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Research Paper

Optimizing NPK Fertilizer and Plant Spacing in Maximizing Yield and Yield Attributes of Maize (*Zea mays*) in Southern Nigeria

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Field experiments were carried out in 2013 and 2014 at the Ministry of Agriculture Research farm, Akpabuyo, Calabar, Cross River State, Nigeria. The experiments comprised of combined treatments of four spacing (50 x 30; 80 x 30; 50 x 50 and 70 x 40cm) with four levels of NPK 20-10-10 fertilizer (0, 60, 90 and 120 kg ha^{-1}) laid out in a 4×4 split plot in a Randomized Complete Block Design (RCBD), replicated three times. The results showed that the NPK fertilizer significantly increased growth parameters (plant height, leaf area, root length, number of leaves), yield and yield components. The highest yield in maize (193.36 t/ha^{-1}) was obtained from application of NPK 90 kgha^{-1}, and with spacing of 70 × 40 cm. The interaction effect of spacing x fertilizer was significant ($p<0.05$) in which the application of 90 kg/ha^{-1} with the spacing of 70 × 40cm yielded 9.20 t/ha^{-1}, which was significantly ($p<0.05$) higher than all other treatment combination under similar experimental condition. This seemed to be appropriate for maize production with better economic returns to the farmer in the study area. Highest Leaf Area (LA) 167.5 cm^2 and Specific Leaf Area (SLA) 455.0 cm^{2}g where obtained from the spacing of 70 × 40 cm while application of 90 kgha^{-1} gave the highest LA of 168.6 cm^2 and highest SLA of 456 cm^{2}g respectively. There was 21.1% unit increase in shelling percentage from maize fertilized with 90 kgha^{-1} NPK fertilizer compared with the application 120 kgha^{-1}.

Key words: Fertilizer, maize, maximum, optimal, plant spacing, yield, yield components

INTRODUCTION

Maize *(Zea mays* L.*)* is a grass plant which belongs to the order poales, family, graminaceae, genus Zea and species mays (Awe *et al.,* 2006), and is a major cereal crop after wheat and rice widely grown throughout in the tropical and sub-tropical zones of the world and its cultivation cut across a range of agro-ecological zones in Nigeria (David and Adam, 1988; Iken *et al.,* 2002).

There are many forms of maize, classified based on the amount of starch in each variety (Ayeni *et al.*, 2008a).

Its diverse use as human food, animal feed and raw materials for industry and the ease of cultivation as sole crop or combination with other crops gives it an advantage over most of other crops grown in a similar ecological zone (Kochhar, 1986).

FAO, (2009) reported that there is a decline in worldwide maize production from 1142.3 in 2008 to 1098.5 mt in 2009 (4% drop). This according to the report was attributed to continual use of low yielding cultivars, use of narrow spacing and incorrect application of desired rate of fertilizer, pest and diseases amongst others.

Most soils in the tropics, especially soils in Cross River State, Nigeria, are low in plant nutrients to meet crop major requirement (NAERL, 1993). If the yield of maize would increase, the low fertility status will require additional nutrients. One of the major causes of low yield is inadequate information on the application rate of inorganic fertilizer, especially compound fertilizer NPK (Awe *et al.,* 2006). Several researches have shown that when inorganic fertilizer is added into the soils it releases nutrients to the soil, improves chemical properties and enhance growth and development of the crop (FAO, 2009). But this nutrients seems to either exceeds the plant requirement or fall short of plant requirement, if not applied in the right amount. Often, farmers do not know the exact amount of NPK fertilizer to apply in the farm and thus adopts a random broadcasting of the fertilizer by applying in excess on the grounds of more nutrients more yield even though this is not applicable to crops.

Furthermore, the use of random spacing in the cultivation of maize have often led to poor yield (Ayeni *et al.*, 2008b). The use of smaller spacings had often led to overcrowding and higher plant density per hectare which leads to high competition for sunlight and available plant nutrients. This have often resulted to poor maize crop development and yield (Kochhar, 1986). Moreover, in this agro-ecology, where maize is rarely planted as a sole crop, but as mixed crop, spacing is not given any priority and hence the continuous decline in maize yield and yield components.
This study will consider an effective and economical rate of NPK fertilizer application and most appropriate plant spacing that will give significant yield of maize and better economic returns to the farmers in Nigeria.

