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Original Research Article

Soil Fertility Properties, Growth and Yield of Groundnut (*Arachis hypogeal* L.) As Influenced By the Application of Wood Ash and NPK Fertilizers in an Ultisol of Southeastern Nigeria

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Abstract: A Greenhouse study to investigate the effect of wood ash and NPK fertilizer on some selected soil fertility indices (pH, organic carbon, organic matter, total nitrogen, available Phosphorus, exchangeable acidity, exchangeable bases and Effective Cation Exchange Capacity), Growth and Yield properties (number of leaves, plant height and number of pods) of Groundnut (*Arachis hypogeal L.*) was carried out in the Teaching and Research Farm, Department of Horticulture and Landscape Technology, Akanu Ibiam Federal Polytechnic, Unwana, Southeastern Nigeria. Factorial Experiment in Complete Randomized Design (CRD) in three replications comprising of three rates (0.1 and 2ton ha^{-1}) wood ash and three rates (0.1 and 2ton ha^{-1}) NPK was used for the study. Results obtained showed that relative to the control experiment, the application of both fertilizer materials both as lone and combined treatments, significantly improved the soil fertility properties, growth and yield properties of Groundnut. Wood ash as lone treatment significantly reduced soil acidity which led to improvement on the quantity of other fertility variables tested. While the single application of the amendment had significant ($P<0.05$) effects on soil chemical properties, however, the interactive effect of these soil improvers were only significant in influencing the available P, Exchangeable bases and ECEC. The improvement on soil fertility properties as well as growth and yield properties of Groundnut was much better in experiments that had 2 tons ha^{-1} wood ash and 1 tons ha^{-1} NPK fertilizers. In view of this observation, treatment rates of 2 tons ha^{-1} wood ash and 1 tons ha^{-1} NPK is recommended for profitable and sustainable groundnut production in this area.

Keywords: Wood Ash, NPK, Soil fertility and Groundnut.

INTRODUCTION

The processes of soil nutrient loss through leaching, erosion, adsorption and plant removal occasioned by intense tropical rainfall, soil acidity, heavy and continuous cultivation to support the growing population in Southeastern Nigeria has led to soil fertility decline and thus low productivity (Azu, *et al.*, 2018). In the light of the above scenario, profitable and sustainable crop production in these highly weathered utisols of southeastern Nigeria can only be a mirage if external fertilizer input is not incorporated into the farming system.

Agrochemicals, especially chemical fertilizers have conventionally been used to improve soil fertility and thus, crop production (Awodum, 2007). Over the years, the persistence and over-use of chemical fertilizers has resulted to various degrees of soil degradation including nutrient imbalance, soil acidity, loss of organic matter, soil erosion (Ojeniyi and Adeniyan, 1999; Azu *et al.*, 2017). Acidification of soil resulting from the aggressive use of mineral fertilizers is claimed to be one of the major reasons for deterioration of soil on global bases (Stammer, 1992). Some human diseases such as cancer, diabetics, and hypertension have been linked to residues of mineral fertilizers in consumed crop produce; thus, Moyin (2007) reported a drastic shift from the consumption of food crops produce with mineral fertilizers to food produced with organic fertilizer in developed nations. Consequently, recent studies have focused on the use of organic matter as soil improvers and sources of nutrient

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to plants (Awodun, 2007). Long term conservation of soil health in terms of structure, biological and chemical properties which are vital in sustainable agriculture is the benefit of organic fertilizers (Ghabbour and Daves, 2001; Young *et al.,* 2000).

One of the cheap and efficient source of organic matter commonly used in agriculture is the wood ash. Ash is the residue from combustion of organic materials, containing most of the inorganic nutrients and trace elements of the biomass (Willand, 2017). However, it is a significant source of a number of plant nutrients including P, K, Mg and Ca together with a number of micronutrients (Bougnom *et al.,* 2011). It also has properties resembling those of lime. Thus, applying ash to agricultural fields can compensate for nutrient losses caused by harvesting and leaching and counteract soil acidification (Saarsalmi *et al.,* 2006; Nkana *et al.,*1998).

