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Responses of an Acid Alfisol and Maize (Zea mays L.) to Liming in Ado – Ekiti, Southwestern Nigeria

B. Osundare
Department of Crop, Soil, and Environmental Sciences,Ekiti State University, Ado – Ekiti,Nigeria
biodunosundare@yahoo. Com

Abstract
The low productivity of most Nigerian soils has been ascribed to the problem of acidity of the soils. Therefore, there is a dire need to address this problem of soil acidity, with a view to increasing the productivity of the soils, and hence, achieving sufficiency of food production. To this end, a two – year experiment was carried out in 2010 and 2011 cropping seasons at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, to determine the effects of different liming materials on the fertility status of an acid Alfisol and grain yield of maize (*Zea mays* L.). The experiment was laid out in a randomized complete block design with three replicates. The different liming materials included: Calcium ammonium nitrate (CAN); Calcium carbonate (CC); Wood ash (WA) and unlimed treatment, which served as the control (C). The results obtained indicated existence of significant (P = 0.05) differences among the different liming materials as regards their effects on chemical properties of acid Alfisol and grain yield of maize. At the end of 2010 cropping, liming significantly (P = 0.05) increased soil organic carbon (SOC) from 0.40 g kg^{-1} for C to 0.52, 0.60 and 0.68 g kg^{-1} for CAN, CC and WA, respectively. Similarly, at the end of 2011 cropping, liming significantly increased SOC from 0.33 g kg^{-1} for C to 0.48, 0.55, and 0.74 g kg^{-1} for the respective CAN, CC and WA. At the end of 2010 cropping, liming significantly increased total N from 0.07 g kg^{-1} for C to 0.21, 0.14 and 0.29 g kg^{-1} for CAN, CC and WA, respectively. Similarly, at the end of 2011 cropping, liming significantly increased total N from 0.04 g kg^{-1} for C to 0.17, 0.10 and 0.34 g kg^{-1} for the respective CAN, CC and WA. Combining means of maize grain yield data across the two years of experimentation, liming resulted in significant increases in maize grain yield from 0.70 t ha^{-1} for C to 1.88, 1.67 and 2.67 t ha^{-1} for CAN, CC and WA, respectively. Of all the liming materials, wood ash gave the highest maize grain yield and yield components in both years, and therefore, wood ash is recommended for maize cultivation.
Keywords: Acid, alfisol, liming, maize, southwestern Nigeria.

INTRODUCTION

Agricultural productivity of tropical soils is adversely affected by the inherently low fertility status of the soils, characterized by low – activity - clay (LAC), organic matter, nitrogen, phosphorus, buffering capacities and exchangeable basic cations (Adenle, 2010; Pestov, 2012).

Recognizing the constraints or limitations for the utilization of the low- activity- clay tropical soils for continuous crop production has necessitated growing search for professionally sound soil fertility management practices, which in recent time, has included the adoption of appropriate and adequate fertilizer packages, involving the use of organic and/ or inorganic fertilizers (Atete, 2012; Lege, 2012). The use of inorganic or mineral fertilizers in maintaining soil fertility has been reported to be ineffective, due to certain limitations. Some of these limitations include: low efficiency (as a result of losses through volatilization and leaching), declined soil organic matter content, nutrient imbalance, soil acidification, as well as soil physical degradation, with resultant increased incidence of soil erosion (Kader, 2012). Asides, high cost and occasional scarcity of mineral fertilizers have posed a lot of problem to their use as nutrient sources (Guman, 2011).

The limitations of the use of mineral fertilizers to improve soil fertility and crop yield has consequently informed 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 – season 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).

Soil acidity has been identified as one of the major constraints or limitations to crop production in several regions of the humid tropics. Acid soils are prevalent in areas experiencing heavy precipitation which leads to leaching of exchangeable basic cations (Young, 2012). Soil acidity could also develop through heavy industrialization leading to acid rains, continuous cropping for several years and prolonged use of nitrogenous fertilizers, which have acidifying properties (Zesith, 2011). Some of the problems associated with soil acidity include aluminium toxicity, low nutrient status, and nutrient imbalance (Zesith, 2011). The most notable effects of soil acidity are drastic reduction of crop yields, poor stands of crops, poor root growth and reduced uptake of nutrient elements, especially, P, K, Ca, Mg and micronutrients (Wumang, 2010; Vucil, 2012).

