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Full Length Research Paper

The result of quantity and placement distances of inorganic 15-15-15 fertilizer in improving soil fertility and yield of maize in a tropical rain forest zone of Nigeria

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The high cost of mineral fertilizer in crop production had necessitated an investigation into the optimum fertilizer rate for profitable maize production. The study was conducted in Akure (7°15'N, 5°12'E) in Nigeria in 2007 and revalidated in 2008. The experimental design was a split plot method in a randomized complete block with fertilizer quantity as the main plot and fertilizer placement distance of maize plant as the sub plots. The NPK 15-15-15 fertilizer rates in the main plot were 0,150,200,250 and 300 kg NPK/ha, while distances of application of the maize plants that formed the subplots were 10, 15 and 20 cm. Improved maize growth parameters were observed in plots treated with fertilizers at 300 and 250 kg per hectare and at placement distances of 10 and 15 cm with higher yield and corresponding higher net revenue. The economic analysis confirmed the efficient use of fertilizer to lift small holder maize farming from subsistence levels to a more business-oriented agricultural economy.

Key words: Optimum fertilizer use, inorganic fertilizer, soil fertility, maize performance and yield.

INTRODUCTION

Fertilizer had been defined as any organic and inorganic material added to a soil to supply certain elements essential to the growth of plants (Brady and Weil, 1999). Fertilizers provide typically in varying proportions, the three major plant nutrients (nitrogen, phosphorus, potassium), the secondary plant nutrients (calcium, magnesium, sulphur) and when required, trace elements (boron, manganese, iron, zinc, copper, molybdenum and chlorine) (Tisdale et al., 2003).

The use of fertilizers in improving crop production had been discussed in previous study as Stewart et al. (2005) evaluated the percentage contribution of fertilizer to the increased yield of agricultural crops that ranged from 40 to 60% in the U.S. and England while Niehues et al. (2004) reported starter nitrogen fertilizer as an effective efficient way of stimulating early growth and improving yields of corn in Kansas.

The effects of fertilizer subsidy in Brazil which caused an increase in the production of wheat, soybean and other agricultural commodities with positive effects on the Brazilian economy were reported (Hall et al., 1983). Bationo et al. (1993) reported an increased yield in pearl millet in Niger, West Africa on the addition of crop residue with fertilizer. The economics of fertilizer application in such crops as cacao was discussed in Opeke (1997) who reported a likely average of 30% yield increase from the application of combined nitrogen and phosphorus fertilizer.

The use of fertilizer was emphasized in the African fertilizer summit held in Abuja, Nigeria in June 2006 by New Partnership for Africa Development (NEPAD), African Union and International Fertilizer Development Centre (IFDC) . The summit was held to increase the awareness of the role that fertilizer could play in stimulating sustainable productivity growth in African agriculture and to discuss approaches for rapidly increasing efficient fertilizer use by African smallholder farmers. The beneficial effects of fertilizer application on soils for a sustainable food crop production had made the need for information on fertilizer supply and use for

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increased food production desirable.

Maize being one of the most widely grown crops in the world and a staple that provided half of the calorie consumed in many countries in Sub-Saharan Africa had been reported to have a high requirement for nutrients which justified its being a good indicator of the nutrient status of the soil as it responded readily to the application of fertilizer (Iken and Amusa, 2004; Ayoola and Makinde, 2009; Yu Helong et al., 2009). The common practice of fertilizer application among farmers in Akure where the research was conducted and in fact in other agrarian towns around had been through broadcasting and localized placement. The broadcasting method had several disadvantages of higher rates to be used and the fertilizer being easily washed away with runoff during heavy rains would make such application method being uneconomical. The localized placement was being practiced haphazardly. There was therefore the need to identify a very appropriate method to guarantee optimum fertilizer usage for maize and other food crops for profit maximization in a business-oriented agricultural economy.

The objective of this study was to investigate the optimum fertilizer rate and the placement distance from the plant to effectively improve soil nutrient status and the performance and yield of maize.

