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Effect of Quantity and Placement Distances of Inorganic 15-15-15 Fertilizer in Improving Soil Fertility Status and the Performance and Yield of Maize in a Tropical Rain Forest Zone of Nigeria

[1]F.O. Adekayode and [2]M.O. Ogunkoya

[1]Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Nigeria
[2]Federal College of Agriculture, Akure, Nigeria

Abstract: The high cost of mineral fertilizer in crop production had necessitated an investigation in 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 kg NPK/ha, 150 kg NPK/ha, 200 kg NPK/ha, 250 kg NPK/ha 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 kg and 250 kg per hectare and at placement distances of 10 cm 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 · 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 [1]. Fertilizers provided 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) [2].

The use of fertilizers in improving crop production had been discussed in previous study as Stewart *et al.* [3] evaluated the percentage contribution of fertilizer to the increased yield of agricultural crops that ranged from 40 to 60% in the USA and England while Niehues *et al.* [4] 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 was reported [5]. Bationo *et al.* [6] reported an increased yield in pearl millet in Niger in West Africa on the addition of crop residue with fertilizer. The economics of fertilizer application in such crops as cacao was discussed in Opeke [7] 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 NEPAD, African Union and 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 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

Corresponding Author: F.O. Adekayode, Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Nigeria

of fertilizer [8-10]. 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 site before the study in 2007 was characterized as a gentle terrain which had been cropped continuously for five years without fertilizer application.

Experimental Design, Land Preparation, 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 kg NPK/ha, 150 kg NPK/ha, 200 kg NPK/ha, 250 kg NPK/ha 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 Downy Mildew Resistant (DMR) open pollinated maize was planted at a spacing of 75 x 25 cm to give a plant population of 53,000 stands per hectare [11,12].

Fertilizer Treatment: NPK 15-15-15 application that formed the main plot was applied at zero, 150, 200, 250 and 300 kg/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 [13]. The particle size distribution was determined using 50 g of soil in 0.1M 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 within a 1 x 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 [14] and Elings [15] 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 [16].

Maize Yield Parameters: Harvesting was carried out at 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 economic analysis based on expenditure and income on maize production at the varied NPK 15-15-15 fertilizer rates and placement distances were computed.

Cost benefit analysis was carried out to evaluate the percentage increase of maize yield and revenue over plots without fertilizer.

RESULTS

Figuer 1a and 1b showed rainfall distribution pattern, relative humidity and temperature regime of Akure in 2007 and 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 pretreatment 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 showed the effects of fertilizer application on soil chemical properties at post planting. The application of the NPK

Table 1: Pre-planting soil analysis

Soil Properties	
pH	5.6
Organic Matter (%)	1.57
Available Phosphorus (ppm)	7.1
Total Nitrogen (%)	0.16
Sodium (cmol/kg)	0.17
Potassium (cmol/kg)	0.17
Calcium (cmol/kg)	2.8
Magnesium (cmol/kg)	1.63

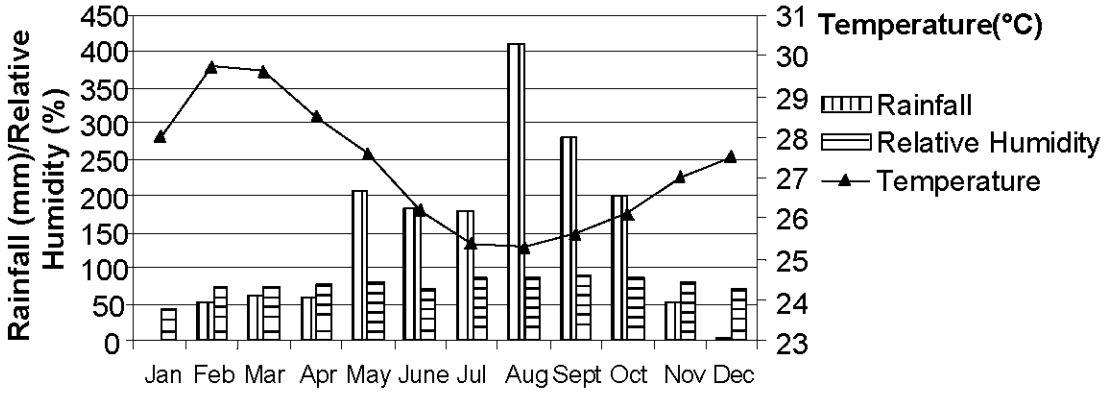

Fig. 1a: The chart of rainfall distribution, relative humidity and temperature regime of Akure in 2007

