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Full Length Research Paper

The use of wood ash as manure to decrease the use of mineral fertilizer for better performance of maize (*Zea mays* L.) as Measured in the chlorophyll content and grain yield

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The increasingly high cost of mineral fertilizers and a preferred economic disposal of wood ash had necessitated a research in the use of wood ash to reduce the rate of fertilizer application for maize production. The comparative effects of wood ash and NPK 15-15-15 on maize were investigated in Akure ($7^0$15'N, $5^0$15'E), Nigeria in 2008. The four treatments investigated were 4 t/ha wood ash, 300 kg/ha NPK 15-15-15, 200 kg/ha NPK 15-15-15 plus 2t/ha wood ash mixture and a control plot without manure; while the land preparation was ploughed and harrowed once. Downy mildew resistant (DMR) open pollinated maize variety was planted at 60 × 30 cm in a randomized complete block experiment replicated four times, and the manure was applied in a ring at 10 cm from the maize plant. Pre-treatment soil analysis that entailed taking soil samples before the application of manure was carried out. Two maize crops were investigated and the means of data were computed for comparisons across treatments. The total leaf area per plant, leaf area index and the chlorophyll content were correlated to the grain yield. The profitable response was computed to confirm the economic viability. The chlorophyll content and the grain yield were significantly high in 200kg/ha NPK 15-15-15 + 2t/ha wood ash mixture and in 300 kg/ha NPK 15-15-15 compared to other treatments. Corresponding higher net revenues were also obtained which confirmed a mixture of wood ash and inorganic mineral fertilizers to be a suitable agronomic practice for profitable maize production.

Key words: Wood ash, mineral fertilizers, chlorophyll content, maize grain yield.

INTRODUCTION

The improved performance of maize as a result of added manure is due to the supply of nutrient elements to the plants, and maize being a crop that has exhausting effects on the soil needs the supply of the necessary nutrients in the correct proportions to produce a satisfactory yield (Ristanovic, 2001). Nitrogen, phosphorus and potassium and other nutrient elements play great physiological importance in formation of chlorophyll, nucleotides, phosphotides, alkaloids as well as in many enzymes, hormones and vitamins for optimum grain yield (Mohamed et al., 2008). Nitrogen deficiency could exert a particularly marked effect on maize crop yield as the plant would remain small and rapidly turned yellow if sufficient nitrogen was not available for the construction of protein and chlorophyll (Kogbe and Adediran, 2003). The lack of chlorophyll had been observed to diminish carbohydrate production and a restriction in the assimilating power of the plant (Amany et al., 2006).

The involvement of other macro and micro nutrients in the metabolic processes of plants including maize had been reported in previous research (Kogbe and Adediran, 2003). The processes of anabolism and catabolism of the carbohydrate metabolism would only proceed normally when the organic compounds had been esterised with phosphoric acid. Potassium had been found to

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accumulate in the parts of the plant in which cell division and growth processes were actively proceeding; calcium influenced the water economy of the plant and the protein carbohydrates in many physiological processes. Magnesium was confirmed a constituent of the chlorophyll, protochlorophyll, pectin and phytin while the micro nutrients, though required in very small quantities, were also involved in the plant metabolic processes (Modi and Asanzi, 2008).

The source of the nutrients essential for plant's growth could either be organic or inorganic or from the two combined. The inorganic sources involved the use of fertilizers and the usefulness of fertilizers in increasing plant growth to a designated optimum had been reported in previous research (Niehues et al., 2004; Stewart et al., 2005; Mohamed et al., 2008). The use of organic manure in form of poultry and goat manures and wood ash had been found to complement the use of inorganic fertilizer as both manures improved crop yield (Brady and Weil, 1999; Meludu, 2005; Odiete et al. 2005). Previous research conducted by Roger and Sharland, (1997), Nottidge et al.(2005), Mbah and Nkpaji (2009) had shown that when synthetic fertilizers were not applied, the use of wood ash produced significant effects on the growth and yield of many crops, particularly maize. Saarsalmi et al. (2001), Bougnom et al. (2009), Rodriguez et al. (2009) in the investigation of the effects of wood ash fertilization on soil chemical properties observed that wood ash significantly increased the effective cation exchange capacity and base saturation and decreased the concentration of exchangeable aluminum in the soil.