MATERIALS AND METHODS

Site description

Two field experiments were conducted in Akure (7°15'N, 5°12'E) in Nigeria in 2007 and revalidated in 2008. The latitude and longitude data were taken with the use of a 12 channel Garmin 72 Global Positioning System (GPS) receiver. The site before the study in 2007 was characterized as a gentle terrain which had been cropped continuously for five years without fertilizer application. The climate was humid tropical with the rainy and dry seasons distinctly defined. The climatic data were obtained from Ondo state agroclimatological unit, Ministry of Agriculture and Natural Resources, Akure. The experiment was carried out in the rainforest agro-ecological zone of Ondo State.

Experimental design, land preparation and planting of maize.

The experimental design was a split plot method in a randomized complete block with fertilizer quantity as the main plot and fertilizer placement distance from maize plant as the sub plots. The NPK 15-15-15 fertilizer rates in the main plot were 0,150,200,250 and 300 kg NPK/ha, while distance of application of the maize plants that formed the subplots were 10, 15 and 20 cm. The land was ploughed and harrowed and late maturing Downy Mildew Resistant (DMR) open pollinated yellow maize planted in April at a spacing of 75 x 25 cm to give a plant population of 53,000 stands per hectare (Phillips, 1977).

Fertilizer treatment

NPK 15-15-15 application that formed the main plot was applied at 0, 150, 200, 250 and 300kg/ha which gave a corresponding weight of 0, 2.8, 3.8, 4.7 and 5.6 g per maize plant, respectively at three weeks after planting.

Soil sampling and analysis

Pre-planting soil samples were taken for analysis before tillage operations of ploughing plus harrowing and the fertilizer application while post planting soil sampling was carried out at the maize flowering stage of 65 days after planting. Soil samples from three points in each plot were bulked air-dried and sieved through a 2 mm sieve and analysed for the chemical properties following the laboratory procedures described by Carter (1993). The particle size distribution was determined using 50 g of soil in 0.1 M NaOH as dispersing agent using Hydrometer (ASTM, 1524) methods. 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 determined by the Bray P-1 method. The exchangeable cations were extracted by leaching 5 g of soil with 50 ml ammonium acetate at pH 7. The potassium and sodium in the leachate were determined with a flame spectrophotometer while the calcium and magnesium were determined with atomic absorption spectrophotometer.

Agronomic parameters

The mean values of plant height, stem girth, total leaf area, leaf area index, ear weight, number of grains/ear and yield of four maize plants with in a 1 m × 1 m quadrat in each subplot were taken for statistical analysis.

Measurement of the total leaf area per plant and leaf area index

The total leaf area of randomly selected four maize plants per subplot was taken and the corresponding leaf area index computed. The leaf area was measured following the procedure of Stewart and Dwyer (1999), Elings (2000) by multiplying the length of leaf by the widest width by alpha where alpha is 0.743 (L x W x 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) .Harvesting was carried out 120 days after planting and the 14% grain moisture content confirmed with the use of grain moisture tester, while the grain yield per hectare was taken.

Statistical analysis

The plant height, stem girth, total leaf area, leaf area index and yield values were subjected to statistical analysis using Statistical Package for the Social Sciences (SPSS), while mean comparisons were made using Duncan Multiple Range Test (DMRT) at 5% probability. The fertilizer rate and the distances of application were each correlated to the growth parameters of plant height, stem girth, total leaf area and leaf area index and the yield parameters of ear weight, number of grains per ear and the yield per hectare. The economic analysis based on expenditure and income on maize production at the varied NPK 15-15-15 fertilizer rates and placement distances were computed.