Liming is an agronomic practice, which is application to the soil, of certain calcium – or magnesium –

containing compounds to reduce the soil acidity or raise its pH or base saturation, cation exchangeable capacity (CEC), available P and improved nutrient uptake by plants and attendant increased crop yield (Babalola, 2012; Voor, 2012). Liming improves the physical, chemical and biological conditions of the soil (Nana, 2011). Liming improves the structure of heavy soils by promoting granulation of heavy soils, thus, enhancing water and air movement in the soil (Nana, 2011; Adegun, 2012). Liming, apart from reducing soil acidity, increases availability of phosphates and exchangeable calcium and magnesium (Tugel, 2011). However, it may cause a decrease in the availability of aluminium, iron and manganese (Adegun, 2012). Liming stimulates microbial activities in the soil, and hence, organic matter breakdown. Also, liming stimulates the activities of both symbiotic and non – symbiotic atmospheric nitrogen fixing bacteria (Babalola, 2011; Awani, 2012).

Although, studies elsewhere (Tugel, 2011; Cher, 2012; Voor, 2012) had established that, liming materials differ in their abilities to reduce soil acidity and increase nutrient availability in the soil, due to differences in their chemical composition, rate of decomposition and nutrient release patterns. However, in view of the paucity of published scientific data and information on the relative efficacy of certain liming materials in reducing soil acidity, and hence, enhancing soil fertility and performance of maize in Nigeria, there is a dire need for critical assessment of the potentials of certain liming materials in reducing soil acidity, and enhancing soil fertility and maize yield performance. To this end, this paper reports the results of a two – year study, aimed at evaluating the effects of different liming materials on chemical properties of an acid Alfisol and yield performance 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 2010 and 2011 cropping seasons. Ado – Ekiti lies on latitude 7^0 30N and longitude 3^0 54E. The total annual rainfall during the period of investigation were 968 and 997 mm in 2010 and 2011, respectively. The mean annual temperature ranged between 26.3^0C and 24.8^0C in 2010 and 2011, respectively, while the average relative humidities were 66 and 79% in 2010 and 2011, respectively. The soil of the study site is an Alfisol (SSS, 2003) of the basement complex, highly leached, with low to medium organic matter content. The study site had earlier been cultivated to many arable crops, among which were cassava, maize, melon, cocoyam, rice before it was left fallow for some years before this research was carried out. The fallow vegetation (mainly shrubs) was manually slashed, after which 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, using a soil auger, were bulked inside a plastic bucket to form a composite sample, which was analyzed for chemical properties. At the end of the first cropping season (2010) and the second cropping season (2011), another soil samples, consisting five cores were collected per each treatment plot of 6 m^2, thoroughly mixed inside a plastic bucket to form a composite sample, which was analyzed to determine changes in the soil nutrient status after cropping. The soil samples were air – dried, ground, and passed through a 2 mm sieve. The processed soil samples were analyzed in accordance with soil analytical procedures, outlined by the International Institute of Tropical Agriculture (IITA) (1989). Also, chemical analysis of wood ash, used in the experiment was carried out to determine its nutrient composition.

Experimental design and treatments: The experiment was laid out in a randomized complete block design with three replicates. The different limes applied included: Calcium ammonium nitrate (CAN); Calcium carbonate (CC); Wood ash (WA) and unlimed treatment, that is, the control (C). The Calcium ammonium nitrate, Calcium carbonate and wood ash were applied at the rates of 400, 450 and 6,000 kg ha^{-1}, respectively (Fondufe, 1995). The wood ash was incorporated into the soil at 15 cm depth, using hoe, three weeks prior to planting, while calcium ammonium nitrate and calcium carbonate were applied in two split doses, at 3 and 6 weeks after planting (WAP). Each plot size was 2 m x 3 m (6 m^2).

