Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.4, No.14, 2014

Improving fertility of an acid Alfisol and maize (*Zea mays* L.) yield performance with integrated application of organic and inorganic soil amendments

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Abstract

In view of the limitations or inadequacies of sole use of organic or inorganic fertilizers to improve soil fertility, as well as high cost and scarcity in Nigeria, of inorganic limes, commonly used for reducing soil acidity. There is a dire need to critically assess the potential of combined application of readily available and cheap organic and inorganic fertilizers, as nutrient sources to improve soil fertility, and the use of organic limes to reduce soil acidity, and thus, ensure balanced crop nutrition with attendant high crop yield. To this effect, a two – year study was designed to evaluate the influence of wood ash – based soil amendments on chemical properties of an acid Alfisol and grain yield of maize (*Zea mays* L.). The experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2011 and 2012 cropping seasons. The experiment was laid out in a randomized complete block design with three replications. The wood ash – based soil amendments included: sole wood ash (SWA); wood ash + NPK (15 – 15- 15) fertilizer (WA+ NPK); wood ash + ammonium sulphate fertilizer (WA+AS); and no fertilizer (NF) (check), which served as the control treatment. The results obtained indicated existence of significant ($P = 0.05$) differences among the wood ash – based soil amendments as regards their effects on chemical properties of the Alfisol and maize grain yield. At the end of 2011 cropping season, application of the wood ash – based soil amendments resulted in significant ($P = 0.05$) increases in soil organic carbon (SOC) from 0.61 g kg^{-1} for NF to 1.47, 1.32 and 1.09 g kg^{-1} for SWA, WA+ NPK, and WA+AS, respectively. Similarly, at the end of 2012 cropping season, application of the wood ash – based soil amendments resulted in significant increases in SOC from 0.43 g kg^{-1} for NF to 1.65, 1.51 and 1.17 g kg^{-1} for SWA, WA+ NPK, and WA+AS, respectively. At the end of 2011 cropping season, application of the wood ash – based soil amendments significantly increased total nitrogen from 0.26 g kg^{-1} for NF to 0.40, 0.57 and 0.51 g kg^{-1} for SWA, WA+ NPK, and WA+AS, respectively. At the end of 2012 cropping season, the wood ash – based soil amendments significantly increased total nitrogen from 0.14 g kg^{-1} for NF to 0.51, 0.66 and 0.60 g kg^{-1} for the respective SWA, WA+ NPK, and WA+AS. Means of maize grain yield data across the two years of experimentation indicated that, the wood ash – based soil amendments significantly increased maize grain yield from 0.86 t ha^{-1} for NF to 2.26, 2.57 and 2.47 t ha^{-1} for the respective SWA, WA + NPK and WA + AS. Of all the fertilizer combination treatments, wood ash + NPK fertilizer gave the highest maize grain yield and yield components in both years, and therefore, a judicious and balanced combination of wood ash and NPK fertilizer is recommended for maize cultivation.

Key words: Acid, alfisol, fertility, inorganic, maize, organic, soil

Introduction

One of the major constraints to crop production in the tropics is the inherently low fertility status of the tropical soils, characterized by low activity clay, organic matter, nitrogen, phosphorus and exchangeable bases (Awodun and Olafusi, 2007; Kader, 2012; Lume, 2013). The limitations of the utilization of the low activity clay (LAC) tropical soils for continuous crop production have necessitated growing search for professionally efficient soil fertility improvement practices, which in recent time, have included adoption of appropriate and adequate fertilizer packages, involving the use of organic and / or inorganic fertilizers (Atete, 2012; Lege, 2012; Wabaza, 2013). The use of inorganic or mineral fertilizers in improving and maintaining soil fertility has been reported to be ineffective, due to certain limitations. Some of these limitations include: low efficiency (due to loss of nutrients through volatilization and leaching), declined soil organic matter content, nutrient imbalance, soil acidification, as well as soil physical degradation and attendant increased incidence of soil erosion (Kader, 2012; Lege, 2012; Sekar, 2013). Asides all these limitations, high cost and occasional scarcity of mineral fertilizers have posed a lot of problem to their use as nutrient sources (Guman, 2011; Exma, 2012).