The effect of wood ash on crop growth has been severally studied in different agro-ecological zones (Abl-soud *et al.,* 2010). According to Onwuka *et al.,* (2007), wood ash application effectively reduced acidity and therefore reported that wood ash if properly used can serve as a suitable alternative to commercial lime in treating acidic tropical soils for better crop production. Just like other organic fertilizer sources, the limitation in the use of wood ash as fertilizer are the difficulty in obtaining large quantity for commercial agriculture and the slow release of nutrients to crops (Iren, 2009). In view of the above, integration of mineral and organic fertilizers in fertility management has become a current trend (Azu *et al.,* 2017; Ano and Asumugha, 2000). Studies on the integrated use of wood ash and NPK as fertilizer have shown improvement on nutrient status by stimulating decomposition rate, speed up nutrient release and enhance crop production especially during the vegetative phase (Sagakkara and Higa, 1992).

Groundnut (Arachis hypogeal) is an important legume crop with more than 100 million metric tonnes produced annually (Eapen, 2003). The highest proportion of its production come from tropical and warm temperate countries and there is great interest by many tropical countries to promote groundnut production to meet the ever increasing demand for protein and vegetable oil (Okello *et al.,* 2010). In Nigeria, it is mainly planted in arid and semi-arid northern regions where over 85% of national produce comes from. Groundnut production in Nigeria has decreased over the years due to soil fertility decline. Even though, groundnut possesses the unique ability of fixing atmospheric nitrogen, reports have shown that this process requires large amount of other nutrients especially P (Osodeke, 2002). With the increased interest in groundnut production in the acid tropical soils of southeastern Nigeria, there is the need to adopt soil fertility management strategy that will enhance soil health and productivity.

Information on the integrated effect of wood ash and NPK on soil properties and yield of groundnut is still limited in southeastern Nigerian. This study was therefore designed to evaluate the integrated effect of wood ash and NPK on soil fertility properties, growth and yield of groundnut in southeastern Nigeria.

MATERIALS AND METHOD.

The pot experiment was carried out in the Green House of Akanu Ibiam Federal Polytechnic Unwana, tropical rain forest zone of Nigeria (coordinates: latitude $5^0$48'N and longitude $7^0$55'E). The soil of the experimental area is a Typic Hapludult (Federal Department of Agriculture and Land Resources, 1985; Nwaogu and Ebeniro, 2009). The air temperature is generally high all year round and the current temperature range is 32^oC -21^oC with total annual rainfall exceeding 3,500 mm (Njoku *et al.,* 2006).The area has being use for cassava cultivation for more than ten years

Soil samples were collected with the soil anger from the Polytechnic multi-purpose farm at 0-20cm depth. This was air dried, sieved with 2mm sieve, after which sub-samples of 5kg each were weighed into 12L capacity plastic buckets perforated at the bottom to allow for air and water movement.

The experiment consisted of 27 treatments, corresponding to three rates (0, 1 and, 2, ton ha^{-1}) wood ash and three rates (0, 1, and 2 ton ha^{-1}) NPK, arranged factorially in a completely randomized design (CRD) with three replications. Seeds of groundnut were planted two weeks after soil amendment. Two seeds were sown per hole in each bucket and later thinned down to one seedling per stand after two weeks of germination. Adequate watering, weeding and pest control were observed throughout the growing period.

At 10 weeks after sowing (WAS), agronomic and growth parameters data were collected from each pot. Data collected at the early bloom stage (6 WAS) included plant height, and number of leaves. At maturity, the yield component collected was the number of pods per plant.

