs at maturity. Analysis of variance was conducted on the data collected using GenStat version 14. The highest plant height of 132.50 cm at 12 WAP and the highest oven-dry cob weight of 7.15 t ha^{-1} were obtained from plots treated with 6.00 and 8.00 t ha^{-1} of ash and PM, respectively, and these were significantly ($p \leq 0.05$) different from the other treatments. The lowest exchangeable acidity of 1.33 cmol kg^{-1} which varied significantly ($p \leq 0.05$) from the other values observed at the other plots was obtained at the plot treated with the combination of 6.00 and 4.00 t ha^{-1} of ash and PM, respectively at 12 WAP. The combination of ash and PM at 3.00 and 8.00 t ha^{-1} gave the highest pH of 6.80, and this was significantly ($p \leq 0.05$) different from the other treatments. Therefore, ash and PM at varying levels of combination can simultaneously ameliorate soil acidity and improve maize performance; however, the best combination of ash and PM application which showed the potential to produce optimum effect in simultaneously ameliorating soil acidity and increasing maize performance was the combination of 6.00 tonnes of ash and 8.00 tonnes of PM.

Key words: soil acidity, ash, maize, poultry manure, soil pH, exchangeable acidity

INTRODUCTION
Maize is of great economic value in Nigeria, and contributes greatly to the global rise in crop production (Monday, 2017). It also has a notable potential to improve food security globally (Monday, 2017). However, the major constraint to the productivity of this crop in various parts of the world is soil acidity (Baligar, 2005). The report of Baligar (2005) showed that a large area of agricultural land across the world is affected by soil acidity, and this could be as a result of increased rainfall leading to leaching; acidic nature of the parent material, organic matter decay, and nitrification of ammonium (Hailiu, 2017). This soil acidity, therefore, poses a threat to global maize production because large part of the world depends on the affected soils for maize production.

It is, therefore, very paramount to ameliorate the soil acidity for optimum maize production. Baligar (2005) explained that the low productivity of crops in acid soils is a consequence of poor nutrient status, low nutrient uptake, immobilization of essential nutrients, poor microbial activities and elemental toxicity. According to Obi and Ebo (1995), the application of adequate rate of manure and liming materials are important strategies in improving crops' productivity in acid soils. They also reported that poultry manure (PM) was noted for its inherent ability to induce soil aggregation and improve water infiltration rate, thereby imparting positively on soil fertility and nutrients availability. Obalum *et al*. (2020) reported that PM reduced soil bulk density and increased soil pH and phosphorus availability as well as sweet potato growth and

Please cite as: Amanze C.T., Amulu L.U., Ukabiala M.E., Kayode A.P., Omatule L.A., Ozomata A.S. and Kolo J. (2022). Combined influence of ash and poultry manure on soil reaction and performance of maize (*Zea mays*) in a coarse-textured acid soil of South-East, Nigeria. *Agro-Science*, **21 (4),** 69-76. DOI: https://dx.doi.org/10.4314/as.v21i4.11

yield in acid sandy-loam Ultisols. There are similar reports of PM-caused increases in soil aggregation (Ogunezi *et al*., 2019) soil pH, soil organic carbon, total nitrogen, available phosphorus, cation exchange (Olayinka, 1990; Umeugokwe *et al*., 2021), as well as crop growth and yields (Olayinka, 1990; Ogunezi *et al*., 2019; Nnadi *et al*., 2020). Duruigbo *et al*. (2007) reported about 40% increases in soil pH at the application of 15 t ha^{-1} of PM which was indicative of its ability to ameliorate soil acidity.

On the other hand, ash reduces soil acidity by replacing the exchangeable hydrogen ions in the soil colloids with exchangeable bases (Erebor, 1998). Several studies have reported increases in soil pH and/or exchangeable bases due to application of ash to acid soils (Nwite *et al*., 2011a, b; Igwe *et al*., 2013; Lalljee and Facknath, 2022). Furthermore, the report of Blaise *et al.* (2011) shows that ash could help in improving soil pH and base deficiency as well as increase soil microbial activities in acid tropical soils. Complementing ash with PM in soil and water management is suggested to improve soil physico-chemical conditions and maize performance in acid tropical soils (Nwite *et al*, 2012a, b), but may also produce antagonistic effects (Nwite *et al*, 2013). Thus, the objective of this study was to determine the effects of ash and PM application on soil reaction and performance of maize (*Zea mays*) in acid tropical soils, as well as the optimum rate of the treatments when they are combined.

MATERIALS AND METHODS

Description of Study Area

The research was conducted at the Research & Training Field of Michael Okpara University of Agriculture, Umudike, Abia State. The area lies within latitudes 5° 29′ to 5° 31′ N and longitudes 7° 30′ to 7° 32′ E, with mean annual rainfall of 2200 mm as reported in NiMet (2019). The area is characterized by bimodal rainfall regimes and a season of dryness. The rainy season starts from March and extends to October with the bimodal peaks in July and September, and a short spell of dryness in August. The dry season starts in November and lasts till February. The mean annual temperature is about 28℃ (NiMet, 2019). The landscape is flat to gently undulating. Coastal plain sands is the dominant parent material in the area with localized regions of alluvial deposits, while it is of the soil taxonomical order Ultisols and great group Hapludults according to the USDA Soil Taxonomy reported in Lekwa and Whiteside (1986) and Amanze *et al.* (2016).