Planting, weeding, collection and analysis of data: In 2010 and 2011 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	56.30
Magnesium	13.60
Potassium	8.01
Phosphorous	7.20
Nitrogen	4.90
Sodium	1.78
pH	10.24

The chemical properties of the Alfisol prior to 2010 cropping season.

Table 2: The chemical properties of the Alfisol prior to 2010 cropping season.

Soil properties	**Values**
pH	5.8 Organic
carbon (g kg^{-1})	0.84
Total nitrogen (g kg^{-1})	0.40
Available phosphorus (mg kg^{-1})	0.66
Exchangeable bases (cmol kg^{-1})	
Potassium	0.44
Calcium	0. 51
Magnesium	0.38
Sodium	0.21
Exchangeable Acidity	0.27
Effective Cation Exchangeable Capacity (ECEC)	1.81
Micro – nutrients (mg kg^{-1})	
Cu	2.60
Zn	2.68
Fe	2.58
Mn	2.63

Changes in nutrient status of the Alfisol at the end of 2010 and 2011 cropping seasons.

Tables 3 and 4 show the chemical properties of the Alfisol as affected by different limes at the end of 2010 and 2011 cropping seasons. At the end of 2010 cropping season, application of limes resulted in significant (P = 0.05) increases in the soil pH from 5.0 for C to 8.1, 9.4 and 12.0 for CAN, CC and WA, respectively. Similarly, at the end of 2011 cropping season, liming treatment significantly (P = 0.05) increased soil pH from 4.5 for C to 8.7, 9.8 and 12.8 for the respective CAN, CC and WA. At the end of 2010 cropping season, liming significantly increased soil organic carbon (SOC) from 0.40 g kg-1 for C to 0.52, 0.60 and 0.68 g kg-1 for the respective CAN, CC and WA. Similarly, at the termination of 2011 cropping season, liming significantly increased SOC from 0.33 g kg-1 for C to 0.48, 0.55 and 0.74 g kg-1 for CAN, CC and WA, respectively. At the end of 2010 cropping season, liming significantly increased total N from 0.07 g kg^{-1} for C to 0.21, 0.14 and 0.29 g kg^{-1} for CAN, CC and WA, respectively. At the end of 2011 cropping season, liming significantly increased total N from 0.04 g kg^{-1} for C to 0.17, 0.10 and 0.34 g kg^{-1} for the respective CAN, CC and WA. At the termination of 2010 cropping season, liming significantly reduced exchangeable acidity from 0.39 cmol kg^{-1} for C to 0.31, 0.23 and 0.15 cmol kg^{-1} for CAN, CC and WA, respectively. Similarly, at the end of 2011 cropping season, liming significantly reduced exchangeable acidity from 0.42 cmol kg^{-1} for C to 0.28, 0.21and 0.12 cmol kg^{-1} for CAN, CC and WA, respectively

At the end of 2010 cropping season, liming significantly increased available P from 0.36 mg kg^{-1} for C to 0.44, 0.51 and 0.59 mg kg^{-1}, respectively. Similarly, at the end of 2011 cropping season, liming significantly increased available P from 0.28 mg kg^{-1} for C to 0.48, 0.54 and 0.61 mg kg^{-1} for CAN, CC and WA, respectively. At the end of 2010 cropping season, liming increased exchangeable K from 0.26 cmol kg^{-1} for C to 0.22, 0.23 and 0.32 cmol kg^{-1} for CAN, CC and WA, respectively. At the end of 2011 cropping season, liming increased exchangeable K from 0.17 cmol kg^{-1} for C to 0.19, 0.20 and 0.37 cmol kg^{-1} for the respective CAN, CC and WA. At the termination of 2010 cropping season, liming significantly increased exchangeable Ca from 0.20 cmol kg^{-1} for C to 0.29, 0.36 and 0.42 cmol kg^{-1} for CAN, CC and WA, respectively. Similarly, at the end of 2011 cropping season, liming significantly increased exchangeable Ca from 0.16 cmol kg^{-1} for C to 0.33, 0.40 and 0.49 cmol kg^{-1} for CAN, CC and WA, respectively. At the end of 2010 cropping season, liming increased exchangeable Mg from 0.24 cmol kg^{-1} for C to 0.21, 0.20 and 0.29 cmol kg^{-1} for the respective CAN, CC and