Post-harvest soil samples were collected from each pot and the following chemical analysis were carried out according to standard procedure: Soil pH (Udo, *et al.,*2009), org. C (Pansu and Gautheyrous, 2006), total N (Simmone *et al.,* 1994), Available P (Bray and Kurtz, 1945) ECEC (Udo, *et al.,*2009)and base saturation was obtained mathematically with:

$$B5(\%) = \frac{\text{Total cations}}{\text{ECEC}} \times \frac{100}{1}$$

Statistical analysis was done by the analysis of variance (ANOVA) and the means separated using FlsD.0.05

RESULTS AND DISCUSSION

Physical and chemical properties of the soil used for the study

Table 2 shows some of the physical and chemical properties of the soil used for the trial. The soil was a clay loam with high clay content (38.31%). The pH was low, indicating acidity. Organic carbon and organic matter were relatively moderate (1.90, 3.29% respectively), nitrogen and P content were low, below the critical values proposed by Osodeke (2000) for most crops in southeastern Nigeria. The low P content observed in this study may be related to high P fixation, consequent of the high Fe^{+2} and Al^{+3} in this soil. Azu *et al.*,(20017) have also reported similar observation. Total acidity was high (4.01cmol/kg). However, the total exchangeable bases were high and thus, base saturation was also high. The high carbonate content of the soil, coupled with the shale parent material of the soil must have been responsible for observed high base concentration as previously reported by Azu *et al.*, (2018). The chemical properties of the soil shows that it is low in fertility and therefore require external manure input for profitable crop production.

Table1.1. Some physical and chemical properties of the soil and wood ash used for the study.

Properties	Soil	Wood ash
Sand (%)	40.13	-
Silt (%)	21.56	-
Clay (%)	38.31	-
Texture	Clayey – loam	-
pH (H_2O)	4.27	11.17
pH ($Cacl_2$)	3.78	10.61
Org. C. (%)	1.90	3.65
Org. M (%)	3.29	6.34
Total N (%)	0.25	0.03
Av. P (mg/kg)	5.62	19.50
Ca (cmol. /kg)	3.18	12.20
Mg (cmol. /kg)	1.00	14.00
K (cmol. /kg)	0.06	4.73
Na (cmol. /kg)	0.02	1.59
Exc. Acidity	4.01	-
ECEC	8.27	-
B.S%	51.51	

Similarly, the chemical properties of the wood ash used for the study is shown in Table 2. Wood ash consists of inorganic minerals and organic compounds remaining in the ash because of incomplete combustion. Nitrogen, which volatalizes during combustion, was found only in very small amount (0.03%), but all the macronutrients occur in the ash. The major proportion of the mineral elements in the ash comprised of P (19.5mg/kg), OC (3.65%),. The exchangeable bases were in the order of Mg>Ca>K>Na. The high base concentration in the wood ash may have led to increased pH (11.17) observed in the study .Other researcher have previously reported high nutrient content in wood ash (Onwuka *et al.*, 2007; Mandre, 2006; Willund, 2017). The high nutrient content in wood ash is an indication of the potentials of wood ash not only as a lime material, but also an important fertilizer source for crop growth.

Effect of Wood Ash and NPK Fertilizer on Soil Chemistry

The effect of wood ash and NPK fertilizer on soil chemical properties is presented in Table 2. Results showed that relative to control, there were improvements in all the properties studied. The effect of raw wood ash and NPK fertilizer on the pH of soil showed significant difference ($P<0.05$). The pH was significantly lower in all NPK lone fertilizer treatments than in the ash treatment. The lone application of wood ash significantly increased the pH and the increases were proportional to amendment rates. This was expected, since wood ash is known to have a neutralizing effect on acid soil, (Etiegni & Campbell, 1991; Ohno, 1992; Nkana *et al.*, 1998). The highest pH value of 6.99 was obtained when 2tons ha^{-1} wood ash was applied. This result may probably be related to the high concentration of basic cations in wood ash which agrees with the report of Onwuka et at al., (2007), who reported a decrease in soil acidity when wood ash was used as a lime material. Mandre, (2006) has also reported increased pH when wood ash was applied in a field experiment. Etigieni and Campbell (1991) argue that the high solubility of ash can lead to a faster rise in soil pH when ash is applied. On the other hand, lone application of NPK did not acidity at the same proportion, the lone application of wood ash did. However, the interactive effect of both materials significantly improved the acidity.