RESULTS

Figures 1 and 2 show rainfall distribution pattern, relative humidity and temperature regime of Akure in 2007 and

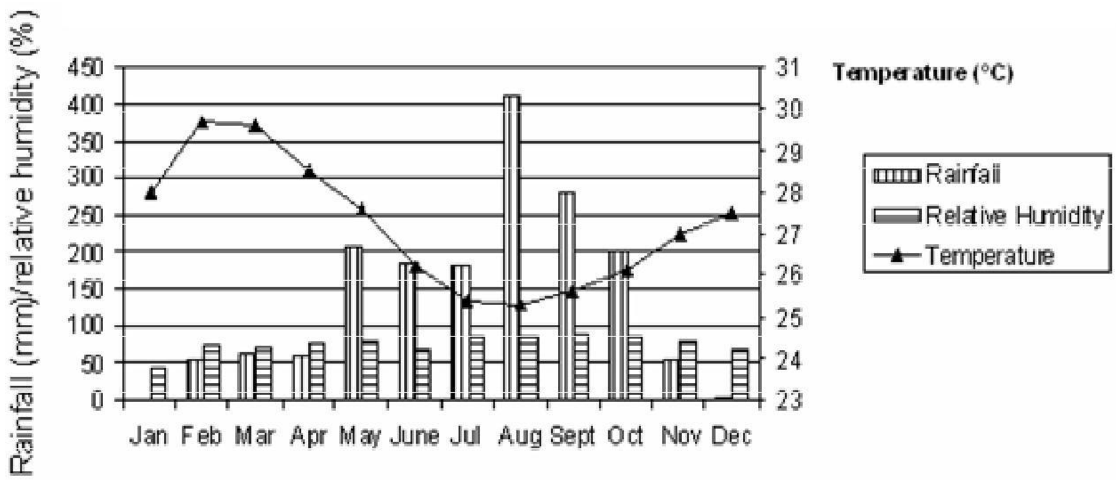

Figure 1. The chart of rainfall distribution, relative humidity and temperature regime of Akure in 2007.
Source: Ondo State Agroclimatological Unit, Ministry of Agriculture and Natural Resources Akure.

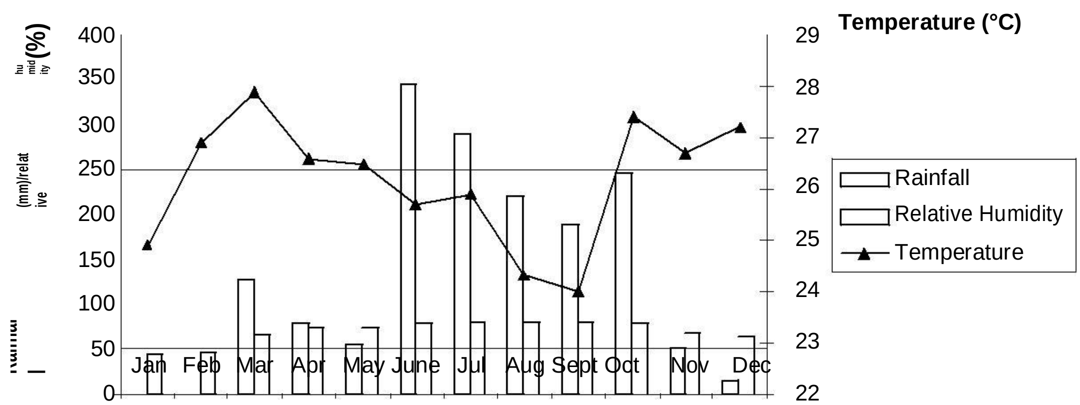

Figure 1b. The chart of rainfall distribution, relative humidity and temperature regime of Akure in 2008.
Source: Ondo State Agroclimatological Unit, Ministry of Agriculture and Natural Resources Akure.

2008 respectively. In the two years, the rainy and dry seasons were distinctly identified. There were higher rainfall values between the months of May and October in 2007 while higher rainfall values were observed between March and October in 2008.

Even though temperature did not follow a corresponding trend with rainfall, the months of June to October had lower values when compared to higher range between November and April in 2007 while in 2008 lower temperature was obtained in January and between the months of June and September (Figure 1b).

Soil analysis

The pre-treatment soil analysis showed the soils to be slightly acidic with low organic matter, total nitrogen, calcium, magnesium, potassium and phosphorus (Table 1).