The limitations of the use of mineral fertilizers to improve soil fertility has consequently resulted in shift of attention to the use of organic fertilizers for soil fertility improvement, especially the highly weathered tropical soils (Ame, 2012; Kader, 2012). However, the use of organic fertilizers, too, has certain demerits of slow release and non – synchronization of nutrient release with period of growth for most short – term crops, as well as being required in large quantities to sustain crop production, which may not readily be available to the small – scale farmers (Kiani, *et al*. 2005; Guman, 2011).

The very low level of productivity of the Nigerian soils has been traced or ascribed to the inherently low fertility status and acidity of the soils (Lume, 2013). There is, therefore, a dire need to seek ways of improving fertility status, as well as preventing acidity of the soils in order to raise the present level of crop yield on farmers' farms. Consequent upon this, the sole use of organic or inorganic fertilizers to improve soil fertility, as well as the use of inorganic limes to prevent soil acidity has been accorded enough research attention in Nigeria. However, in view of the inadequacies of sole use of organic or inorganic fertilizers to improve soil fertility, as well as the high cost and non – availability in Nigeria, of inorganic limes, it is thus, imperative to critically assess the potential of combined application of readily available and cheap organic and inorganic fertilizers, as nutrient sources to improve soil fertility, and the use of organic limes to reduce soil acidity, and thus, ensure balanced crop nutrition with attendant high crop yield. To this end, this study was designed to evaluate the influence of integrated application of wood ash and inorganic fertilizers on fertility status of an acid Alfisol and grain yield of maize.

Materials and Methods

Study site: A two year field experiment was conducted at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2011 and 2012 cropping seasons. The soil of the study site has been identified as an Alfisol (SSS, 2003) of the basement complex. The site had earlier been under the cultivation of arable crops, among which were cassava, maize, melon, sweet potato and cocoyam before it was allowed to go into fallow. During the period of fallow, cattle, sheep and goat used to graze on the fallow land. The fallow vegetation (mainly shrubs) was manually cleared, thereafter, the land was ploughed and harrowed.

Collection and analysis of soil samples: Prior to planting, ten core soil samples, randomly collected from 0 – 15 cm soil depth, were bulked inside a plastic bucket to form a composite sample, which was analyzed for chemical properties. At the end of each year cropping, another set of soil samples was collected in each treatment plot and analyzed. The soil samples were air – dried, ground, and passed through a 2 mm sieve. The processed soil samples and the wood ash, used in the experiment were analyzed in accordance with the soil and plant analytical procedures, outlined by the International Institute of Tropical Agriculture (IITA) (1989).

Experimental design and treatments: The experiment was laid out in a randomized complete block design with three replicates. The wood ash – based soil amendments included: sole wood ash (SWA); wood ash + NPK 15 – 15- 15 fertilizer (WA+ NPK); wood ash + ammonium sulphate fertilizer (WA+AS); and no fertilizer (NF) (check), which served as the control treatment. The wood ash was applied at the rate of 4.8 t ha^{-1} (Guman, 2011; Ame, 2012), and incorporated into the soil at 15 cm depth,using a traditional hand hoe, two weeks before planting (WBP). The NPK (15 – 15 – 15) and ammonium sulphate fertilizers were applied at the rates of 400 and 320 kg ha^{-1}, respectively (Guman, 2011; Ame, 2012). They were applied in two split doses, at four and seven weeks after planting (WAP). Each plot size was 2 m x 2 m.

Planting, weeding, collection and analysis of data: In 2011 and 2012 cropping seasons, planting of maize was done on March 21 and March 26, respectively. Three seeds of Oba Super 1 maize variety, dressed with Apron Plus, were planted at a spacing of 75 cm x 30 cm, but later thinned to one seedling per stand (44,444 maize plants ha^{-1}), two weeks after seedling emergence (WASE). Weeding was done manually at 3, 6 and 9 weeks after planting (WAP). At harvest, data were collected on maize yield and yield components. All the data collected were subjected to analysis of variance, and treatments means were compared, using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

Results

The nutrient composition of wood ash used in the experiment.

Table 1: Nutrient composition of wood ash used in the experiment.

Nutrient elements	Concentration (g kg^{-1})
Calcium	56.24
Magnesium	12.11
Potassium	8.04
Phosphorous	7.21
Nitrogen	4.67
Sodium	1.58
pH	10.23

The chemical properties of the Alfisol prior to 2011 cropping season.

Table 2: The chemical properties of the Alfisol prior to 2011 cropping season.