WA. Similarly, at the end of 2011 cropping season, liming increased exchangeable Mg from 0.21 cmol kg^{-1} for C to 0.18, 0.19 and 0.36 cmol kg^{-1} for CAN, CC and WA, respectively. At the termination of 2010 cropping season, liming increased exchangeable Na from 0.08 cmol kg^{-1} for C to 0.09, 0.12 and 0.18 cmol kg^{-1} for CAN, CC and WA, respectively. Similarly, at the end of 2011 cropping season, liming increased exchangeable Na from 0.06 cmol kg^{-1} for C to 0.07, 0.09 and 0.20 cmol kg^{-1} for the respective CAN, CC and WA.

Table 3: Chemical properties of the Alfisol as affected by different limes after 2010 cropping season.

Treatments	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Exch. Acidity (cmol kg^{-1})	Av. P. (mg kg^{-1})	Exch. bases (cmol kg^{-1}) K	Ca	Mg	Na	Micro – nutrients (mg kg^{-1}) Cu	Zn	Mn	Fe
Control	5.0d	0.40d	0.07d	0.39a	0.36d	0.20b	0.20d	0.24b	0.08b	3.21a	3.20a	2.90a	2.89a
CAN	8.1c	0.52c	0.21b	0.31b	0.44c	0.22b	0.29c	0.21b	0.09b	2.89b	3.00b	2.81b	2.77b
CC	9.4b	0.60b	0.14c	0.23c	0.51b	0.23b	0.36b	0.20b	0.11b	2.77c	2.88c	2.73c	2.71c
WA	12.0a	0.68a	0.29a	0.15d	0.59a	0.32a	0.42a	0.29a	0.18a	2.70d	2.74d	2.68d	2.63d

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). CAN = Calcium ammonium nitrate; CC = Calcium carbonate; WA = Wood ash

Table 4: Chemical properties of the Alfisol as affected by different limes after 2011 cropping season.

Treatments	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Exch. Acidity (cmol kg^{-1})	Av. P (mg kg^{-1})	Exch. bases (cmol kg^{-1}) K	Ca	Mg	Na	Micro – nutrients (mg kg^{-1}) Cu	Zn	Mn	Fe
Control	4.5d	0.33d	0.04d	0.42a	0.28d	0.17b	0.16d	0.21b	0.06b	3.27a	3.26a	2.94a	2.92a
CAN	8.7c	0.48c	0.17b	0.28b	0.48c	0.19b	0.33c	0.18b	0.07b	2.96b	3.10b	2.83b	2.81b
CC	9.8b	0.55b	0.10c	0.21c	0.54b	0.20b	0.40b	0.19b	0.09b	2.89c	2.95c	2.77c	2.75c
WA	12.8a	0.74a	0.34a	0.12d	0.61a	0.37a	0.49a	0.36a	0.20a	2.77d	2.82d	2.70d	2.67d

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). CAN = Calcium ammonium nitrate; CC = Calcium carbonate; WA = Wood ash

Maize yield and yield components : Table 5 shows the yield and yield components of maize as affected by different limes in 2010 and 2011. Combining the means of maize grain yield data across the two years of experimentation, liming resulted in significant increases in maize grain yield from 0.70 t ha^{-1} for C to 1.85, 1.67 and 2.67 t ha^{-1} for CAN, CC and WA, respectively. Similarly, liming significantly increased maize cob diameter from 6.97 cm for C to 15.16, 13.16 and 17.12 cm for the respective CAN, CC and WA. Liming significantly increased maize cob length from 9.43 cm for C to 14.80, 14.19 and 18.86 cm for CAN, CC and WA, respectively.

Table 5: Maize yield and yield components as affected by different limes at harvest.