Effects of NPK fertilizer application on soil chemical properties at post planting

Table 2 shows the effects of fertilizer application on soil chemical properties at post planting. The application of the NPK fertilizer increased the organic matter, percentage nitrogen, phosphorus and potassium content compared to the values observed in the pre-treatment soil analysis. This apparently showed in the mean values observed in plots without fertilizer application (0 kg NPK/ha) compared to plots treated with 150, 200, 250 300 kg NPK/ha respectively. The pH did not however follow any sequence at post planting as soils ranged from

Table 1. Pre-planting soil analysis.

Soil properties	Value
pH	5.6
Organic matter (%)	1.57
Available Phosphorus (ppm)	7.10
Total Nitrogen (%)	0.16
Sodium (cmol/kg)	0.17
Potassium (cmol/kg)	0.17
Calcium (cmol/kg)	2.80
Magnesium (cmol/kg)	1.63

Table 2. The effects of NPK 15 – 15 – 15 on soil chemical properties at post planting.

Fertilizer (Kg/Ha)	Distance of application (cm)	pH	Organic matter (%)	Nitrogen (%)	Available K (ppm)	Na (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)
0	10	6.0	1.57	0.16	7.3	0.18	0.17	3.03	1.90
	15	5.6	1.60	0.16	7.1	0.17	0.17	2.97	1.63
	20	5.7	1.64	0.17	7.2	0.17	0.17	2.80	1.80
150	10	5.9	3.23	0.19	8.3	0.19	0.27	3.40	2.10
	15	6.2	3.05	0.22	9.2	0.17	0.24	3.53	2.53
	20	6.1	3.04	0.18	8.1	0.16	0.21	3.60	2.17
200	10	6.3	3.69	0.25	11.4	0.20	0.33	3.80	2.40
	15	6.2	3.26	0.24	11.9	0.18	0.33	4.03	2.10
	20	6.3	3.07	0.20	10.9	0.19	0.26	3.67	2.00
250	10	6.3	3.83	0.29	12.2	0.20	0.32	3.60	2.30
	15	6.8	3.64	0.29	12.4	0.20	0.34	4.13	2.40
	20	6.3	3.15	0.23	11.8	0.21	0.25	3.83	2.07
300	10	6.8	4.23	0.32	12.6	0.18	0.36	4.10	2.440
	15	6.7	4.00	0.32	13.1	0.20	0.38	4.03	2.30

slightly acidic to medium acidic level.

Effects of fertilizer quantity on maize growth parameters

Table 3 shows the effects of fertilizer application on maize plant height, stem girth, total leaf area and leaf area index. There was observed significantly high maize plant height in plots treated with 200, 250 and 300 kg/ha NPK compared with 0 and 150 kg/ha NPK fertilizer with the highest value of 197.6 cm in 300 kg NPK/ha and the least value of 167.9 cm in plot without fertilizer (0 kg NPK/ha). Similar trends of significantly high values were observed for stem girth, total leaf area and the leaf area index. The fertilizer rate was positively correlated to the growth parameters with correlation coefficient values of 0.90, 0.96, 0.99 and 0.98 in plant height; stem girth, total leaf area and leaf area index, respectively (Table 9).

Effects of fertilizer on maize yield parameters

Table 4 shows the effects of fertilizer quantity on maize ear weight, number of seeds per ear and yield per hectare. The ear weight, number of grains per ear and the grains yield per hectare showed significantly high values in plots treated with 300 kg/ha NPK fertilizer compared to other plots. The values decreased in a decreasing order of magnitude in 250, 200, 150 kg NPK/ha and plot without fertilizer (0 kg NPK/ha). The fertilizer rate was positively correlated with the yield parameters with correlation coefficient values of 0.99, 0.94 and 0.97 in ear weight, number of grains per ear and grains yield per

Table 3. Effects of quantity of fertilizers on the maize growth parameters of plant height, stem girth, total leaf area and leaf area index.