Soil properties	Values
pH	5.20
Organic carbon (g kg^{-1})	1.89
Total nitrogen (g kg^{-1})	0.69
Available phosphorus (mg kg^{-1})	0.66
Exchangeable Aluminium (cmol kg^{-1})	0.73
Exchangeable bases (cmol kg^{-1})	
Potassium	0.70
Calcium	0. 65
Magnesium	0.59
Sodium	0.41
Exchangeable Acidity	0.29
Effective Cation Exchangeable Capacity (ECEC)	2.64
Micro – nutrients (mg kg^{-1})	
Cu	2.76
Zn	2.61
Mn	2.58
Fe	2.56

Changes in nutrient status of the Alfisol at the end of 2011 and 2012 cropping seasons.

Tables 3 and 4 show the chemical properties of the Alfisol as affected by different wood ash – based soil amendments at the end of 2011 and 2012 cropping seasons. At the end of 2011 cropping season, application of wood ash – based soil amendments resulted in significant (P = 0.05) increases in the soil pH from 3.6 for NF to 10.2, 8.3 and 8.1 for SWA, WA+NPK and WA+ AS, respectively. Similarly, at the end of 2012 cropping season, wood ash – based soil amendment treatments significantly (P = 0.05) increased soil pH from 3.5 for NF to 10.6, 8.7 and 8.2 for the respective SWA, WA+ NPK and WA +AS. At the end of 2011 cropping season, wood ash – based soil amendments significantly increased soil organic carbon (SOC) from 0.61 g kg^{-1} for NF to 1.47, 1.32 and 1.09 g kg^{-1} for the respective SWA, WA+NPK and WA + AS. Similarly, at the end of 2012 cropping season, wood ash – based soil amendments significantly increased SOC from 0.43 g kg^{-1} for NF to 1.65, 1.51 and 1.17 g kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2011 cropping season, wood ash – based soil amendments significantly increased total N from 0.26 g kg^{-1} for NF to 0.40, 0.57 and 0.51 g kg^{-1} for SWA, WA + NPK and WA +AS, respectively. At the end of 2012 cropping season, wood ash – based soil amendments significantly increased total N from 0.14 g kg^{-1} for NF to 0.51, 0.66 and 0.60 g kg^{-1} for the respective SWA, WA + NPK and WA + AS.

At the end of 2011 cropping season, wood ash – based soil amendments significantly increased available P from 0.39 mg kg^{-1} for NF to 0.58, 0.51 and 0.46 mg kg^{-1} for SWA, WA + NPK and WA + AS, respectively. Similarly, at the end of 2012 cropping season, wood ash – based soil amendments significantly increased available P from 0.33 mg kg^{-1} for NF to 0.61, 0.54 and 0.49 mg kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2011 cropping season, wood ash – based soil amendments significantly reduced exchangeable Al from 0.81 cmol kg^{-1} for NF to 0.48, 0.55 and 0.67 cmol kg^{-1} for SWA, WA + NPK and WA + AS, respectively. Similarly, at the end of 2012 cropping season, wood ash – based soil amendments significantly reduced exchangeable Al from 0.84 cmol kg^{-1} for NF to 0.44, 0.51 and 0.63 cmol kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2011 cropping season, wood ash – based soil amendments significantly increased exchangeable K from 0.31cmol kg^{-1} for NF to 0.56, 0.44 and 0.36 cmol kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2012 cropping season, wood ash – based soil amendments significantly increased exchangeable K from 0.26 cmol kg^{-1} for NF to 0.62, 0.51 and 0.43 cmol kg^{-1} for the respective SWA, WA + NPK and WA +AS.