Wood ash which is the inorganic and organic residue remaining after the combustion of wood had been confirmed to be a good source of potassium, phosphorus, magnesium, calcium and the micronutrients (Kakier and Summer, 1996; Demeyer et al., 2001; Saarsalmi et al., 2001). The burning of sesbenia wood and incorporation of the ash into soil increased grain yield of maize markedly ICRAF (1996) while the application of ash to young maize plants had significantly increased the yield of maize (Odiete et al., 2005). Iremiren (1989) observed increase in yield of maize resulting from ash through trash burning to be consistent to observed increase in the amount of phosphorus in the soil. Previous studies had indicated wood ash to have the same liming effects as commercial lime and in several studies where traditional limestone and wood ash had been compared, the result had confirmed wood ash to give better plant growth responses than limestone because of the additional nutrients that the ash contained (Roger and Sharland, 1997; Awodun et al., 2007). The effects of organic and inorganic manure in increasing the chlorophyll content in maize had also been documented (Amujiyegbe et al., 2007; Mohamed et al., 2008).

The objectives of this research were to investigate the effectiveness of wood ash as manure for a sustainable improved maize production.

MATERIALS AND METHODS

Physical setting

The experiments were conducted in 2008 in the Teaching and Research Farm of the Federal University of Technology, Akure (7^0 15'N, $5^0$15'E). The experimental site had been continuously used for arable maize and cassava crop production for five years without any manure application. The experimental design was a randomized complete block with four treatments replicated four times. Each plot size was 3 × 3 m and discard of 1 m between plots giving experimental area of 18 × 18 m (324 m^2). Maize seeds resistant to Downy Mildew and Streak (DMRESR) obtained from the Ondo State Agricultural Development Project (OSADEP), Akure were planted at 60 x 30 cm to give a plant population of 55,000 stands per hectare. The four treatments were 4 t/ha wood ash, 300 kg/ha NPK 15-15-15, 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture and a control plot without manure; and the manure was applied three weeks after planting in a ring at 10 cm from the maize plant while the land preparation was ploughed and harrowed once.

Soil sample collection and laboratory analysis

Soil samples were taken with a soil auger to a depth of 30 cm both before and after manure application. After the manure application, soil samples were collected to a depth of 30 cm ninety days after planting at harvest for the first maize crop planted in April, and to observe the residual effects of the applied manure, soil samples were taken at ninety days after planting for the second maize crop planted in August 2008. The soil samples collected were air dried and sieved through a 2 mm mesh and analyzed for soil chemical properties (Carter, 1993). The soil pH was determined in water using a glass electrode pH meter. Organic carbon was determined by oxidising soil sample with dichromate solution and later titrated with ferrous sulphate solution. The total nitrogen was determined using micro-kjeldahl method and the available phosphorus extracted colorimetrically by the molybdenum blue method. The exchangeable cations were extracted by leaching 5 g of soil with 50 ml of ammonium acetate at pH 7. The potassium and sodium in the leachate were determined with a column model 21 flame spectrophotometer while the calcium and magnesium were determined with atomic absorption spectrophotometer.

Measurement of the total leaf area per plant, leaf area index and determination of chlorophyll content

The total leaf area of each randomly selected fifteen maize stands per plot was taken and the corresponding leaf area index was computed. The leaf area was measured following the procedure of Stewart and Dwyer (1999) and Elings (2000) by multiplying the length of leaf by the widest width by alpha, where alpha is 0.743 (L × W × 0.743) . The leaf area index was computed by dividing the total leaf area of a maize plant stand by the total land area occupied by the single stand (Mauro et al., 2001). The chlorophyll was determined by extraction in 80% acetone and reading the absorbance of the solution at 645, 663 and 652 nm (Ibitoye, 2005).

Maize yield parameters

Harvesting was carried out at ninety days after planting and the 14% grain moisture content confirmed with the use of grain moisture tester and the grain yield per hectare was taken.

Table 1. The means of soil chemical properties at harvest in the first and second cropping season.

Treatment	pH	Organic matter (%)	% N	Avail P (ppm)	Na (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)
Wood ash at 4t/Ha	7.9	2.92	1.84	9.4	0.19	0.23	3.42	0.43
NPK 15-15-15 at 300kg/Ha	6.9	3.14	2.12	12.4	0.17	0.26	1.98	0.22
NPK 15-15-15 at 200kg/Ha plus wood ash at 2t/Ha	7.3	3.28	2.06	10.2	0.16	0.24	3.26	0.48
Control without manure	5.4	1.6	0.11	8.4	0.15	0.17	1.32	0.26
LSD (0.05)	0.3	0.36	0.02	6.9	0.03	0.02	0.49	0.02

Table 2. Effects of manure application on the total leaf area, leaf area index, chlorophyll content and maize grain yield in tons per hectare.