Fertilizer (kg/ha)	Plant height (cm)	Stem girth (cm)	Total leaf area (cm^2)	Leaf area index
0	167.90^{c}	3.80^{d}	3521.00^{d}	1.88^{d}
150	175.50^{b}	4.50^{c}	3806.60^{c}	2.03^{c}
200	198.10^{a}	5.40^{b}	4021.80^{b}	2.15^{b}
250	197.00^{a}	5.60^{a}	4030.40^{b}	2.15^{b}
300	197.60^{a}	5.60^{a}	4161.50^{a}	2.22^{a}

Figures followed by the same letters were not significant using Duncan multiple range text (DMRT) at 5% probability.

Table 4. Effects of quantity of fertilizers on the maize yield parameters of cob weight, number of seeds per cob and yield per hectare.

Fertilizer (kg/ha)	Ear weight (gm)	Number of grains per ear	Grains yield (kg/ha)
0	217.60^{c}	386^{d}	894.60^{e}
150	234.10^{d}	455^{c}	1123.50^{d}
200	241.20^{c}	565^{b}	1465.20^{c}
250	247.10^{b}	567^{b}	1561.80^{b}
300	256.90^{a}	570^{a}	1661.70^{a}

Figures followed by the same letters were not significant using Duncan multiple range text (DMRT) at 5% probability.

Table 5. Effects of fertilizer placement distance from maize plant on the maize growth parameters of plant height, stem girth, total leaf area and leaf area index.

Distance (cm)	Plant height (cm)	Stem girth (cm)	Total leaf area	Leaf area index
10	187.60^{a}	5.00^{b}	3929.80^{a}	2.09^{a}
15	186.60^{a}	5.10^{a}	3940.50^{a}	2.00^{a}
20	186.50^{b}	4.80^{c}	3854.50^{b}	2.06^{b}

Figures followed by the same letters were not significant using Duncan multiple range text (DMRT) at 5% probability.

hectare, respectively (Table 9).

Effects of distance of fertilizer placement on the maize growth and yield parameters

Tables 5 and 6 show the effects of distance of fertilizer placement on maize growth and yield parameters, respectively. There were significantly higher mean values in plant height, stem girth, total leaf area and the leaf area index when fertilizer was placed at a distance of 10 and 15 cm compared to fertilizer placed at a distance of 20 cm from the plant. The ear weight, number of seeds per ear and the grains yield per hectare had lower significant values when fertilizer was placed at a distance of 20 cm when compared with when it was placed at 10 and 15 cm.

The interaction effects of fertilizer and distance on maize growth and yield parameters

Tables 7 and 8 show the interaction effects of fertilizer and placement distance on maize growth and yield parameters, respectively. Higher values were obtained by application of fertilizers at a rate of 200, 250 and 300 kg/ha and at distances of 10 and 15 cm compared with the lowest values observed in 0 and 150 kg fertilizer per hectare and at a distance of 20 cm of maize plants. At each rate of fertilizer application, the placement distance of 20 cm consistently had lower values.

Table 5 shows the correlation between the fertilizer rate and the distances of application respectively to the growth parameters of plant height, stem girth, total leaf area and leaf area index and also to the yield parameters of ear weight, number of grains per ear and

Table 6. Effects of fertilizer placement distance from maize plant on the maize yield parameters of cob weight, number of seeds per cob yield per hectare.

Distance (cm)	Ear weight (gm)	Number of grains per ear	Grains yield (kg/ha)
10	240.80[a]	510 [a]	1351.50[a]
15	241.90[a]	510[a]	1352.70[a]
20	235.40[b]	505[b]	1317.70[b]

Figures followed by the same letters were not significant using Duncan multiple range text (DMRT) at 5% probability.

Table 7. The interaction effects of fertilizer and distance on maize growth parameters.