Sources and Preparation of Experimental Materials

The trial involved two factors namely ash and poultry manure (PM). The ash was a mixture of wood ash, cocoa husk ash and palm bunch ash, and was locally sourced from the kitchens of the students' cafeteria where they combine the use of wood, cocoa husk and palm bunch as source of fuel for cooking. The PM was sourced from the poultry farm at National Root Crops Research Institute, Umudike. The PM was air-dried, and crushed into fine texture. The test crop, maize, was of the variety, Oba Super 2, procured from the Farm Centre of Michael Okpara University of Agriculture, Umudike.

Treatment Combinations and Experimental Design

The experiment was a two-factor factorial experiment in randomized complete block design (RCBD) involving three levels of ash and three levels of PM. The levels of ash were 0.00, 3.00 and 6.00 t ha^{-1}, while the levels of PM were 0.00, 4.00, and 8.00 t ha^{-1}. The levels of the factors were combined to obtain nine treatment combination which were: 0.00 × 0.00, 0.00 × 4.00, 0.00 × 8.00, 3.00 × 0.00, 3.00 × 4.00, 3.00 × 8.00, 6.00 × 0.00, 6.00 × 4.00, 6.00 × 8.00 t ha^{-1}. These treatments combinations were replicated three times to give 27 observational plots. The first value in each combination was for ash and the second was for PM, while the control treatment was 0.00 × 0.00.

Land Preparation, Treatment Application and Planting of Test Crop

The land which was under continuous cultivation, and formerly cultivated to cassava was cleared of the existing vegetation. Treatment plots were marked out such that each plot measured 3.00 × 3.00 m, and the spacing of 0.50 and 1.00 m between plots and blocks. The treatments were randomly assigned to the plots. The treatments were incorporated into the soils at each plot and allowed to decompose for two weeks before planting. The maize plants were maintained at two plants per stand at a planting space of 75.00 × 25.00 cm. Each plot had plants density of 48 plants while the total plant population was 53,333 plants per hectare.

Soil Sampling and Sample Preparation

The soil of the site was characterized by the collection of 60 representative soil samples at the depth of 0-15 cm across the land area using simple random sampling method. The representative soil samples were thoroughly mixed to obtain a bulk sample. Soils were also randomly collected after treatments application from each plot at 3, 6, 9, and 12 WAP. The soil samples were air-dried, sieved with 2.00 mm-sieve and analyzed in the laboratory.

Plants Sampling and Data Collection

Five plants were selected across various portions of each plot as observational units, on which measurements of plant height and cob oven-dry weight were done. Data on plant height were collected at 3, 5, 7, and 9 WAP while cob oven-dry weight was obtained by harvesting the cobs at maturity and drying the cobs in an oven at a temperature of 65℃ to a constant weight after three days.

Laboratory Analysis

Particle size distribution was determined as described by Gee and Or (2002). Soil pH was determined as explained in McLeans (1982). Total nitrogen was determined by the micro Kjeldahl method as outlined by Bremner (1996). Organic carbon was determined by the dichromate oxidation method as modified by Nelson and Sommers (1982). Exchangeable acidity was determined as outlined in McLeans (1982). The exchangeable hydrogen and aluminum as well as the exchangeable cations were determined by the methods explained in Tel and Hagarty (1984). Exchangeable calcium and magnesium were determined by titration while exchangeable sodium and potassium were determined using flame photometer. Available phosphorus was extracted using Bray II method and determined using photospectrometer as outlined in Olsen and Sommers (1984). Effective cation exchange capacity (ECEC) was obtained by the summation of the determined exchangeable cations, while percentage base saturation (%BS) was obtained by calculation as shown below:

$$\%\ Base\ saturation = \frac{Total\ exchageable\ bases}{Effective\ cation\ exchange\ capacity} \times 100$$

Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA) using GenStat software package version 14.0, and significant means were separated using Fisher's least significant different (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Site Characterization

The texture of the soil was sand with percentage sand, silt and clay contents of 939.20, 37.20, and 23.60 g kg^{-1}, respectively. It has the pH of 4.7 indicative of very strongly acidic soil. It had organic matter content of 1.00 g kg^{-1} indicative of low organic matter. The exchangeable Na was 0.05 cmol kg^{-1} which indicated that it was very low, while exchangeable K, Ca and Mg were moderate with values of 0.20 cmol kg^{-1}, 2.40 cmol kg^{-1} and 1.60 cmol kg^{-1} for exchangeable K, Ca and Mg, respectively. The exchangeable acidity of 2.80 cmol kg^{-1} was high while the available phosphorus of 4.80 mg kg^{-1} was critically low. The soil had low ECEC and low to moderate percentage BS of 7.00 cmol kg^{-1} and 60.1%, respectively.

The dominance of sand in the soil could be attributed to the continuous cultivation of the soil, which loosened the soil aggregates and exposed the clay and silt particles to lose by erosion. This observation was similar to the report of Kutilek (2005) and Amanze *et al*. (2017) that continuous cropping on soil increased the loss of clay particles by erosional processes resulting in the accumulation of sand. The soil was highly weathered, and it is of the coastal plain sands; this may have contributed to the acidic nature of the soil. This report corroborated Lekwa and Whiteside (1986) and Amanze *et al*. (2016) who earlier reported that highly weathered soils of the coastal plain sands are characterized by increased acidity. The possible leaching of the basic cations due to the increased porosity of the soil as influenced by the coarse texture of the soil may have also contributed to the acidic nature of the soil. Amanze *et al.* (2017) had earlier reported in support of this finding that the leaching of the exchangeable bases due to excessive drainage resulted in accelerated soil acidity. Furthermore, plant uptake of nutrients including the basic cations coupled with crop removal via harvest and low residue turnover as reported by IITA (1999) and Amanze *et al.* (2017) may have contributed to the increased acidic nature of the soil.