Treatments	Maize grain yield (t ha^{-1}) 2010	2011	Mean	Maize cob length (cm) 2010	2011	Mean	Maize cob diameter (cm) 2010	2011	Mean
Control	0.73d	0.67d	0.70	9.51d	9.34d	9.43	7.00d	6.94d	6.97
CAN	1.89b	1.80b	1.85	14.89b	14.71b	14.80	15.20b	15.09b	15.16
CC	1.70c	1.63c	1.67	14.27c	14.10c	14.19	13.21c	13.11c	13.16
WA	2.61a	2.73a	2.67	18.71a	18.90a	18.86	17.04a	17.19a	17.12

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). CAN = Calcium ammonium nitrate; CC = Calcium carbonate; WA = Wood ash

DISCUSSION

The chemical properties of soil in the study site, prior to cropping, indicated that the soil was slightly acidic, with a pH of 5.80. The soil organic carbon (SOC) value of 0.84 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 0.40 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 0.44 cmol kg^{-1} was above the critical level of 0.20 cmol kg^{-1} (Lege, 2012). The Ca, Mg and Na contents were all below the established critical levels for soils in Southwestern Nigeria (Nottidge, *et al*. 2007; Babalola, 2011).

At the termination of the experiment, the highest soil pH value obtained in the wood ash plots, compared to other liming materials, can be ascribed to the release of calcium ions (Ca^{2+}) into the soil during the microbial decarboxylation of the wood ash (Babalola, 2011; Lege, 2012). This observation points to the superiority of wood ash treatment to other limes evaluated in this study, as far as reducing soil acidity is concerned. In view of the efficacy of wood ash in reducing soil acidity, high cost, scarcity, imbalanced nutrition and other problems, associated with the use of inorganic or synthetic commercial limes, the use of organic limes, such as wood ash on acid soils, is therefore, strongly recommended. The lowest soil pH value, obtained in the check (no fertilizer) plots can be adduced to the lowest values of exchangeable basic cations at the exchange sites of soil in the check plots, due to exhaustive uptake of the exchangeable bases by maize during the growing period (Lege, 2012). Application of calcium carbonate resulted in a significantly higher soil pH value than that of CAN, suggesting greater liming effects of the former than the latter. The lower liming effects of CAN, can be attributed to the acidifying effects or acid – forming nature of CAN, due to the presence of ammonium ions (NH_4^+), which on nitrification by soil microbes, produces hydrogen ions (H^+), according to this chemical equation: $NH_4^+ + 20_2 \Rightarrow N0_3^- + H_20 + 2H^+$. Consequently, the hydrogen ions, so produced would have informed the lower liming effects of CAN (Cher, 2012; Awani, 2012). The significantly higher value of exchangeable acidity for CAN than that for calcium carbonate, attests to the acidifying effects of CAN (Tables 3and 4).

The highest SOC value that attended application of wood ash, can be attributed to the high organic matter content of the wood ash, which on decomposition, would have resulted in the release of many other nutrients. This observation corroborates those of Nottidge, *et al*. (2007) and Nana (2011), who noted that, wood ash contained various amounts of plant nutrients, although, the authors emphasized that, the amount of plant nutrients contained in wood ash, depends on the nature of plant materials, the plant parts, age of plants and the intensity of burning. The lowest SOC value recorded in the check plots, as against what obtained in the plots of other limes, agrees with the observations of Tugel (2011); Cher (2012) and Voor (2012), who noted that, application of liming materials resulted in significant increases in SOC, relative to the control treatment. This observation can be adduced to acidification of soil in the control treatment plots. This is because, previous studies (Nana, 2011; Adegun, 2012; Awani, 2012) had established that, the rate of organic matter decomposition by soil microbes, as well as microbial population, depend on pH of the soil medium, with the rate of organic matter decomposition being higher in an alkaline soil than in an acid soil. These authors also added that, the rate of organic matter decomposition becomes negligible at a soil pH value below 5.1. So, acidification of soil in the control treatment plot can be implicated for the observed lowest SOC value for the check, since the acidification may have impaired microbial decomposition of the native organic matter of soil in the check plots and attendant mineralization regimes. This implies that, liming (i. e. reduction of soil acidity) can indirectly influence nutrient availability in the soil through its effects on soil pH, which in turn, determines the rate of decomposition and mineralization of organic matter in the soil system.