Significant difference on the organic carbon and organic matter when the treatments were applied both as single and combined treatments. The application of wood ash as lone treatments showed consistence higher proportion than NPK in organic carbon and matter content and the amount of these parameters increased with rate of wood ash application. On the other hand, organic carbon and matter tend to decrease with increased application of NPK. Mineral fertilizers have been reportedly known to decrease soil organic matter (Brady and Weil, 2008; Azu *et al.,* 2017, Awodum, 2007). The increase in soil organic carbon and organic matter as a result of wood ash application can be a reflection of the high content of this element in wood ash. This therefore suggests the potentials of wood ash as source of organic carbon to the soil.

Nitrogen content of the soil was significantly ($P<0.05$) increased as a result of the treating the soils with both wood ash and NPK fertilizer and the improvement increased with application rate. However, NPK consistently showed higher improvement in N content as lone treatment than wood ash. This observation can be attributed to the fact that Nitrogen volatilizes during combustion and thus has little effect on the soil N content. However, the interactive effect of the treatment showed significant increased N and the highest amount of 0.31% was obtained in the experiment that content 2tons ha^{-1} each of wood ash and NPK. Recent studies have reported better improvement of soil fertility condition when organic manures are integrated with mineral fertilizer in farming systems (Ano and Asumugh, 2000; Azu *et al.,* 2017).

Table2. Mean effect of wood ash and NPK on soil chemical properties

WA + NPK		pH		Av.P	Org.C	Org.M	TN	TEB	TEA	ECEC	BS
	Ton ha^{-1}	H_20	$CaCl_2$	mg/kg		%			Cmol/kg	%	
0 + 0	4.87	4.42	5.05	1.97	3.40	0.13	2.60	3.99	6.59	39.49	
0 + 1	4.63	4.24	5.86	1.50	2.59	0.18	3.37	3.79	7.16	55.58	
0 + 2	4.31	4.80	5.22	1.33	2.63	0.20	3.36	3.80	7.36	45.96	
1 + 0	6.73	5.92	6.48	2.18	3.77	0.13	3.91	4.52	8.43	51.64	
1 + 1	6.63	5.63	6.51	2.00	3.46	0.24	5.23	2.48	7.71	67.78	
1 + 2	6.58	5.38	6.10	1.84	3.18	0.25	3.45	2.62	6.07	56.67	
2 + 0	6.99	6.59	6.80	2.90	4.98	0.23	4.92	2.71	7.63	66.09	
2 + 1	6.93	6.13	7.08	2.36	3.76	0.24	6.14	1.60	7.74	78.30	
2 + 2	6.51	6.05	7.07	2.04	3.52	0.31	6.00	2.28	8.28	72.49	
Lsd(0.05)WA	0.013	0.131	0.036	0.109	1.376	0.0007	0.017	0.012	0.582	24.598	
Lsd(0.05)NPK	0.013	0.131	0.036	0.109	1.376	0.0007	0.017	0.012	0.582	24.598	
WA x NPK	NS	NS	0.217	NS	NS	NS	0.052	0.026	1.747	NS	

Significant differences ($P<0.05$) in available P were observed as a result of the application of wood ash and NPK both as single and combined treatments. Relative to the control experiment, available P increased with the amendments. The reduction in soil acidity due the addition of wood ash must have encouraged the solubility of adsorbed P (Osodeke and Ubah, 2005). As a consequence of raised pH, wood ash can contribute to lowering Al toxicity and increase available P (Demeyer *et al.,* 2001; Mbah *et al.,* 2010).