The continuous cultivation of the soil was probably the reason for the low of organic carbon (OC) content of the soil. Moreover, the low vegetation cover that exposed the soil to intense heat of the sun may have accentuated the oxidation and breakdown of the soil organic matter leading to loss of soil organic carbon. This finding was consistent with Balesdent *et al.* (2000) and Amanze *et al.* (2022) who reported that the availability of air in the soil increased with pulverization and alters the temperature and moisture of the top soil; hence increased the rate of SOM decomposition.

It could be inferred that the low available P content of the soil may be attributed to the increased acidic property of the soil which reflects increased exchangeable Al concentration that immobilized the phosphorus in the soil. The report of Ano (2004) and Onwuka *et al*. (2016) confirmed that Al formed mineral complex with P in acid soils resulting to P-fixation and phosphorus unavailability. The low exchangeable cations (Ca, Mg and K) contents of the soil was possibly a result of increased leaching of basic cations, plant uptake of Ca, Mg and K, plant removal at harvest, and low biomass turnover to the soil (Onwuka *et al*., 2016).

Table 1: Characterization of the soil before treatments application

Soil properties	Values
Sand (*g* kg^{-1})	939.20
Silt (g kg^{-1})	37.20
Clay (g kg^{-1})	23.60
Textural class	Sand
pH	4.73
Organic carbon (g kg^{-1})	0.99
Available phosphorus (g kg^{-1})	4.76
Exchangeable acidity (cmol kg^{-1})	2.80
Exchangeable calcium (cmol kg^{-1})	2.40
Exchangeable magnesium (cmol kg^{-1})	1.60
Exchangeable potassium (cmol kg^{-1})	0.16
Exchangeable sodium (cmol kg^{-1})	0.05
Effective cation exchange capacity (cmol kg^{-1})	7.01
Base saturation (%)	60.06

It could be noted that the low to moderate ECEC and %BS of the soil was a resultant effect of the low OC content of the soil and the coarse texture of the soil (sand). This observation was consistent with the findings of Nwadialo (1991) and Emma-Okafor *et al*. (2022) who reported a positive relationship between OC, and CEC as well as negative relationship of coarse textured soil and BS; hence low OC in the soil resulted in decreased soil ECEC and %BS. The high value of exchangeable acidity could be inferred on the loss of basic cations by crop removal and leaching resulting in the accumulation of exchangeable aluminum and hydrogen. These reports corroborated the findings of Hailiu (2017) that reduced concentration of basic cations in the soil resulted in decreased soil pH which encouraged the increase availability of exchangeable H and Al.

Effect of Ash and Poultry Manure Interaction on Soil pH

There was significant interaction effect ($p \leq 0.05$) of ash and PM on soil pH at 6 WAP (Figure 1). The highest pH of 6.9 was obtained at the plot treated with combination of 3.00 × 0.00 of ash and PM, and this varied significantly ($p \leq 0.05$) from the other treatment combinations. The lowest pH of 4.5 which varied significantly ($p \leq 0.05$) form the other values obtained at the other treatment combinations was obtained at 0.00 × 0.00 (control plot).

It could be inferred that the increase in soil pH at the treated soils was probably as the result of the effect of the released basic cations from the ash and PM. These basic cations may have displaced hydrogen ions and saturated the soil colloidal complex. The notable improvement of soil pH by the inclusion of ash in the treatment combinations could be inferred on the reports of Baligar (2005), Blaise *et al*. (2011), Akinmutimi and Ukonu (2020) who stated that the simultaneous application of ash and PM reduced soil acidity by supplying the basic cations which replaced the active H ions in the soil colloids via massive action. Conversely, the lowest pH observed in the untreated plot could be attributed to the coarse texture of the soil having its textural class as sand. This coarse texture of the soil may have increased the loss of basic cations by leaching, and this may have resulted in the increased concentration of active H ions in the soil causing increased soil acidity (Emma-Okafor *et al*., 2022).

Interaction Effects of Ash and Poultry Manure on Exchangeable Acidity

There was significant ($p \leq 0.05$) variation among the treatments on exchangeable acidity (EA) at the various sampling periods (Table 2). The highest EA of 3.47, 5.73, 6.40 and 6.40 cmol kg^{-1} obtained at 3, 6, 9 and 12 WAP, respectively, were for the untreated soil (0.00 × 0.00), and these were significantly ($p \leq 0.05$) different from the values observed for the other treatments across the various sampling periods. The EA has been shown to be more of an acquired than inherited soil property (Obalum *et al.,* 2012). The results further showed that there was a progressive increase in EA with time at the untreated plot, whereas it fluctuated with time at the treated plots. The lowest EA of 1.20, 0.93, 1.87 and 1.33 cmol kg^{-1} at 3, 6, 9, and 12 WAP, respectively, were obtained from 0.00 × 8.00, the duo of 3.00 × 0.00 and 6.00 × 8.00, 6.00 × 8.00 and 6.00 × 4.00 treatments, respectively. The lowest EA at 3 WAP was similar ($p \geq 0.05$) to the other values except for that at the control (0.00 × 0.00). Also, the lowest EA of 0.93 cmol kg^{-1} obtained at 6 WAP was not significantly ($p \geq 0.05$) different from other treatments except 0.00 × 0.00 and 0.00 × 4.00. Similarly, at 9 and 12 WAP, the lowest EA of 1.87 and 1.33 cmol kg^{-1} observed under 6.00 × 8.00 and 6.00 × 4.00, respectively were similar ($p \geq 0.05$) with the other treatments combinations except those of 0.00 × 0.00 and 0.00 × 4.00.