The highest total N value, obtained in the plots of wood ash can be ascribed to the presence of N in the wood ash, as indicated in its nutrient composition (Table 1). The significantly higher total N value for CAN, compared to $CaCO_3$, can be adduced to the ability of the former to enrich the soil by supplying N in the form of ammonium ions (NH^+_4) and nitrate ions (NO^-_3). Available P significantly increased with increasing pH, suggesting that, the relative abundance of available P decreased with increasing acidity. This implies that, soil acidification can result in decreased available P value (Awani, 2012). The decreased available P value, associated with soil acidification can be ascribed to conversion of P into unavailable forms under acid soil conditions, as a result of fixation by Fe and Al, which abound under acid soil conditions (Ziri, 2013; Zynth, 2013). The lowest values of total N and exchangeable bases (K, Ca, Mg and Na), observed in the control treatment plots can be ascribed to exhaustive uptake of these nutrient elements by maize during the growing period.

The highest concentration of the micro – nutrients (Cu, Zn, Mn and Fe), recorded in the check plots can be attributed to the lowest pH values of soil in the check plots. This is because Ziri (2013); Zynth (2013) had reported correlation between availability of the micro – nutrients in the soil and the pH of the soil medium, with their (micro – nutrients) availability increasing with decreasing soil pH (i.e. increasing acidity). Thus, the lowest pH values of soil in the check plots accounted for the observed highest concentrations of micro – nutrients of soil in the control plots.

The higher values of pH, SOC, total N and exchangeable calcium for wood ash treatment at the end of the second year (2011) cropping season, can be attributed to higher residual effects of application of wood ash during the first year (2010), coupled with the additional application of wood ash in the second year (2011).

The highest values of yield and yield components of maize, consistently obtained in the wood ash plots, agree with the observations of Cher (2012) and Adegun (2012), who observed that, application of wood ash resulted in highest maize grain yield and yield components, compared to other limes. These observations point to the superiority of wood ash to other limes, as regards their effects on maize yield and yield components. The superiority of wood ash can be attributed to the regulatory action of calcium and magnesium, contained in the wood ash, on soil chemical properties, especially, reduction of soil acidity and attendant prevention of aluminium toxicity, which would have resulted in stubbiness of maize roots (due to the interference effects of aluminium 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 and Mg, as noted by Babalola (2011) and Awani (2012), who obtained positive and significant responses of maize to application of wood ash, due to its high N, P, K, Ca and Mg contents. The increases in availability of plant nutrients, 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 lowest maize grain yield, consistently recorded in the control plots can be adduced to acidification of soil in the control plots, which consequently resulted in aluminium toxicity and deficiency of the exchangeable bases or cations, as these exchangeable bases are unavailable in acid soils (Voor, 2012). The significantly higher maize grain yield for CAN than that of $CaCO_3$ can be attributed to the presence of calcium and nitrogen in CAN, unlike $CaCO_3$, that contains and can only supply calcium (Babalola, 2011; Pestov, 2012; Atete, 2012). The yield and yield attributes of maize for wood ash treatment were higher in 2011 than what obtained in 2010. These observations can be ascribed to two reasons: First, there was more nutrient availability in the second year (2011), due to nutrient release, following decomposition of the residues of maize planted in 2010, which were carefully worked into the soil prior to 2011 planting. Second, the residual effects of application of wood ash during the first year (2010), coupled with the additional application of wood ash in the second year (2011).

CONCLUSION

The values of maize grain yield and yield components, adduced to the different liming materials can be ranked as: C < CC < CAN < WA. After cropping, and relative to the control treatments, application of the liming materials resulted in significant increases in soil pH, organic carbon, total nitrogen, available P and the exchangeable bases. On the contrary, liming resulted in significant decreases in exchangeable acidity after cropping.

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