At the end of 2011 cropping season, wood ash – based soil amendments significantly increased exchangeable Ca from 0.28 cmol kg^{-1} for NF to 0.51, 0.40 and 0.33 cmol kg^{-1} for SWA, WA + NPK and WA + AS, respectively. Similarly, at the end of 2012 cropping season, wood ash – based soil amendments significantly increased exchangeable Ca from 0.21 cmol kg^{-1} for NF to 0.59, 0.48 and 0.41 cmol kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2011 cropping season, wood ash – based soil amendments significantly increased exchangeable Mg from 0.24 cmol kg^{-1} for NF to 0.42, 0.35 and 0.28 cmol kg^{-1} for the respective SWA, WA + NPK and WA + AS. Similarly, at the end of 2012 cropping season, wood ash – based soil amendments significantly increased exchangeable Mg from 0.21 cmol kg^{-1} for NF to 0.59, 0.48 and 0.41 cmol kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2011 cropping season, wood ash – based soil amendments significantly increased exchangeable Na from 0.14 cmol kg^{-1} for NF to 0.31, 0.25 and 0.20 cmol kg^{-1} for SWA, WA + NPK and WA + AS, respectively. Similarly, at the end of 2012 cropping season, wood ash - based soil amendments significantly increased exchangeable Na from 0.10 cmol kg^{-1} for NF to 0.38, 0.32 and 0.26 cmol kg^{-1} for the respective SWA, WA + NPK and WA + AS. At the end of 2011 cropping season, wood ash - based soil amendments significantly increased Cu from 2.65 mg kg^{-1} for NF to 2.37, 2.48 and 2.54 mg kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2012 cropping season, wood ash - based soil amendments significantly increased Cu from 2.81 mg kg^{-1} for NF to 2.30, 2.40 and 2.51 mg kg^{-1} for SWA, WA + NPK and WA + AS, respectively.

At the end of 2011 cropping season, wood ash - based soil amendments significantly increased Zn from 2.49 mg kg^{-1} for NF to 2.24, 2.33 and 2.41 mg kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2012 cropping season, wood ash - based soil amendments significantly increased Zn from 2.71 mg kg^{-1} for NF to 2.19, 2.27 and 2.32 mg kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2011 cropping season, wood ash - based soil amendments significantly increased Fe from 2.42 mg kg^{-1} for NF to 1.97, 2.10 and 2.19 mg kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2012 cropping season, wood ash - based soil amendments significantly increased Fe from 2.58 mg kg^{-1} for NF to 1.83, 1.94 and 2.06 mg kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2011 cropping season, wood ash - based soil amendments significantly increased Mn from 2.36 mg kg^{-1} for NF to 1.70, 1.87 and 2.00 mg kg^{-1} for SWA, WA + NPK and WA + AS, respectively. At the end of 2012 cropping season, wood ash - based soil amendments significantly increased Mn from 2.44 mg kg^{-1} for NF to 1.58, 1.65 and 1.88 mg kg^{-1} for SWA, WA + NPK and WA + AS, respectively.

Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.4, No.14, 2014

Table 3: Chemical properties of the Alfisol as affected by different wood ash – based soil amendments after 2011 cropping season.

		Org. C	Total N	Av. P.	Exch. Al	Exch. bases (cmol kg^{-1})				Micro – nutrients (mg kg^{-1})			
Treatments	pH	(g kg^{-1})	(g kg^{-1})	(mg kg^{-1})	(cmol kg^{-1})	K	Ca	Mg	Na	Cu	Zn	Fe	Mn
NF	3.6d	0.61d	0.26d	0.39d	0.81a	0.31d	0.28d	0.21d	0.14d	2.65a	2.49a	2.42a	2.36a
SWA	10.2a	1.47a	0.40c	0.58a	0.48d	0.56a	0.51a	0.42a	0.31a	2.37d	2.24d	1.97d	1.70d
WA+NPK	8.31b	1.32b	0.57a	0.51b	0.55c	0.44b	0.40b	0.35b	0.25b	2.48c	2.33c	2.10c	1.87c
WA+AS	8.1c	1.09c	0.51b	0.46c	0.67b	0.36c	0.33c	0.28c	0.20c	2.54b	2.44b	2.19b	2.00b

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). NF = no fertilizer; SWA = sole wood ash; WA = Wood ash; AS = ammonium sulphate.

Table 4: Chemical properties of the Alfisol as affected by different wood ash – based soil amendments after 2012 cropping season.