Exchangeable bases were significantly higher in treatments that had wood ash than those that had NPK as lone treatments. However, significant difference in basic cations was observed when these materials were applied as lone and combined treatments. Wood ash can increase exchangeable base cations and ECEC (effective cation exchange capacity), as shown by Nkana *et al.,* (1998).Similarly, the exchangeable acidity was reduced due to wood ash application.

Effect of wood ash and NPK on plant performance

The effect of wood ash and NPK fertilizer on the growth and yield of groundnut is shown in figure 1. Improvements on the plant parameters relative to control were observed.

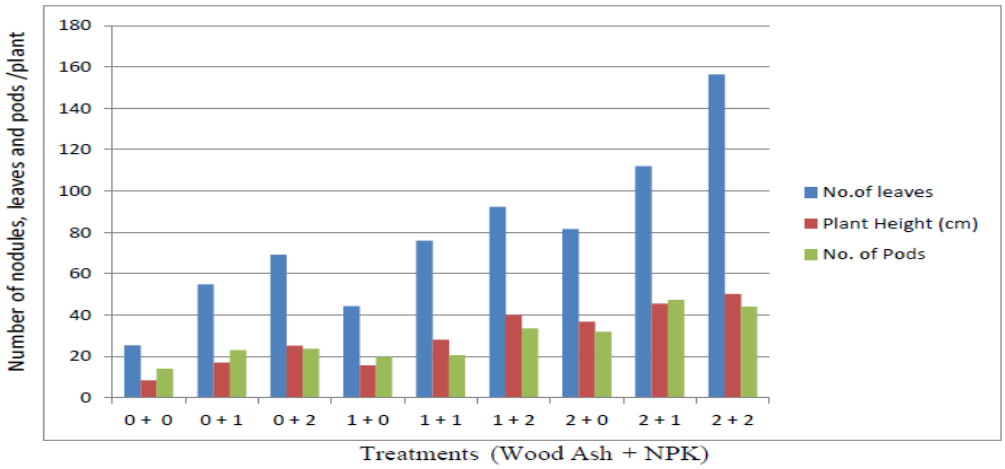

Fig. 1. Number of leaves, plant height and number of pods of groundnut as affected by the addition of Wood Ash and NPK Fertilizer

The number of leaves was significantly increased with the addition of both fertilizer materials and the increase was proportional to the amendment rates. Similarly, the plant height and number of pods and number of pods were increased with increased addition of the fertilizer materials. This result may be attributed to the high nutrient content in wood ash and NPK. The treatment combination of 2tons ha^{-1} wood ash and 1ton ha^{-1} NPK gave the best result in all plant parameters studied. Several others Researchers have previously reported better plant yield consequent of wood ash application (Onwuka *et al.*, 2007; Mandre, 2006; Wiklund, 2017).

CONCLUSION

Several changes and improvements in the chemical composition of the soil studied appeared after application of wood ash and NPK fertilizer. Wood ash usually increases the pH, organic matter, organic carbon and base saturation more than the NPK. However, the NPK was more effective than wood ash in improving the N content of the soil. Apart from few fertility parameters, significant effect ($P<0.05$) were observed with treatments comprising wood ash and NPK both as lone and combined treatments. The treatment combination of 2tons ha^{-1} w00d ash and 1ton ha^{-1} NPK relatively proved to be superior in soil chemical properties compared to other treatment combinations.

It is evident that the enrichment and improved mineral composition of soil due to the application of wood ash and NPK may cause changes in the metabolism and physiological activity of the groundnut, thus the observed increase in both growth and yield properties. While the number of leaves and plant height were better improved by lone application of NPK, number of pods was higher in wood ash treated pots. However, the interaction between the treatments was superior to their single application. Similarly, the treatment combination of 2tons ha^{-1} wood ash and 1ton ha^{-1} NPK relatively proved to be superior in soil chemical properties compared to other treatment combinations. It is therefore recommended that for profitable and sustainable production in Southeastern Nigeria, treatment combination of 2tons ha^{-1} w00d ash and 1ton ha^{-1} NPK should be adopted.

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