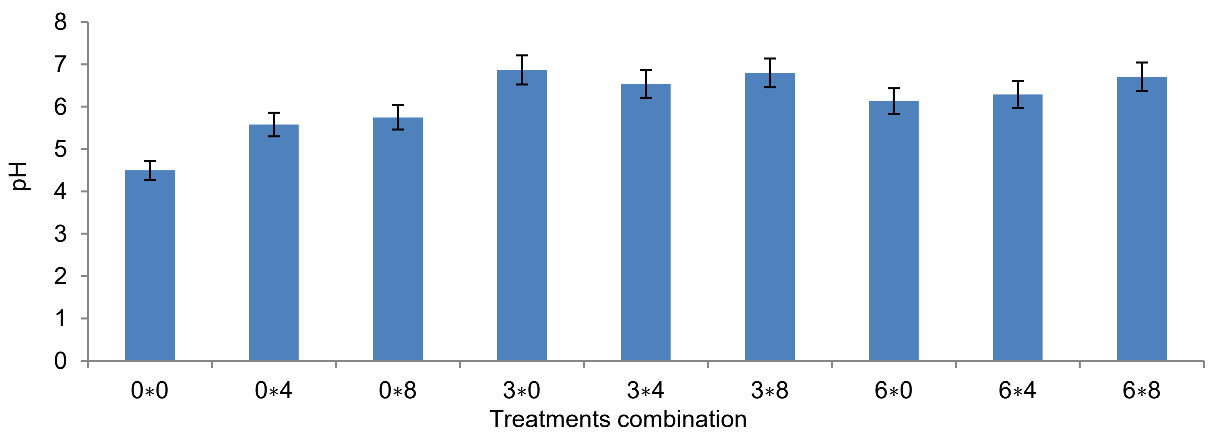

Figure 1: Interaction effect of ash and poultry manure on soil pH (LSD = 0.61)
0.00 ash and 0.00 poultry manure (0.00 × 0.00), 0.00 ash and 4.00 poultry manure (0.00 × 4.00), 0.00 ash and 8.00 poultry manure (0.00 × 8.00), 3.00 ash and 0.00 poultry manure (3.00 × 0.00), 3.00 ash and 4.00 poultry manure (3.00 × 4.00), 3.00 ash and 8.00 poultry manure (3.00 × 8.00), 6.00 ash and 0.00 poultry manure (6.00 × 0.00), 6.00 ash and 4.00 poultry manure (6.00 × 4.00), 6.00 ash and 8.00 poultry manure (6.00 × 8.00).

Table 2: Interaction effect of ash and poultry manure on exchangeable acidity (cmol kg^{-1})

Treatments combination (t ha^{-1})	3 WAP	6 WAP	9 WAP	12 WAP
0.00 × 0.00 (ash × PM)	3.47	5.73	6.40	6.40
0.00 × 4.00 (ash × PM)	2.00	1.73	3.73	2.93
0.00 × 8.00 (ash × PM)	1.20	1.20	2.67	1.60
3.00 × 0.00 (ash × PM)	1.87	0.93	2.13	1.60
3.00 × 4.00 (ash × PM)	1.87	1.20	2.67	1.87
3.00 × 8.00 (ash × PM)	1.33	1.07	2.67	1.60
6.00 × 0.00 (ash × PM)	2.27	1.07	2.13	1.60
6.00 × 4.00 (ash × PM)	1.47	1.47	2.40	1.33
6.00 × 8.00 (ash × PM)	2.00	0.93	1.87	1.87
LSD ($p \leq 0.05$)	0.88	0.61	1.84	1.01

LSD - least significant difference ($p \leq 0.05$), WAP - weeks after planting, PM - poultry manure. 0.00 ash and 0.00 poultry manure (0.00 × 0.00), 0.00 ash and 4.00 poultry manure (0.00 × 4.00), 0.00 ash and 8.00 poultry manure (0.00 × 8.00), 3.00 ash and 0.00 poultry manure (3.00 × 0.00), 3.00 ash and 4.00 poultry manure (3.00 × 4.00), 3.00 ash and 8.00 poultry manure (3.00 × 8.00), 6.00 ash and 0.00 poultry manure (6.00 × 0.00), 6.00 ash and 4.00 poultry manure (6.00 × 4.00), 6.00 ash and 8.00 poultry manure (6.00 × 8.00)

The decrease in the exchangeable acidity (EA) with treatments application at the various sampling periods could be attributed to the release of basic cations (K, Ca, Mg and Na) from the treatments; these basic cations may have saturated the exchange site and displaced Al and H ions by effect of massive action. This finding agrees with the reports of Duruigbo *et al.* (2007), Akinmutimi and Ukonu (2020) that H and Al ions were responsible for soil exchangeable acidity and affirmed that these were displaced by the mass flow action of the basic cations following the application of soil organic amendments, thus reducing the acidity.