MATERIALS AND METHODS

Experimental location

The field experiments were carried out, at the Ministry of Agriculture Research Farm, about 4 km from the University of Calabar, Teaching and Research Farm, Akpabuyo, located in the Southern Cross River (5°32' and 04° 57'N, 07°15' and 09°28'E) during the 2013 and 2014 cropping seasons. The study area has a humid tropical climate and rainforest vegetation characterized by high rainfall with distinct wet and dry seasons (Eshiett, 1994).

The experiments were designed to study the growth and yield of maize *(Zea may L.)* as influenced by spacing and NPK 20:10-10 fertilizer treatments. The Nigerian hybrid yellow maize SUWAN - SR-1, a disease resistant and high yielding variety was used. Leaf Area was measured by multiplying leaf length, leaf width and a factor 0.905 (Kochhar,1986). Specific leaf area was calculated thus:

$$\frac{LA}{LW} cm^2 g$$.

Experimental design

A split plot design was used with four spacing (50 x 30; 80 x 30; 50 x 50 and 70 x 40cm) as main plots and fertilizer N:P:K: (20:10:10) at (0, 60, 90 and 120 $kgha^{-1}$) as sub-plots which were laid out in a Randomized Complete Block Design, replicated three times. Unit plot size was 5 × 3m (15 m^2) with 1 and 0.5m pathway between each replication and the plots respectively. The four rates of fertilizer were applied as per treatment in two equal split doses at two and four weeks after sowing (WAS) in ring form. Manual weeding was done at two to four weeks after planting using simple hoe.

Parameters measured

Parameters measured with the standard laboratory methods include: plant height, grain yield, stove yield, root yield, Leaf Area (LA) cm^2, and Specific Leaf Area SLA (cm^2g).

Determination of soil physical and chemical properties

Soil samples from each location in the seven local government areas were sampled using a soil auger to depth of 0-40 cm. The soil samples were bulked differently, air dried, crushed, sieved to pass through 2 mm mesh and analyzed for physico-chemical properties using standard laboratory procedures as follows;
(a) Soil particle size distribution for percent silt, clay and sand using hydrometer method of Bouyoucos.
(b) Soil pH at 1:2.5 soil liquid ratio in water and KCl using electrode pH meter.
(c) Organic carbon was determined using Walkey and Black method of 1934.
(d) Total nitrogen was determined using Jackson procedures of 1965.
(e) Exchangeable Acidity was determined using the Mclean procedures of 1965.
(f) Exchangeable Bases Mg, K and Na were determined using Flame Photometry while Ca was determined by the Atomic Absorption Spectrophotometry.
(g) Available phosphorus was determined using the Bray and Kurtz procedures of 1945.
(h) Effective cation exchange capacity (ECEC) was obtained by summation.

Table1. Physico-chemical properties of the soil used in the Experiment.

Soil properties	Values
pH (H_20)	5.3
Organic C (%)	6.12
Total N (%)	0.08
Available P (mg/kg^{-1})	6.15
Exch. Bases (cmol kg^{-1})	0.79
Ca	0.42
Mg	0.13
K	0.16
Na	0.08
Exchangeable acidity	0.25
CEC (cmol kg^{-1})	0.12
Base saturation (%)	68.0
%Sand	65.0
%Silt	23.2
%Clay	145
Textural class	Sand loam

Results of physical and chemical properties of soils are presented in (Table 1).

Statistical analysis

The data collected were subjected to Analysis of Variance (ANOVA) and means separated, using Duncan Multiple Range Test at 5% probability level using the procedures of Obi, 2000 and the Genstat software version 4.0.

RESULTS AND DISCUSSION

Characteristics of the soil used for the study

The result of the analysis of the soil used for the study is presented in (Table 1). The soil was moderately acidic with a soil pH was of 5.3, Organic Carbon 6.12%, CEC was 1.22 cmol kg^{-1} while Total N and available P were 0.08% and 6.15 mg kg^{-1} respectively. The soil was sandy loam (sand 65%, silt as 232 gkg^{-1} and clay as 145 gkg^{-1}), Total N and available P contents were very low compared with the critical levels of 0.1% for N and 10-12 mg kg^{-1} for available P, (FAO, 1976) obtained for soils in southeastern Nigeria. Using the critical level of 0.2 cmol kg^{-1}, exchangeable K was low (Unamba, 1985). And using FAO (1976) established critical values for nutrients in these the soils, the soils were deficient in N, Ca, Mg and K, with respect to maize production, which could be due to long term cropping of the land.