Fertilizer (kg/ha)	Distance (cm)	Plant height (cm)	Stem girth (cm)	Total leaf area	Leaf area index
0	10	166.90	3.80[c]	3505.90	1.87
	15	167.30	3.80 [c]	3549.10	1.89
	20	169.40	3.80 [c]	3508.10	1.87
150	10	176.50	4.60[b]	3837.10	2.05
	15	175.60	4.70 [b]	3886.40	2.07
	20	174.30	4.30 [b]	3696.30	1.97
200	10	198.60	5.40[a]	4037.70	2.15
	15	199.00	5.50[a]	4034.70	2.15
	20	196.70	5.20[a]	3993.10	2.13
250	10	197.70	5.70[a]	4059.00	2.16
	15	197.60	5.80[a]	4052.70	2.16
	20	195.70	5.30[a]	3979.30	2.12
300	10	198.10	5.60[a]	4209.10	2.24
	15	198.50	5.70[a]	4179.60	2.23
	20	196.30	5.40[a]	4095.90	2.18

the yield per hectare. Increasing fertilizer had a positive correlation with maize growth and yield parameters while the increasing distances of fertilizer application had a negative correlation with the maize growth and yield parameters. Increasing the distance from 15 to 20 cm caused reduction in maize growth and yield values.

Effects of fertilizer rates and placement distance on maize profitable response

Table 10 shows the profitable response of maize to fertilizer rates and placement distance. The highest maize yield of 2,622.3 and 1,876.7 kg/ha were obtained in plots treated with 300 and 250 kg NPK fertilizer per hectare and at placement distances of 15 and 10 cm of maize plants and gave correspondingly higher net revenues of ₦134,284.00 and ₦ 74,636.00 respectively. The lowest yield value of 871.3 kg/ha was obtained in plot without fertilizer treatment (0 kg fertilizer per hectare) and the lowest net revenue of ₦27,900.00 observed in plot treated with 150 kg fertilizer per hectare and at a distance placement of 20 cm from the maize plant.

DISCUSSION

The tropical climatic pattern had been validly confirmed from the rainfall distribution, relative humidity and temperature values shown in Figures 1 and 2. Akintola (1986) in previous study of rainfall distribution in Nigeria for a period of 1892 to 1983 (91 years) described the tropical climate in relation to rainfall distribution and temperature pattern.

Table 8. The interaction effects of fertilizer quantity and distance of fertilizer placement on maize yield parameters.

Fertilizer (Kg/ha)	Distance (cm)	Ear weight (g)	Number of Grains per ear	Grains yield (kg/ha)
0	10	219.70	387	915.30^{g}
	15	216.00	385	895.30 ^{g}
	20	217.00	385	871.30 ^{g}
150	10	232.70	455	1124.30^{f}
	15	238.00	460	1140.30 ^{f}
	20	231.70	448	1105.00 ^{f}
200	10	243.00	565	1464.00^{e}
	15	242.30	569	1481.30 ^{e}
	20	238.30	559	1450.00 ^{e}
250	10	248.70	568	1572.70^{d}
	15	252.70	569	1570.00 ^{d}
	20	240.00	563	1539.70 ^{d}
300	10	260.00	574	1876.70b
	15	260.70	568	2622.30a
	20	250.00	562	1681.30c

Table 9. Correlation between fertilizer rate and the distances of application and maize growth and yield parameters.

	Plant height	Stem girth	Total leaf area	Leaf area index	Ear weight	Number of grains per ear	Grains yield (kg/ha)
Fertilizer rate	0.90	0.96	0.99	0.98	0.99	0.94	0.97
Distances of application	-0.90	-0.65	-0.80	-0.33	-0.77	-0.87	-0.85

The lowest fertility status as observed in the pre-treatment soil analysis could be due to the previous continuous cropping of the land without fertilizer application. This made the response of maize to the NPK fertilizer treatment apparent. Tisdale et al. (2003) had previously explained Mitscherlich's principle on the positive response of crops to the supply of the limiting elements in the soil. The critical limits of nutrients in the soil had previously been discussed in the study of productivity limitation of soils in North Western Nigeria (Kparmwang and Malgwi, 1997).