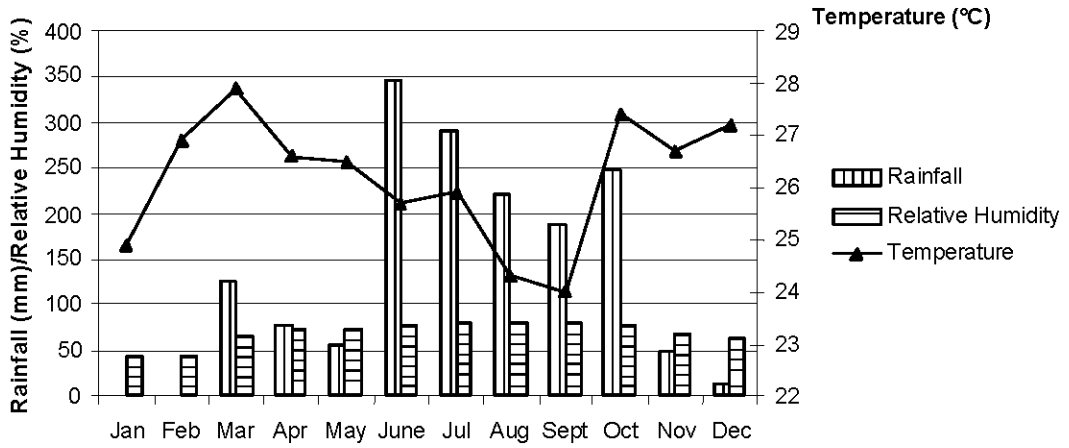

Fig. 1b: The chart of rainfall distribution, relative humidity and temperature regime of Akure in 2008

Table 2: The Effects of NPK 15-15-15 on soil chemical properties at post planting

Fertilizer (Kg/Ha)	Distance (cm)	pH	Organic Matter (%)	Nitrogen (%)	Available Phosphorus (ppm)	Na	K	Ca	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
	20	6.5	3.64	0.31	12.6	0.19	0.33	3.93	2.00

Table 3a: 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	167.9^e	3.8^d	3521.0^d	1.88^d
150	175.5^b	4.5^c	3806.6^c	2.03^c
200	198.1^a	5.4^b	4021.8^b	2.15^b
250	197.0^a	5.6^a	4030.4^b	2.15^b
300	197.6^a	5.6^a	4161.5^a	2.22^a

Figures followed by the same letters were not significant using Duncan Multiple Range Text (DMRT) at 5 % probability

Table 3b: 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	217.6^e	386^d	894.6^e
150	234.1^d	455^c	1123.5^d
200	241.2^c	565^b	1465.2^c
250	247.1^b	567^b	1561.8^b
300	256.9^a	570^a	1661.7^a

Figures followed by the same letters were not significant using Duncan Multiple Range Text (DMRT) at 5 % probability

Table 3c: 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	187.6^a	5.0^b	3929.8^a	2.09^a
15	186.6^a	5.1^a	3940.5^a	2.00^a
20	186.5^b	4.8^c	3854.5^b	2.06^b

Figures followed by the same letters were not significant using Duncan Multiple Range Text (DMRT) at 5 % probability

Table 3d: 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	240.8^a	510^a	1351.5^a
15	241.9^a	510^a	1352.7^a
20	235.4^b	505^b	1317.7^b

Figures followed by the same letters were not significant using Duncan Multiple Range Text (DMRT) at 5 % probability

Table 4a: 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	166.9	3.8	3505.9	1.87
	15	167.3	3.8	3549.1	1.89
	20	169.4	3.8	3508.1	1.87
150	10	176.5	4.6	3837.1	2.05
	15	175.6	4.7	3886.4	2.07
	20	174.3	4.3	3696.3	1.97
200	10	198.6	5.4	4037.7	2.15
	15	199.0	5.5	4034.7	2.15
	20	196.7	5.2	3993.1	2.13
250	10	197.7	5.7	4059.0	2.16
	15	197.6	5.8	4052.7	2.16
	20	195.7	5.3	3979.3	2.12
300	10	198.1	5.6	4209.1	2.24
	15	198.5	5.7	4179.6	2.23
	20	196.3	5.4	4095.9	2.18

Table 4b: 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/ear	Grains yield (kg/ha)
0	10	219.7	387	915.3
	15	216.0	385	895.3
	20	217.0	385	871.3
150	10	232.7	455	1124.3
	15	238.0	460	1140.3
	20	231.7	448	1105.0
200	10	243.0	565	1464.0
	15	242.3	569	1481.3
	20	238.3	559	1450.0
250	10	248.7	568	1572.7
	15	252.7	569	1570.0
	20	240.0	563	1539.7
300	10	260.0	574	1876.7
	15	260.7	568	2622.3
	20	250.0	562	1681.3

Table 5: Income and Expenditure showing the profitable response of maize production to NPK 15 -15 -15 at varying rates and distances