Effect of NPK fertilizer rates on growth parameters of maize

Height is one of the significant characteristics associated with the productive potentials of a plant in terms of fodder, and fruit yield. In real sense, the optimum height of a plant is said to be directly correlated with production capacity of the plant.

Table 2 features some of the growth characteristics of maize as influenced by spacing and NPK fertilizer treatments. The response of maize to different spacing and different rates of NPK fertilizer treatment was significant ($P<0.05$). While 70×40 cm spacing gave the highest plant height, (224.40 cm), the application of 90 kgha^{-1} recorded the highest plant height (220.60 cm) and this was significantly ($P<0.05$) taller than all other values, under similar experimental conditions. However, maize planted at 50×30 cm spacing with application of 0 kgha^{-1} gave the lowest values throughout the study period. This finding agrees with the reports of Ayeni *et al. (*2008a), whose results showed similar poor yield attribute for maize planted at this spacing distance.

Results on the grain stover and root yields were significantly ($P<0.05$) influenced by the treatment combinations of spacing and NPK fertilizer. The results showed that higher grain stover and root yields were recorded in wider spacing (70 × 40 cm) and their values were significantly ($P<0.05$) higher than values obtained from all other spacing under similar experimental conditions. Equally, values obtained from grain stover and root yields where 90 kgha^{-1} NPK was applied were significantly ($P<0.05$) higher than all other values during the study period. The application of 90 kgha^{-1} recorded the tallest plant (12.38 cm), grain yield (195.53 t/ha^{-1}) and stover yield (16.74 t/ha^{-1}) compared with nil fertilizer treatments and these values were significantly ($p<0.05$) higher than all other values obtained from either the application 60 kgha^{-1} or 120 kgha^{-1}. This is agreement with the findings of (Chisto and Onuh, 2005; Philip *et al.,* 2010). The spacing of 70 × 40 cm tend to produce higher plant height, grain yield, leaf area, root yield, stover yield and SLA when statistically compared with the results obtained from same parameters using other spacing treatments, throughout the study season. The wider spacing of 70 × 40 cm provided sufficient opportunity for the roots to feed extensively within the nutrient water solution level without interrupting and competition, and this might have resulted to an enhanced root development with highest root yield (75.56 t/ha^{-1}) which was significantly ($p<0.05$) higher than all other values obtained from other spacings during the study. This support the earlier reports of Tindall, 1983; Kochhar, 1986; Youdeowei *et al.,* 1989 who all opined that wider spacing improves feeding area of the plant and enhances plant growth and development.

Similarly, the application of 90 kgha^{-1} resulted to an enhanced plant growth and development such that values obtained from number of leaf blades/plant, leaf area, root length and number of cobs per plant tended to be significantly higher in plots with 90 kgha^{-1} than in either 120, 60 or 0 kgha^{-1} under similar conditions.

Table 2. Effect of NPK fertilizer and spacing on some yield and yield attributes of maize for 2013 and 2014 cropping seasons.

Treatment	Plant height (cm)	Grain yield (t/ha^{-1})	Stover yield (t/ha^{-1})	Root yield (t/ha^{-1})	% increase in grain yield
Spacing					
50 x 30cm	160.15a	2.76a	3.69d	1.42b	22.3
80 x 30cm	202.10c	4.68c	4.58c	1.38b	28.9
50 x 50cm	213.29b	6.19b	5.32b	2.96a	30.7
70 x 40cm	224.40d	8.36a	6.13a	2.96a	86.6
SE±	66.241	0.412	0.380	0.265	-
Fertilizer	N:P:K: (20:10:10)				
$0kgha^{-1}$	119.52c	4.05c	1.26d	1.09c	0.62
$60kgha^{-1}$	200.19b	5.78b	3.84c	1.46bc	21.9
$90kgha^{-1}$	220.60a	9.39a	5.67a	2.16a	58.6
$120kgha^{-1}$	210.96ab	7.08b	4.17b	1.78b	35.2
SE±	0.286	0.185	0.348	0.116	-
Interaction Spacing x Fertilizer	S	S	S	S	-

S = Significant: Mean with the same letters in each column for each factor are not significantly different ($p<0.05$) by DMRT.