The significantly higher plant height, stem girth, total leaf area and leaf area index observed in plots treated with 300, 250 and 200 kg NPK fertilizer over 150 and 0 kg fertilizer showed the improvement of maize performance resulting from increased rate of NPK fertilizer (Odiete et al., 2005). The NPK 15-15-15 fertilizer supplied the elements nitrogen, phosphorus and potassium in equal proportions and therefore higher rates resulted in higher amounts of the nutrient elements. The best luxuriant growth expressed through higher total leaf area in plots treated with 300, 250 and 200 kg NPK fertilizer per hectare and at placement distances of 10 and 15 cm could be adduced to higher availability of potash which had been described to stimulate the synthesis of carbohydrates for the development of the framework substance of maize plants and this was explained from previous research to be accelerated with sufficient quantities of nitrogen (Hershey, 2002; Kiran, 2004). The leaf area index; a factor influencing crop growth due to the influence on photosynthesis had a significantly higher value of 2.22 in plot treated with 300 kg NPK fertilizer per hectare and this showed higher availability of the nutrient element nitrogen, phosphorus and potassium for the plants improved growth (Gobron, 2009). The significantly higher ear weight, number of grains per ear and the yield per plot treated with 300 kg NPK/ha showed improved yield with an optimal NPK fertilizer application (Whitbread et al., 2004; Odiete et al., 2005). Previous study had reported phosphate to principally affect the development and the set of the ear grains (Babalola and Salako, 2006). The placement distance

Table 10. Income and expenditure showing the profitable response of maize production to NPK 15 -15 -15 at varying rates and distances.

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*Exchange rates: 1US Dollar = 156 Nigerian Naira (₦156.00), **pd = person days (Farm labour wage).

of 10 and 15 cm indicated optimum distances for efficient uptake of nutrients by the plants while the fertilizer application distance of 20 cm resulted in less fertilizer elements to be available to maize plants which caused the negative correlation between fertilizer placement distances and maize growth and yield parameters. Previous study had confirmed placement to influence the effectiveness of fertilizer on plant’s performance. (Yu Helong et al., 2009).

The highest maize grain yield resulting from higher fertilizer application at the appropriate distances of 10 and 15 cm showed the efficient application method that could result in higher economic returns to maize farmers. Ojo (2000) and Zhiying Xu et al. (2009) observed that application of fertilizer to maize farms gave significantly higher yield with correspondingly improved financial status to producers while Bifarin et al. (2008) observed an economic empowerment for maize farmers when there was an increased production resulting from increased use of fertilizers.

CONCLUSION

Increasing the rate of NPK fertilizer from 150 kg/ha to increasing magnitude of 200, 250 and 300 kg/ha improved soil nutrient status and at the NPK fertilizer appropriate placement distances of 10 and 15 cm from the maize plant correspondingly improved maize yield which also resulted in higher economic returns to the maize farmers.

REFERENCES

Akintola JO (1986). Rainfall Distribution in Nigeria, 1892 to 1983. Impact Publishers Nigeria Ltd. Ibadan, Nigeria. p.380.

Ayoola OT, Makinde EA (2009). Maize Growth, Yield and Soil Nutrient Change with N-Enriched Organic Fertilizers. Afri. J. Food, Agric. Nutr. Dev., 9(1): 580–592.

Babalola OA, Salako FA (2006). Comparative study of Ogun

Phosphate rock and single superphosphate on three varieties of cowpea and maize and their effects on soil. Nig. J. Soil Sci., 16: 84–89.

Bationo A, Christianson CB, Klaij MC (1993). The effect of crop residue and fertilizer use on pearl millet. Nutrient Cycling in Agroecosystems, 34: 251–258.

Bifarin JO, MoyinJesu EI, Essiet EE (2008). Economic Analysis of post harvest losses of maize in Ondo State. In: Agele SO, Adekunle VAJ, Olufayo MO, Osho, IB (eds) Agriculture in Nigeria Wetlands: Proceedings of the Fourth Annual Conference of the School of Agriculture and Agricultural Technology, Federal University of Technology, Akure, Nigeria, pp: 237-240.