		Org. C	Total N	Av. P	Exch.Al	Exch. bases (cmol kg^{-1})				Micro – nutrients (mg kg^{-1})			
Treatments	pH	(g kg^{-1})	(g kg^{-1})	(mg kg^{-1})	(cmol kg^{-})	K	Ca	Mg	Na	Cu	Zn	Fe	Mn
NF	3.5d	0.43d	0.14d	0.33d	0.84a	0.26d	0.21d	0.14d	0.10d	2.81a	2.71a	2.58a	2.41a
SWA	10.6a	1.65a	0.51c	0.61a	0.44d	0.62a	0.59a	0.48a	0.38a	2.30d	2.19d	1.83d	1.58d
WA+NPK	8.7b	1.51b	0.66a	0.54b	0.51c	0.51b	0.48b	0.41b	0.32b	2.40c	2.27c	1.94c	1.65c
WA+AS	8.2c	1.17c	0.60b	0.49c	0.63a	0.43c	0.41c	0.34c	0.26c	2.51b	2.32b	2.06b	1.88b

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). NF = no fertilizer; SWA = sole wood ash; WA = Wood ash; AS = ammonium sulphate.

Maize yield and yield components: Table 5 shows the yield and yield components of maize as affected by wood ash – based soil amendments in 2011 and 2012. Means of maize grain yield data across the two years of experimentation, indicated that, wood ash – based soil amendments resulted in significant increases in maize grain yield from 0.86 t ha^{-1} for NF to 2.26, 2.57 and 2.47 t ha^{-1} for SWA, WA+NPK and WA+AS, respectively. Similarly, wood ash – based soil amendments significantly increased maize cob diameter from 10.11 cm for NF to 15.67, 16.66 and 16.19 cm for the respective SWA, WA+NPK and WA +AS. Wood ash – based soil amendments significantly increased maize cob length from 9.44 cm for NF to 14.93, 18.81 and 16.10 cm for SWA, WA+NPK and WA + AS, respectively.

Table 5: Maize yield and yield components as affected by wood ash – based soil amendments at harvest.

	Maize grain yield (t ha^{-1})			Maize cob length (cm)			Maize cob diameter (cm)		
Treatments	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**
NF	0.90d	0.82d	0.86	9.51d	9.36d	9.44	10.21d	10.01d	10.11
SWA	2.20c	2.31c	2.26	14.89c	14.97c	14.93	15.50c	15.84c	15.67
WA+NPK	2.51a	2.62a	2.57	18.71a	18.90a	18.81	16.41a	16.91a	16.66
WA+AS	2.43b	2.50b	2.47	16.88b	17.11b	16.10	16.00b	16.38b	16.19

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). NF = no fertilizer; SWA = sole wood ash; WA = Wood ash; AS = ammonium sulphate.

Discussion

The chemical properties of soil in the study site, prior to cropping, indicated that the soil was slightly acidic, with a pH of 5.2. The soil organic carbon (SOC) value of 1.89 g kg^{-1} was below the critical level of 7.6 g kg^{-1} for soils in Southwestern Nigeria (Awani, 2012). The total nitrogen content of 0.69 g kg^{-1} was below the critical level of 1.50 g kg^{-1}, according to Awani (2012) and Lege (2012). The K status of 0.70 cmol kg^{-1} was above the critical level of 0.35 cmol kg^{-1} (Lege, 2012). The Ca, Mg and Na contents were all below the established critical levels for soils in Southwestern Nigeria (Oli, 2011; Wabaza, 2013).

Relative to the control treatment, the significant increases in soil pH at the end 2011 and 2012 cropping seasons, observed in the plots of the wood ash – based soil amendments, agree with the findings of Weil (2012); Wabaza (2013), who reported significant increases in pH of an acid Alfisol, after cropping, following application of wood ash – based soil amendments. The lowest soil pH value recorded in the check (no fertilizer) plots can be ascribed to the lowest value of the exchangeable bases on the exchange sites of soil in the check plots, due perhaps, to their (exchangeable cations) exhaustive uptake by maize during the growing period. Sole application of wood ash resulted in the highest soil pH value after cropping, suggesting greater liming effects of wood ash, compared to other wood ash – based soil amendments. This observation points to superiority of sole wood ash to other wood ash – based soil amendments as regards reducing soil acidity. The significantly lower pH value of soil in the wood ash + NPK fertilizer and wood ash + ammonium sulphate fertilizer plots than that of the soil in the sole wood ash plots, can be attributed to acidifying effects of NPK and ammonium sulphate fertilizers, which must have consequently contributed to the reduced liming effects of the wood ash (Audu, 2011; Weil, 2012). The acidifying effects of NPK fertilizer can be ascribed to its acid – forming nature, which is due to its N and P content, while soil acidification, associated with application of ammonium sulphate, is due to the presence of ammonium ions (NH_4^+), which on nitrification by soil microbes (according to this equation: $NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$), generates hydrogen ions (H^+), which would have contributed to the observed lower soil pH value, adduced to the wood ash + ammonium sulphate fertilizer (Audu, 2011; Weil, 2012). The soil pH value for wood ash + ammonium sulphate fertilizer was significantly lower than that for wood ash + NPK, suggesting greater acidifying effects of ammonium sulphate fertilizer than its NPK counterpart.