		Cost (#)* of Farm Operations with Fertilizer Rate and at the Distance of Applicati on														
		0kg/Ha NPK			150kg/Ha NPK			200Kg/Ha NPK			250kg/Ha NPK			300Kg/Ha NPK		
S/N	Farm Operations	10cm	15cm	20cm	10cm	15cm	20cm	10cm	15cm	20cm	10cm	15cm	20cm	10cm	15cm	20cm
1	Land Preparation (Ploughing and Harrowing)	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
2	Purchase of Maize Seeds	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
3	Planting (8 pd** at #500.00/pd)	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
4	Purchase of NPK 15-15-15	Nil	Nil	Nil	15000	15000	15000	20000	20000	20000	25000	25000	25000	30000	30000	30000
5	Application of NPK 15-15-15	Nil	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
6	Purchase of Primextra (Pre-emergence herbicide	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
7	Application of Premextra	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
8	Cost of one supplementary weeding (20 pd** at #500.00/pd)	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
9	Cost of Harvesting	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
10	Cost of Storage in the Crib	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
11	Cost of Shelling and Bagging	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
12	Total Cost	41500	41500	41500	60500	60500	60500	65500	65500	65500	70500	70500	70500	75500	75500	75500
13	Maize Yield (Kg/Ha)	915.3	895.3	871.3	1124.3	1140.3	1105	1464	1481.3	1450	1572.7	1570	1539.7	1681.3	1876.7	2622.3
14	Gross Revenue (1Kg sold at #80,000.00)	73224	71624	69704	89944	91224	88400	117120	118504	116000	125816	125600	123176	134504	150136	209784
15	Net Revenue	31724	30124	28204	29444	30724	27900	51620	53004	50500	55316	55100	52676	59004	74636	134284
16	% Increase in Yield over 871.3kg/Ha	5.1	2.7	Nil	29.0	30.9	26.8	68.0	70.0	66.4	80.5	80.2	76.7	115.4	201.0	93.0
17	% Increase in Net Revenue over #27900	13.7	8.0	1.1	5.5	10.1	Nil	85.0	90.0	81.0	98.3	97.5	88.8	167.5	381.3	111.5

*Exchange Rates: 1US Dollar = 156 Nigerian Naira (#156.00)

**pd = person days (Farm labour wage)

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/ha) compared to plots treated with 150 kg NPK/ha, 200 kg NPK/ha, 250 kg NPK/ha and 300 kg NPK/ha, respectively. The pH did not however follow any sequence at post planting as soils ranged from slightly acidic to medium acidic level.

Effects of Fertilizer Quantity on Maize Growth Parameters: Table 3a showed 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 300kg/ha and the least value of 167.9 cm in plot without fertilizer (0 kg/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.

Effects of Fertilizer on Maize Yield Parameters: Table 3b showed 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 300kg/ha fertilizer compared to other plots. The values decreased in a decreasing order of magnitude in 250kg/ha, 200kg/ha, 150kg/ha and plot without fertilizer (0kg/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 hectare, respectively.

Effects of Distance of Fertilizer Placement on the Maize Growth and Yield Parameters: Tables 3c and 3d showed 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 cm 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 4a and 4b showed 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 kg 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.

Effects of Fertilizer Rates and Placement Distance on Maize Profitable Response: Table 5 showed the profitable response of maize to fertilizer rates and placement distance. The highest maize yield of 2,622.3 kg/ha and 1,876.7 kg/ha were obtained in plots treated with 300 kg 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 1a and 1b. Akintola [17] 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 while Ristanovic [12] had related the suitability of soils developed under tropical conditions for the production of tropical crops.

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.* [2] 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 [18].

The significantly higher plant height, stem girth, total leaf area and leaf area index observed in plots treated with 300 kg, 250 kg and 200 kg NPK fertilizer over 150 kg and 0 kg fertilizer showed the improvement of maize performance resulting from increased rate of NPK fertilizer. 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 kg, 250 kg 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 [19,20]. 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 [21]. The significantly higher ear weight, number of grains / ear and the yield / plot treated with 300 kg NPK/ha showed improved yield with an optimal NPK fertilizer application [22,23], while previous indicated optimum distances for efficient uptake of nutrients by the plants. Previous study had reported phosphate to principally affect the development and the set of the ear grains [24]. The placement distance of 10 and 15 cm indicated optimum distances for efficient uptake of nutrients by the plants. Previous study confirmed the beneficial effects of fertilizer could be increased by placement [6].

The highest maize grain yield resulting from higher fertilizer application at the appropriate distances of 10 and 15cm showed the efficient application method that that could result in higher economic returns to maize farmers. Ojo [25] and Zhiying Xu *et al.* [26] observed that application of fertilizer to maize farms gave significantly higher yield with correspondingly improved financial status to producers while Bifarin *et al.* [27] 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 kg/ha, 250 kg/ha and 300 kg/ha improved soil nutrient status and at the NPK fertilizer appropriate placement distances of 10 cm and 15 cm from the maize plant correspondingly improved maize yield which also resulted in higher economic returns to the maize farmers.

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