Treatment	Total leaf area/plant (cm^2)	Leaf area index	Chlorophyll content (mg/100g)	Grain yield/Ha (mg/Ha)
Wood ash at 4 t/Ha	3874.2	2.15	1.25	1.62
NPK 15-15-15 at 300 kg/Ha	3954.1	2.19	1.46	1.65
NPK 15-15-15 at 200 kg/Ha plus Wood Ash at 2 t/Ha	4039.1	2.24	1.50	1.97
Control without manure	3715.2	2.06	0.88	0.82
LSD (0.05)	NS	NS	0.03	0.02

Statistical analysis

The average values of the soil and grain yield parameters of the first and second maize crops were determined for statistical analysis of means comparison, using the least significant difference (lsd at 5% probability).

RESULTS

The pretreatment soil analysis of the experimental plot indicated the soil to be sandy clay loam with a composition of 67% sand, 12% silt and 21% clay. The soil chemical properties indicated pH 5.3, 1.25% organic matter, 9.5 ppm available phosphorous, 0.12% nitrogen, 0.15 cmol/kg sodium, 0.19 cmol/kg potassium, 1.32 cmol/kg calcium and 0.24 cmol/kg magnesium while the analysis of the wood ash used showed composition of pH 11.8, 1.19% nitrogen, 8.7 ppm phosphorus, 0.87% potassium, 0.16% sodium, 1.84% calcium, 0.63% magnesium.

Table 1 showed the mean values of soil chemical properties. The pH values were significantly higher in the plots treated with wood ash compared with the other plots while the organic matter values were 3.45 and 3.30% in 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture and 300 kg/ha NPK 15-15-15, respectively compared to other treatment plots. Significantly higher nitrogen and potassium values were obtained in plots treated with 300 kg/ha NPK 15-15- 15 and in 200 kg/ha NPK 15- 15-15 plus 2 t/ha wood ash mixture compared to other treatment plots. Calcium and magnesium were significantly higher in plots treated with wood ash compared with other treatments.

Table 2 showed the mean values of total leaf area, leaf area index, chlorophyll content and the maize grain yield. There were no significant differences in total leaf area and leaf area index among treatments, though a higher value of 4039.1 cm^2 was obtained in 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture and in a decreasing order of magnitude of 3954.1, 3874.2 and 3715.2 cm^2 in 300 kg/ha NPK 15- 15-15, 4 t/ha wood ash and control plot without manure respectively for the total leaf area. A corresponding trend of 2.24, 2.19, 2.15 and 2.06, respectively were obtained for the leaf area index. Significantly higher chlorophyll content values of 1.50 and 1.46 mg/g were obtained in 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture and 300 kg/ha NPK 15-15-15 with correspondingly higher nitrogen content compared with other treatment plots. Significantly higher yield value of 1.93 t/ha was obtained in 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture and followed in a decreasing order of magnitude by 1.89, 1.67 and 0.82 t/ha in 300 kg/ha NPK 15-15-15, 4 t/ha wood ash and control plot without manure, respectively while the corresponding percentage increase in yield over the control plot without manure were 115.8, 101.2 and 97.6%, respectively. The grain yield values were correlated with the total leaf area, the leaf area index and the chlorophyll content with correlation values 0.96, 0.97 and 0.95, respectively. Table 3 which showed the profitable analysis indicated net revenue of 77,630.00, 66,780.00, 45,255.00 and ₦10,255.00 in 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture, 300 kg/ha NPK 15-15-15, 4 t/ha wood ash and control plot without manure, respectively.

Table 3. The profitable analysis of maize production with the application of wood ash and NPK 15-15-15 at various rates.

Farm operations	Wood ash at 4t/Ha (₦)*	NPK 15-15-15 at 300Kg/Ha (₦)*	Wood ash at 2t/Ha plus 100Kg/Ha NPK 15-15-15 (₦)*	Control without manure application (₦)*
Land preparation (Ploughing and Harrowing)	10,000.00	10,000.00	10,000.00	10,000.00
Manure procurement /transportation	20,000.00	1,500.00	12,500.00	Nil
Purchase of maize seeds	3,900.00	3,900.00	3,900.00	3,900.00
Planting (8 pd at ₦ 500.00/pd)**	4,000.00	4,000.00	4,000.00	4,000.00
Application of manure (8 pd at ₦ 500.00/pd)**	4,000.00	4,000.00	4,000.00	4,000.00
Cost of one supplementary weeding (20 pd at ₦ 500.00/pd)**	10,000.00	10,000.00	10,000.00	10,000.00
Cost of harvesting (20 pd at ₦ 500.00/pd)**	10,000.00	10,000.00	10,000.00	10,000.00
Cost of shelling and bagging	3,000.00	3,000.00	3,000.00	3,000.00
Sub-total cost	64,900.00	46,400.00	57,400.00	44,900.00
Miscellaneous expenses	3,245.00	2,320.00	2,870.00	2,245.00
Total cost	68,145.00	48,720.00	60,270.00	47,145.00
Yield (T/Ha)	1.62	1.65	1.97	0.82
Gross revenue (Sales at ₦ 70,000.00 per ton)	113,400.00	115,500.00	137,900.00	57,400.00
Net revenue	45,255.00	66,780.00	77,630.00	10,255.00
% Increase in yield over plot without manure	97.6	101.2	115.8	