Effect of Ash and Poultry Manure on Plant Height

The interaction of ash and PM on plant height was shown in Table 3. The untreated plot recorded the lowest maize heights of 3.50, 5.70, 6.40, and 6.40 cm for 3, 6, 9 and 12 WAP, respectively, and these varied significantly ($p \leq 0.05$) from the other treatments combinations at the various sampling periods. The highest maize height of 10.20 cm observed at plot treated with 0.00 × 4.00 t ha^{-1} of ash and PM at 3 WAP was significantly different from the values at other treatment combination except 9.90, 9.70 and 10.00 cm observed at 0.00 × 8.00, 3.00 × 8.00 and 6.00 × 8.00, respectively. The highest maize plant height of 29.30 cm observed in 0.00 × 8.00 at 6 WAP was significantly different ($p \leq 0.05$) from the other treatments combinations except 26.30 cm recorded at 6.00 × 8.00. The highest plant heights of 65.70 and 132.50 cm at 9 and 12 WAP, respectively, were observed under 6.00 × 8.00. The highest height at 9 WAP was not significantly ($p \geq 0.05$) different from those of 0.00 × 8.00 (63.50 cm) and 3.00 × 8.00 (57.00 cm), but varied significantly ($p \leq 0.05$) from those of other treatments combinations. The highest height at 12 WAP was not significantly ($p \geq 0.05$) different from those of 0.00 × 8.00 (110.50 cm) and 3.00 × 4.00 (114.40 cm), but varied significantly ($p \leq 0.05$) from others. The remarkable increase in the heights of the maize plants at the treated plots in the various sampling periods could be attributed to the release of basic cations from the treatments which decreased the soil reaction and improved nutrients uptake in the plant. Consequently, the stunted and sluggish growth of the maize plants at the untreated plot could be inferred on the increased soil acidity which may have decreased the availability of phosphorus as shown in the results of soil characterization (Table 1). These findings corroborate the reports of Baligar (2005) and Emma-Okafor *et al.* (2022) that increased acidity decreased nutrients availability and uptake in plants resulting to poor growth and performance of plants. On the other hand, the improvement of soil acidity which resulted to the release and availability

Table 3: Interaction effect of ash and poultry manure on plant

Treatment combination (t ha^{-1})	3 WAP (cm)	6 WAP (cm)	9 WAP (cm)	12 WAP (cm)
0.00 × 0.00 (ash × PM)	4.37	7.67	13.10	20.50
0.00 × 4.00 (ash × PM)	10.17	21.63	39.90	93.50
0.00 × 8.00 (ash × PM)	9.87	29.27	63.50	110.50
3.00 × 0.00 (ash × PM)	5.67	13.53	24.90	59.00
3.00 × 4.00 (ash × PM)	7.20	17.97	36.50	114.40
3.00 × 8.00 (ash × PM)	9.73	24.33	57.00	86.70
6.00 × 0.00 (ash × PM)	8.27	20.43	43.90	102.10
6.00 × 4.00 (ash × PM)	8.90	20.97	44.50	97.70
6.00 × 8.00 (ash × PM)	10.03	26.27	65.70	132.50
LSD ($p \leq 0.05$)	1.60	3.83	11.71	23.66

LSD - least significant difference, WAP - weeks after planting, PM - poultry manure. 0.00 ash and 0.00 poultry manure (0.00 × 0.00), 0.00 ash and 4.00 poultry manure (0.00 × 4.00), 0.00 ash and 8.00 poultry manure (0.00 × 8.00), 3.00 ash and 0.00 poultry manure (3.00 × 0.00), 3.00 ash and 4.00 poultry manure (3.00 × 4.00), 3.00 ash and 8.00 poultry manure (3.00 × 8.00), 6.00 ash and 0.00 poultry manure (6.00 × 0.00), 6.00 ash and 4.00 poultry manure (6.00 × 4.00), 6.00 ash and 8.00 poultry manure (6.00 × 8.00)

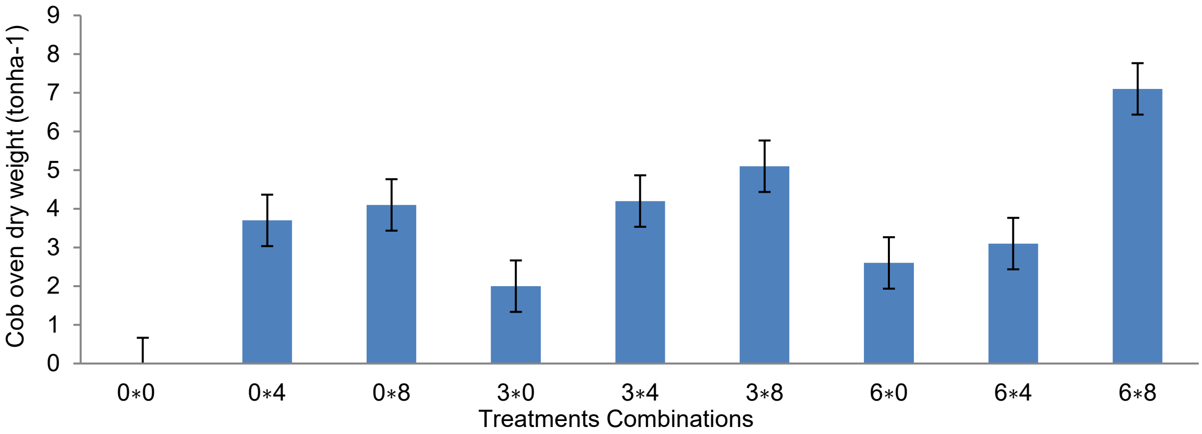

Figure 2: Interaction effect of ash and poultry manure on cob oven-dry weight (ton ha^{-1}) LSD = 1.05
0.00 ash and 0.00 poultry manure (0.00 × 0.00), 0.00 ash and 4.00 poultry manure (0.00 × 4.00), 0.00 ash and 8.00 poultry manure (0.00 × 8.00), 3.00 ash and 0.00 poultry manure (3.00 × 0.00), 3.00 ash and 4.00 poultry manure (3.00 × 4.00), 3.00 ash and 8.00 poultry manure (3.00 × 8.00), 6.00 ash and 0.00 poultry manure (6.00 × 0.00), 6.00 ash and 4.00 poultry manure (6.00 × 4.00), 6.00 ash and 8.00 poultry manure (6.00 × 8.00)