The significant increases in SOC, after cropping, adduced to the wood ash – based soil amendments, corroborate the results of Exma (2012) and Era (2013), who reported significant increases in SOC, following application of wood ash – based soil amendments. The significantly lower SOC value for wood ash + NPK and wood ash +ammonium sulphate fertilizer, compared to what obtained for sole wood ash, was probably due to the lower soil pH values for the wood ash + NPK and wood ash + ammonium sulphate fertilizer. This is because, studies by Arena (2009) and Exma (2012), had established that, the rate of organic matter decomposition by soil microbes, depends on the pH of the soil medium, with the rate of organic matter decomposition decreasing with decreasing pH (i .e. increasing acidity). These authors also noted that, the rate of organic matter decomposition becomes negligible at a soil pH value below 5.1. So, the lower pH value (higher acidity) of soil in the wood ash +NPK and wood ash + ammonium sulphate plots can be implicated for the observed lower SOC value for wood ash +NPK and wood ash + ammonium sulphate, since this condition of lower pH may have impaired microbial decomposition of organic matter of soil in the plots of wood ash + NPK and wood ash + ammonium sulphate fertilizer, with resultant lower SOC value. This implies that, liming (i.e. reducing soil acidity), can indirectly influence nutrient availability in the soil through its effects on pH of the soil medium, which in turn, determines the rate of decomposition and subsequent mineralization of organic matter in the soil system.

The significantly higher total N value for wood ash + NPK and wood ash + ammonium sulphate fertilizer than that for the sole wood ash treatment, can be adduced to the release of more N under wood ash + NPK and wood ash + ammonium sulphate due to the presence of NPK and ammonium sulphate fertilizers, which are both N – fertilizers.

The lowest available P value, associated with the control treatment, can be attributed to the lowest pH value of soil in the control treatment plots. This is because, the availability of P in the soil, depends on the pH of the soil medium, with available P decreasing with decreasing pH (Zorok, 2012). The decreasing available P phenomenon, associated with increasing acidity or decreasing pH, is due to the conversion of P into unavailable forms under acid soil conditions, as a result of fixation by micro – nutrients, such as Fe and Al, which abound in acid soils (Zorok, 2012; Zynth, 2012). In view of the crucial physiological roles of P in the nutrition of maize, and to avert the problem of non – availability of P, occasioned by fixation of P by micronutrients in acid soils, liming of soil to be cultivated to maize is, therefore recommended.

The significantly lower exchangeable Al, adduced to sole wood ash, wood ash + NPK and wood + ammonium sulphate , can be attributed to the higher pH values (i.e. lower acidity) for these soil amendments. This is because the availability of exchangeable Al depends on pH of the soil medium, with exchangeable Al value decreasing with increasing pH (i.e. decreasing acidity) (Ekwueme,2013). The decrease in exchangeable Al, associated with increasing pH, can be explained in the light of precipitation of aluminium hydroxide [$Al(OH)_3$], which occurs at increased soil pH (Zorok, 2012). Havlin (2010) and Sekar (2013) had earlier reported that, at soil pH above 6.0, Al exists in the soil as insoluble aluminium hydroxide [$Al(OH)_3$]. The highest concentrations of the micronutrients (Cu, Zn, Mn and Fe), recorded in the check plots can be attributed to the lowest pH value of soil in the check plots. This is because the availability of these micronutrients depends on their solubility, which in turn, is pH dependent, with their solubility, and hence, availability increasing with decreasing pH of the soil medium. Thus, the lowest pH value of soil in the check plots accounts for the observed highest concentrations of the micronutrients of soil in the check plots (Aritoff, 2012; Kapa, 2013). The significantly higher values of the exchangeable bases, recorded in the plots of sole wood ash, wood ash + NPK and wood ash + ammonium sulphate, as agaist what obtained in the check plots, can be adduced to release of these exchangeable cations by wood ash, on decomposition. The higher values of pH, SOC total N, exchangeable bases, available P and the micronutrients, recorded in the plots of sole wood ash, wood ash + NPK and wood ash + ammonium sulphate at the end of the second year (2012) cropping season, compared to what obtained at the end of the first year (2011)cropping season, can be adduced to the residual effects of application of the wood ash – based soil amendments during the first year, coupled with additional application of the wood ash - based soil amendments in the second year.