*Exchange rates: 1US Dollar = 146 Nigerian Naira (₦ 146.00); ** pd = person days (Farm labour wage).

DISCUSSION

The pH 5.3 of the soil in the experimental site before the application of manure indicated the soil to have medium acidity level. Soil with a pH range of 5.2 - 5.6 had been reported to be of medium acidity (Brady and Weil, 1999). This justified the investigation with the use of wood ash as soil amendment. This agreed with the principle on the use of wood ash only on soils that were not alkaline since such essential elements as iron, manganese and zinc would be locked up and made unavailable to plants on highly alkaline soils (Demeyer et al., 2001) . Also the generally low level of plant nutrients in the experimental plot was as a result of a continuous cultivation of the experimental site for arable maize and cassava crops without application of manure to replenish the soil of nutrients. Tisdale et al. (2003) had explained with Mitscherlich's principle of plant's positive response to applied nutrients that were previously limiting in the soil.

The significantly higher pH values of 7.7 and7.5 in 4 t/ha wood ash and 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture plots was due to the liming effects of the wood ash added. Demeyer et al. (2001) and Lickaaz (2002) had described wood ash to be similar to burned or hydrated lime as it contained oxides and hydroxides of potassium, sodium, calcium and magnesium. This also could be responsible for the significantly higher sodium, calcium and magnesium levels in plots treated with wood ash compared with the plot treated with the 300 kg/ha NPK 15-15-15 and control plot without manure. Nitrogen and potassium, being major components of NPK 15-15-15 inorganic compound fertilizer caused their significantly high levels in 300 kg/ha NPK 15-15-15 and 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture. The

The phosphorus content did not show significant differences among treatments because phosphorus formed a major component in both NPK fertilizers and wood ash (Ayeni et al., 2008), while the pretreatment soil analysis indicated the soil not to be originally deficient in phosphorus. The significantly high organic matter values in 200 kg/ha NPK 15- 15-15 plus 2 t/ha wood ash mixture and 300 kg/ha NPK 15-15-15 signified high soil fertility which reflected in significantly high maize grain yield which corroborated earlier observation of Roger and Sharland (1997) and Bruno et al. (2002).

The order of magnitude of total leaf area and the leaf area index values which were higher in 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture and which also reflected in the yield of maize grain corroborated with the earlier assertion of leaf area to be essential for simulation of light interception and photosynthate production (Stewart and Dwyer, 1999; Subedi and Ma, 2005). Mauro et al. (2001) had also explained leaf area index and leaf angle distribution as important parameters for estimating the exchange of energy and gases in vegetative canopies. The total leaf area, leaf area index and chlorophyll content which had positive correlation with the maize grain yield (r = 0.96, 0.97 and 0.95 respectively) confirmed the assertion of Mohamed et al. (2008) that chlorophyll content and photosynthesis were biochemical processes which increased the grain yield of maize. The highest grain yield value of 1.97 t/ha in 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture compared with other treatments showed a high yield obtainable when wood ash alone or in combination with inorganic manure was used to improve soil fertility for increased crop production (Amujityegbe et al., 2007; Roger and Sharland, 1997; Awodun et al., 2007).

The higher net revenue of seventy seven thousand six hundred and thirty naira obtained in 200 kg/ha NPK 15-15- 15 plus 2 t/ha wood ash mixture compared to the sixty six thousand seven hundred and eighty naira obtained in 300 kg/ha NPK 15-15-15 confirmed that the rate of inorganic fertilizer can be reduced by replacement with wood ash to obtain a highly profitable maize production for an economic emancipation of maize farmers (Oladeebo and Ezekiel, 2006).

Conclusion

The significantly higher maize grain yield obtained in 200 kg/ha NPK 15-15-15 plus 2 t/ha wood ash mixture compared with when 300 kg/ha NPK 15-15-15 or 4t/ha wood ash, confirmed that a combination of both organic and inorganic nutrient sources gave higher maize grain yield than when each was applied separately and the reduction in the rate of inorganic fertilizers would increase the profit margin of maize production.

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