of essential nutrients elements and uptake by plants following the application of combined treatments of ash and PM translated to the formation of complex organic substances in the plants leading to increased cell division, multiplication and growth (Baligar, 2005; Emma-Okafor *et al.*, 2022). Hence, the increase in plant's height with increased rate of treatment combination was possibly due to improved nutrients availability and increased rate of nutrient absorption and utilization (Olayinka, 1990; Onwuka and Nsofor, 2011; Philip *et al.,* 2019).

Interaction Effect of Ash and Poultry Manure on Cob Dry Weight

There was significant ($p \leq 0.05$) interaction effect of ash and PM on the oven-dry weight of the cob of maize plant (Figure 2). No maize cob was obtained from the untreated plot (0.00 × 0.00), but the highest oven-dry cob weight of 7.15 t ha^{-1} was obtained under the combination of ash and PM at the rates of 6.00 and 8.00 t ha^{-1}, respectively, and this differed significantly from the oven-dry cob weight due to the other treatment combinations.

The improvement in oven-dry cob weight with treatments application could probably be as a result of the increased release of phosphorus from the soil organic amendments, and reduction in soil reaction by decrease in the concentration of Al and H in the soil solution (Emma-Okafor *et al.*, 2022). These acid-forming elements (Al and H) immobilize phosphorus by forming complexes leading to the unavailability of phosphorus; thus, soil organic amendments rich in phosphorus and basic cations were helpful in releasing more phosphorus in the soil while improving the availability of phosphorus by mobilizing the fixed phosphorus in soil (Mbagwu, 1992; Emma-Okafor *et al.*, 2022). Consequently, the possible improved availability of phosphorus to the maize plants at the treated plots by reduction in Al and H ion concentrations may have encouraged fruiting, seed formation and development in the maize plants (Mbagwu, 1992; Ijoyah, 2009; Emma-Okafor *et al.*, 2022). Also, the reduction in soil acidity via the release of basic cations may have helped to reduce toxicity and improved root growth which enhanced the nutrient absorption capacity of the crop and its nutrient utilization efficiency (Obi and Ebo, 1995; Onwuka *et al.*, 2016). Therefore, the highest value of cob dry weight obtained at 6.00 of ash × 8.00 t ha^{-1} of PM was possibly a result of the significant reductions in soil acidity by the ash and possible increase in the release of essential plant nutrients (phosphorus as well as K, Ca and Mg) from PM (Olayinka, 1990; Emma-Okafor *et al.*, 2022).

Relating the above observation to the data attained Unagwu *et al.* (2012) showing that PM at 8.00 t ha^{-1} plus reduced NPK fertilizer gave the highest maize dry matter, it would appear that PM at this application rate requires any soil amendment that enhances the status of phosphorus and base-forming nutrient elements for optimal agronomic effects in coarse-textured acid soils. The present results agree with the reports of Agboola and Unanema (1991), Mbagwu (1992) and Emma-Okafor *et al.* (2022) that an increase in the yields of maize and guinea corn was a result of application of liming material and manure, respectively. So, the zero yields observed at the control plots was possibly due to the increased soil acidity, decreased phosphorus availability and low contents of basic cations as shown in the data of soil characterization (Table 1). This result agrees with lower maize yields from untreated compared to treated similar soils (Unagwu *et al.*, 2012; Olufemi *et al.*, 2018).

CONCLUSION

The interaction of poultry manure and ash improved soil reaction and performance of maize plant. The combination of ash and poultry manure at the rates of 6.00 × 8.00 t ha^{-1}, respectively produced the optimum effect in simultaneously improving the soil reaction and performance of maize. Therefore, combined application of ash and poultry manure at these rates is proposed for ameliorating soil acidity and increasing maize production in these soils.

REFERENCES

Agboola A.A. and Unanema R.P.A. (1991). Maintenance of soil fertility under traditional farming system. Proc. Nat. Org. Fert., pp. 7-20

Akinmutimi A. and Ukonu A. (2020). Comparative effects of wood ash and poultry manure on soil pH and potassium released from an Ultisol in Umudike, Abia State, Nigeria. *Curr. Investig. Agric. Curr. Res.,* **8 (2).** https://doi.org/10.32474/CIACR.2020.08.000283

Amanze C.T., Oguike P.C. and Eneje R.C. (2017). Land use effect on some physicochemical properties of Ultisol at Ndume Ibeku, southeastern Nigeria. *Int. J. Sci. Res.,* **7 (9),** 2250-3153

Amanze C.T., Oguike P.C. and Lekwa G. (2016). Characterization and classification of soils at Mbara Achara Ubowalla, Emekuku in Owerri North LGA, Imo State. *Nig. J. Soil Environ. Res.,* **14,** 245-255

Amanze C.T., Oguike P.C., Eneje R.C. *et al.* (2022). Organic carbon in relation to water retention characteristics of a Typic Hapludult under four land use types at Ndume Ibeku in southeastern Nigeria. *Int. J. Agric. Rural Dev.,* **25 (2),** 6512-6517