The significantly higher maize yield consistently obtained in the plots of wood ash –based soil amendments, relative to the control treatment, confirm the findings of Oli (2011) and Lume (2013). This can be attributed to the regulatory action of calcium and magnesium, contained in the wood ash, on soil chemical properties, especially reduction of soil scidity and attendant prevention of aluminium toxicity, which would have resulted in stubbiness of maize roots (due to interference effects of Al toxicity on phosphorylation of sugars); a condition that would have consequently resulted in low maize yield (Nana, 2011). Asides, wood ash increases availability of plant nutrients, notably, N, P, K, Ca, Mg and Na, as reported by Babalola (2011) and Awani (2012), who obtained significant yield responses of maize to application of wood ash, due to its high N, P, K, Ca, Mg and Na content. The increase in availability of plant nutriens, associated with wood ash application can be explained in the light of its ability to reduce soil acidity; a condition that favours and promotes microbial decomposition of soil organic matter with resultant increased release of nutrients into the soil (Awani, 2012).

The significantly higher maize grain yield and yield components, adduced to wood ash + NPK and wood ash + ammonium sulphate than those for sole wood ash, agree with the findings of Adeuti (2008) and Steiner (2013), who noted significantly higher maize grain yield and yield components under integrated application of wood ash and inorganic fertilizers, compared to sole application of wood ash. These observations point to the superiority of integrated application of wood ash and mineral fertilizers to sole application of wood ash. The superiority can be ascribed to the complementary roles of combined application of organic fertilizers (wood ash) and inorganic fertilizers in improving soil fertility, and enhancing crop yield. This is because the complementary use of organic and inorganic fertilizers increases water and nutrient use efficiency, with the organic fertilizer component increasing the organic matter content of the soil, as well as providing certain essential micro – nutrients, which are not present in inorganic fertilizers (Auzer, 2012). Asides, the addition of the organic fertilizer component of the mixture results in the prevention of Al toxicity, due to increased soil pH and base saturation (Auzer, 2012). The complementarity of integrated application of organic and inorganic fertilizers satisfies immediate nutrient requirements of crops, as the inorganic fertilizer component releases its nutrients faster than its organic fertilizer counterpart, thus, making nutrients more readily available to crops (Awani, 2012). The higher maize grain yield, obtained in the plots of wood ash – based soil amendments at the end of the second year, compared to what obtained at the end of the first year can be adduced to more nutrient availability during the second year cropping season, due to the residual effects of application of the wood ash – based soil amendments during the first year, coupled with the additional application of the wood ash – based soil amendments in the second year.

Conclusion

The values of maize yield and yield components under the fertilizer treatments can be ranked as: NF < SWA < WA + AS < WA + NPK. At the end of both cropping seasons, and relative to the control treatment, application of SWA, WA + NPK and WA+ AS resulted in increases in organic carbon, total N, available P and the exchangeable bases.

References

Adeuti, M. M. 2008. Studies on mineral nutrition of maize. *Plant Nutrition and Crop Improvement*. 26:72 – 78.

Ame, S.P. 2012. Influence of integrated application of organic and inorganic fertilizers on chemical properties of a degraded acid Alfisol in southwestern Nigeria. *Journal of Pure and Applied Sciences.* 51:822 – 828.

Arena, J. K. 2009. Efficiency of compost – fertilizer blends compared to fertilizer alone. *Soil Science Research*. 43: 554 – 559.

Aritoff, C. C. 2012. The effects of nitrogen nutrition of maize on the development of soil acidity in southwestern Nigeria. *Soil Chemistry.* 28(2): 453 – 459.

Atete. B. S. 2012. Ameliorating a severely degraded acid Alfisol and maize yield by plant residues. *Soil Fertility.* 56:652 – 658.

Audu, I. P. 2011. Influence of liming on carbon and nitrogen contents of tropical soils. *Journal of Soil and Environmental Sciences.* 33:214 – 219.