Brady NC, Weil RR (1999). The Nature and Properties of Soils. (12th Editon). Prentice Hall Inc, New Jersey, p.881.

Carter MR **(**1993). Soil Sampling and Methods of Soil Analysis. Canadian Society of Soil Science. Lewis Publishers, London. p.823.

Elings A (2000). Estimation of leaf area in tropical maize. Agron. J. 92: 436–444.

Gobron N (2009). Leaf Area Index. ftp://ftp.fao.org/docrep/fao/011/0197e/i0197e15.pdf

Hall NH, Stulp VJ, Reed MR (1983). Effects of a Fertilizer Subsidy on Brazilian Crop Production and Exports. Am. J. Agric. Econ., 65:571-575.

Hershey D (2002). How do the amounts of fertilizer affect plant growth. MadSci. Network. http://www.madsci.org/posts/archives/2002-04/1019088560.Bt.r.html

Iken JE, Amusa NA (2004) Maize Research and Production in Nigeria. Afri. J. Biotechnol. 3: 302–307.

Kparmwang T, Malgwi WB (1997). The Genesis, Classification and Productivity Limitations on Sandstone Soils in North Western Nigeria. In: Singh BR (ed) Management of Marginal Lands in Nigeria Proceedings of the 23rd Annual Conference of Soil Science Society of Nigeria held at Usmanu Danfodiyo University, Sokoto, Nigeria. pp: 43–50.

Kiran RJ (2004). Effect of Time of Weeding and Levels of N and P_2O_5 Fertilizers on the Grain Yield of Maize. Nepal. Agric. Res. J., 5:69–70

Mauro A, Homem A, Elizabeth A Walter-Shea, Mesarch MA (2001). Test of an extended mathematical approach to calculate maize leaf area index and leaf angle distribution. Agric. For. Meteorol. 108(1): 45–53.

Niehues BJ, Lamond RE, Godsey CB, Olsen CJ (2004). Starter Nitrogen Fertilizer Management for continuous N0-Till Corn Production. Agron. J., 96: 1412–1418.

Odiete I, Chude VO, Ojeniyi SO, Okozi AA, Hussaini GM (2005) Response of Maize to Nitrogen and Phosphorus sources in Guinea Savanna Zone of Nigeria. Nig. J. Soil Sci., 15:90–101.

Ojo SO (2000) Factor Productivity in Maize Production in Ondo State, Nigeria. Appl. Trop. Agric., 5: 57–63.

Opeke LK (1997). Tropical Tree Crops. Spectrum Books Limited, Ibadan. p.326.

Phillips TA (1977). An Agricultural Notebook. (With special reference to Nigeria) Lowe and Brydone Printers Limited, Great Britain. p.310.

Stewart DW, Dwyer LM (1999). Mathematical characterization of leaf shape and area of maize hybrids. Crop Sci.. 39: 422–427.

Stewart WM, Dibb DW, Johnston AE, Smyth TJ (2005). The Contribution of Commercial Fertilizer Nutrients to Food Production. Agron. J., 97: 1–6.

Tisdale SL, Nelson WL, Beaton JD, Havlin, JL (2003). Soil Fertility and Fertilizers, 5th Edition, Pearson Education, Inc. New Jersey. p.634.

Whitbread A, Mushayi P, Waddington S (2004). Modeling the Effects of Phosphorus on Maize Production and Nitrogen Use Efficiency on Small Holder Farms in Sub-Humid Zimbabwe. Fourth International Crop Science Congress in Brisbane, Australia 2004.

Yu Helong, Chen Guifen, Liu Dayou (2009). Research and Application of Precision Fertilization on Maize. Int. Federation Information Processing Book Series. 293: 477–486.
http://www.springerlink.com/content/027rt/h143342721/

Zhiying X, Zhengfei G, Jayne TS, Black R. (2009). Factors influencing the profitability of fertilizer use on maize in Zambia. Agric. Econ., 40(4):437–446.