Ano O.A. (2004). Soil fertility assessment. Federal Fertilizer Department, NSPFS, Abuja, Nigeria, p. 62

Balesdent J., Chenu C. and Balabane M. (2000). Relationship of soil organic matter dynamics to physical protection and tillage. *Soil Till. Res.,* **53,** 215-230

Baligar V.C. (2005). Soil acidity, impact on nutrients use efficiency and yield sustainability of crops. Research Project, World Congress of Soil Science [Abstract]

Blaise P.B., Brigitte A.K., Zambou F. and Heribert I. (2011). Possible use of wood ash and compost for improving acid tropical soils. In: *Recycling of Biomass Ashes* (pp. 87-105). https://doi.org/10.1007/978-3-642-19354-5_7

Bremner J.M. (1996). Total nitrogen. In: Black C.A. (ed.), *Methods of Soil Analysis, Part 2* (vol. 196, pp. 1119-1178). Am. Soc. Agron., Madison, WI

Duruigbo C.I., Obiefuna J.C. and Onweremadu E.U. (2007). Effect of poultry manure rates on soil acidity in an Ultisol. *Int. J. Soil Sci.,* **2 (2),** 154-158

Emma-Okafor L., Obijuru E., Nwokeji L., Echereobia C. and Okoli N. (2022). Effect of poultry manure and wood ash on the growth and yield of cucumber (*Cucumis sativum* L.) in Owerri, eastern Nigeria. *Net J. Agric. Sci.,* **10 (2),** 49-53

Erebor O. (1998). *Comprehensive Agricultural Science.* A.J. Publishers Limited, Lagos, Nigeria, p. 26

Gee G.W. and Or D. (2002). Particle size analysis. In: Dane J.H., Topp G.C. (eds.), *Methods of Soil Analysis, Physical Methods* (pp. 255-293). Am. Soc. Agron., Soil Sci. Soc. Am., Madison, WI

Hailiu Z. (2017). Causes and effects of soil acidity. Ferguson College of Agricultural Research, Oklahoma State University, p. 744

Igwe C.A., Nwite J.C., Agharanya K.U., Watanabe Y., Obalum S.E., Okebalama C.B. and Wakatsuki T. (2013). Aggregate-associated soil organic carbon and total nitrogen following amendment of puddled and *sawah*-managed rice soils in southeastern Nigeria. *Arch. Agron. Soil Sci.,* **59 (6),** 859-874. https://doi.org/10.1080/03650340.2012.684877

IITA (1999). Effect of liming on soil acidity. Internet In-service Training, International Institute of Tropical Agriculture, Ibadan. Retrieved from http://www.ubcap.clement.edu./blpprt/acid2.htm

Ijoyah M.O. (2009). Effects of different levels of decomposed poultry manure on yield of cabbage (*Brassica oleraceae* L.) at Anse Boileau Seychelles. *Agro-Science,* **8 (1),** 20-23

Kutilek M. (2005). Change of soil porous system due to land use. Lecture Notes, College of Soil Physics, Int. Center for Theoretical Physics, Trieste, Italy

Lalljee B.C. and Facknath S. (2022). Effects of lime on nutrient content of soil, yield and nutrient content of potato and infestation by leaf miners. Retrieved from https://www.gov.mu/portal/sites/ncb/moa/faro/amas2001/html/s4.htm

Lekwa G. and Whiteside E.P. (1986). Coastal plain sands of south eastern Nigeria: Morphological classification and genetic relationship. *Soil Sci. Soc. Am. J.,* **50,** 154-160

Mbagwu J.S.C. (1992). Improving the productivity of degraded Ultisol in Nigeria using organic and inorganic amendments: Chemical properties and yield of maize. *Bioresour. Technol.,* **4,** 149-154

Mcleans E.O. (1982). Soil pH and lime requirement. In: Miller R.H., Keeny D.R. (eds.), *Methods of Soil Analysis, Part 2* (pp. 199-224). Am. Soc. Agron., Madison, WI

Monday A. (2017). Economic value of maize (*Zea mays* L.) in Nigeria and its impacts on global food production. *Int. J. Sci. World,* **6 (1),** 27. https://doi.org/10.14419/ijsw.v6i1.8771

Nelson D.W.M. and Sommers L.E. (1982). Total carbon, organic carbon and organic matter. In: Page A.L., Miller R.H., Keeny D.R. (eds.), *Methods of Soil Analysis, Part 2* (pp. 539-580). Am. Soc. Agron., Madison, WI

NiMet (2019). *Seasonal Rainfall Prediction for 2019.* Nigeria Meteorological Agency Publications, Maitama, Abuja, pp. 18-19

Nnadi A.L., Nnanna P.I., Onyia V.N., Obalum S.E. and Igwe C.A. (2020). Growth and yield responses of high-density coverage sweet potato to liming and fertilizer combinations for sandy-loam Ultisols at Nsukka, southeastern Nigeria. In: *Climate-Smart Soil Management, Soil Health/ Quality and Land Management: Synergies for Sustainable Ecosystem Services* (pp. 263-269), Proceedings of the 44th Annual Conference of Soil Science Society of Nigeria (SSSN), 16-20 March 2020 [Colloquia SSSN 44], Enugu State University of Science & Technology (ESUT), Enugu, Enugu State, Nigeria

Nwadiola B.E. (1991). The Effect of poultry manure on the productivity of a Kandic Paleustult. *Nig. Agric. J.,* **26,** 29-35