Auzer, N.O. 2012. Dynamics of soil organic matter fractions and maize yield under different plant residues management practices. *Soil Fertility.* 48:141 – 149.

Awani, P.S. 2012. Effects of wood ash and poultry manure on leaf nutrient content, growth and yield of spinach. *Plant Nutrition and Fertilizer Research.* 67:711 – 717.

Awodun, M. A. and R.A. Olafusi 2007. Effects of integrated application of goat manure and urea on soil nutrient content and yield of okra. *Nigerian Journal of Soil Science.* 17:126 – 129.

Babalola, Y. A. 2011. Solid and liquid goat manure application on an Alfisol. *Advances in Fertilizer Research.* 53:653 – 659.

Ekwueme, D. 2013. Observations on the use of wood ash and goat manure in improving soil fertility and maize yield. *Journal of Biological Sciences.*

Era, E. S. 2013. Effects of organic fertilizers on physical and chemical properties of an acid Alfisol and maize yield in southwestern Nigeria. *Soil Fertility Research.* 78:1234 – 1239.

Exma, L.T. 2012. Responses of an acid Alfisol and maize yield to wood ash – based soil amendments *Journal of Food and Agricultural Research.* 31:421 – 427.

Guman, S. B. 2011. Influence of poultry manure amended calcium ammonium nitrate on chemical properties of an Alfisol. *Soil Science and Environmental Quality*. 36:143 – 149.

Havlin, F.M. 2010. Effects of different wood ash levels on nutrient content of maize and chemical properties of an acid Alfisol. *Global Journal of Food and Agricultural Sciences.*62:890 – 896.

International Institute of Tropical Agriculture (IITA) 1989. Automated and semi – automated methods of soil and plant analysis. Manual Series, No 7, IITA, Ibadan, Nigeria.

Kader, E. 2012. Nitrogen and phosphorus uptake by maize as affected by organic matter quality, soil characteristics and land use history of soils from southwestern Nigeria. *Soil Fertility Bulletin.* 18: 222 – 227.

Kapa, A.A. 2013. Phosphorus requirements of groundnut and soybean as affected by N nutrition. *Plant Nutrition Research*. 45:56 – 62.

Kiani, M. J., K.M. Abbas and N. Rahim 2005.Use of organic manure with mineral N – fertilizers to increase wheat yield at Rawakalot Azad. *Archives of Agronomy and Soil Science*. 51:299 – 309.

Lege, B. N. 2012. Soil chemical properties as affected by phosphorus and nitrogen – based manure and compost application. *Soil Conservation*. 21:411 – 416.

Lume, C. O. 2013. Growth rate response of bacteria communities to pH in limed and ash - treated forest Alfisol. *Soil Microbiology.* 33:881 – 888.

Nana, G. O. 2011. Influence of different soil amendments on the physical and chemical properties of a degraded acid Alfisol in Eastern Nigeria. *Land Development*. 47:413 – 418.

Oli, F. S. 2011. Liming effects on the response of maize to P and K fertilizers on an acid Alfisol. *Soil Fertility and Fertilizer Research.* 50:555 – 562.

Sekar, M. P. 2013. Evaluation of the influence of liming on exchange acidity and grain yield of maize. *International Journal of Agricultural Sciences.* 62:231 – 238.
Soil Survey Staff (SSS) 2003. Keys to soil taxonomy, 9th edition, United States Department of Agriculture. Washington D. C. 306 pp.
Steiner, R. 2012. Soil organic matter dynamics and maize yield under application of wood ash – based *soil amendments. Journal of Agricultural Science*. 54:165 – 170.
Wabaza, K. T. 2013.Comparative nutrients release from cocoa pod ash, poultry manure and rock phosphate and their effects on soil fertility and maize yield. *Advances in Soil Fertility.*51:8 -14.
Weil, A. S. 2012. Amelioration of a severely degraded Alfisol through application of plant residues and rice husk ash. *International Journal of Pure and Applied Sciences*. 63:1173 – 1179.
Zorok, A. A. 2012. Suitability of wood ash – amended rock phosphate on growth and yield of maize and soil nutrients. *Plant and Soil Science Journal.* 28(2): 673 – 678.
Zynth, C. F. 2012. Effects of wood ash, poultry manure and rock phosphate on soil nitrogen and phosphorus availability in corn production. *Journal of Sustainable Agriculture.* 21(2):108 – 113.

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