Nwite J.C., Essien B.A., Anaele M.U., Igwe C.A., Obalum S.E. and Okolo C. (2012b). Effect of rice husk and rice husk ash supplemented with poultry dropping on soil chemical properties, growth and yield of maize (*Zea mays*) in Ishiagu. Presented under *Climate Change, Soil Management Alternatives and Sustainable Food Production,* the 36th Annual Conference of Soil Science Society of Nigeria (SSSN), 12-16 Mar. 2012, Hall of Fame, University of Nigeria, Nsukka, Nigeria

Nwite J.C., Essien B.A., Anaele M.U., Obalum S.E., Keke C.I. and Igwe C.A. (2012a). Supplementary use of poultry droppings and rice-husk waste as organic amendments in southeastern Nigeria. 1. soil chemical properties and maize yield. *Libyan Agric. Res. Centre J. Int.,* **3 (2)**, 90-97

Nwite J.C., Igwe C.A. and Obalum S.E. (2011b). The contributions of different ash sources to the improvement in properties of a degraded Ultisol and maize production in southeastern Nigeria. *American-Eurasian J. Sustainable Agric.*, **5 (1)**, 34-41

Nwite J.C., Keke C.I., Obalum S.E., Essien J.B., Anaele M.U. and Igwe C.A. (2013). Organo-mineral amendment options for enhancing soil fertility and nutrient composition and yield of fluted pumpkin. *Int. J. Vegetable Sci.*, **19 (2)**, 188-199. https://doi.org/10.1080/19315260.2012.705233

Nwite J.C., Obalum S.E., Igwe C.A., and Wakatsuki T. (2011a). Properties and potential of selected ash sources for improving soil condition and *sawah* rice yields in a degraded inland valley in southeastern Nigeria. *World J. Agric. Sci.*, **7 (3)**, 304-310

Obalum S.E., Nwite J.C., Watanabe Y., Igwe C.A. and Wakatsuki T. (2012). Comparative topsoil characterization of *sawah* rice fields in selected inland valleys around Bida, north-central Nigeria: physicochemical properties and fertility status. *Trop. Agric. Dev.,* **56 (2),** 39-48. https://doi.org/10.11248/jsta.56.39

Obalum S.E., Ogumba P.O. and Uzoh I.M. (2020). Influence of tillage-seedbed and manure-NPK-micronutrient management options on selected soil properties of sandy-loam Ultisols evaluated using sweet potato. *Nigerian J. Soil Sci.,* **30 (3),** 117-125

Obi M.E. and Ebo P.O. (1995). The effect of organic and inorganic amendments on soil physical properties and maize production in a severely degraded sandy soil in southern Nigeria. *Bioresour. Technol.,* **51,** 117-123

Ogunezi K.C., Okebalama C.B. and Obalum S.E. (2019). Optimum poultry droppings rate for coarse-loamy Ultisols based on soil macro-aggregation and fertility indices and evaluation using cucumber (*Cucumis sativus*). Presented under *Understanding Nigerian Soils for Sustainable Food & Nutrition Security and Healthy Environment,* the 43rd Annual Conf. Soil Sci. Soc. Nigeria (SSSN), 15-19 July 2019, University of Agriculture, Makurdi, Benue State, Nigeria

Olayinka A. (1990). Effect of poultry manure, corn straw and sawdust on plant growth and soil chemical properties. *Ife J. Agric.,* **12,** 1

Olufemi G., Oyodele O. and Ogunwale G. (2018). Effect of the application of poultry manure and wood ash on maize (*Zea mays* L.) performance. *J. Hort. Plant Res.,* **4,** 11-16. https://doi.org/10.18052/JHPR.4.11

Onwuka M. and Nsofor H. (2011). The effect of kitchen residue, ash, poultry manure and goat dung on soil properties and yield of cowpea (*Vigna unguiculata*) in a typic Kandiudult of southeastern Nigeria. *J. Agric. Food Sci.,* **96 (2).** https://doi.org/10.4314jafsv9i2.6

Olsen S.R. and Sommers L.E. (1984). Determination of available phosphorus. In: *Methods of Soil Analysis Part 2, Chemical and Microbial Properties* 2nd ed. (pp. 403-430). Agron. Monogr. No. 9

Philip J.B., Ariel A.S. and Paul O.S. (2019). Fertilizer efficacy of poultry litter and ash blended with lime or gypsum as fillers. *Environ.,* **6 (5),** 50. https://doi.org/10.3390environment6050050

Tel D.A. and Hagarty M. (1984). Soil and plant analysis. Study guide for agricultural laboratory directors and technologists working at International Institute for Tropical Agriculture, Ibadan, Nigeria and University of Guelph, Ontario, Canada, p. 277

Umeugokwe C.P., Ugwu V.U., Umeugochukwu O.P., Uzoh I.M., Obalum S.E., Ddamulira G., Karwani G.M. and Alenoma G. (2021). Soil fertility indices of tropical loamy sand as influenced by bambara groundnut variety, plant spacing and fertilizer type. *Agro-Science*, **20 (1),** 65-71. https://dx.doi.org/10.4314/as.v20i1.11

Unagwu B.O., Asadu C.L.A. and Obalum S.E. (2013). Maize performance in a sandy loam Ultisol amended with NPK 15-15-15 and poultry manure. In: *The Role of Crop Science in the Agricultural Transformation Agenda* (pp. 135-141), Proceedings of the 1st National Annual Conference of the Crop Science Society of Nigeria (CSSN), 15-19 Sep. 2013, University of Nigeria, Nsukka, Nigeria