Table 3. Effect of NPK fertilizer and spacing on some growth characters of maize for 2013 and 2014 cropping seasons.

Treatment	No of leaf blade per plant	Leaf Area (cm^2)	Root Length (cm)	No of cobs per plant
Spacing				
50 x 30cm	10.26b	152.10	10.52	2.35c
80 x 30cm	10.35b	163.57	10.53	2.41c
50 x 50cm	10.28a	172.51	12.31	3.53b
70 x 40cm	12.15a	193.36	15.82	4.13a
SE±	0.332	82.114	0.615	0.323
Fertilizer	N:P:K: (20:10:10)			
$0kgha^{-1}$	8.11d	148.12d	9.42d	2.28d
$60kgha^{-1}$	9.26c	157.91c	12.36c	3.19c
$90kgha^{-1}$	12.38a	195.53a	16.74a	4.48a
$120kgha^{-1}$	10.25b	172.44b	14.55b	3.15b
SE±	0.415	74.220	0.514	4.48a
Interaction Spacing x Fertilizer	S	S	S	S

S = Significant: Mean with the same letter (s) in each column for each factor are not significantly different ($p<0.05$) using Duncan's Multiple Range Test (DMRT).

It is therefore cost effective for the farmer to increase production by the application of 90 $kgha^{-1}$ than 120 $kgha^{-1}$ (Adediran and Banjoko, 2003).

Table 4, shows the effect of NPK treatment and spacing on some growth parameters of maize in which the highest spacing 70 × 40cm had the highest mean values for Leaf Area (LA) 167.5 cm^2 and the highest specific leaf area 455.0 (cm^2g) and these values were significantly higher than all other values obtained from other spacing . Mean values of 70 × 40 cm spacing were more than double the values recorded for 50 × 30 cm, in terms of plant height, grain yield, stover yield and root yield spacing in all parameters during the study period. This was also in line with the reports and results of (Christo and Onuh, 2005).

The NPK fertilizer application at the rate of 90 $kgha^{-1}$ increased LA by 168.6 (cm^2) and SLA by 456.9 (cm^2g) compared with zero fertilizer application rate and these mean values were significantly ($p<0.05$) higher than all other mean values obtained from all other fertilizer rates used throughout the study period.

These mean values were significantly ($P<0.05$) higher than mean values obtained from all other fertilizer rates, and more than double the mean values from plots where 0 $kgha^{-1}$ was applied. There was 21.1% increase in shelling percentage by applying NPK 90 $kgha^{-1}$ compared with 120 $kgha^{-1}$. This is cost effective in that the cost of 120 kg fertilizer will be more than 90 kg required by the farmer to increase production with greater economic return at the end of the season. This result is in agreement with those of other researchers (Barber and Olson, 1968; Eze and Obi, 2008, Ayeni *et al.,* 2008b, Ubi, 2004 and Eshett, 1985) all of whom have equally stressed on the significance of the use

Table 4. Effect of NPK fertilizer and spacing on some growth parameters of maize for 2013 and 2014 cropping seasons.

Treatment	Length of cobs	GROWTH PARAMETERS Grain yield (t/ha^{-1})	Stover yield (t/ha^{-1})	Root yield (t/ha^{-1})
Spacing				
50 x 30cm	5.31d	2.65	1.22	34.15
80 x 30cm	6.4c	4.16	2.05	54.62
50 x 50cm	7.16b	5.27	2.74	62.38
70 x 40cm	10.48a	6.85	3.89	75.56
SE±	0.416	0.328	0.217	6.33
Fertilizer	N:P:K: (20:10:10)			
0kgha^{-1}	5.11d	2.18d	1.06a	28.24d
60kgha^{-1}	6.92c	3.65c	2.77b	67.58c
90kgha^{-1}	10.39a	6.72a	3.39a	86.27a
120kgha^{-1}	8.36b	5.12b	2.61b	71.31b
SE±	0.365	0.327	0.131	6.79
Interaction Spacing x Fertilizer	S	S	S	S

S = Significant: Mean with the same letter (s) in each column for each factor are not significantly different ($p<0.05$) using Duncan's Multiple Range Test (DMRT).

Table 5. Interaction between spacing and NPK fertilizer on grain yield of maize for 2013 and 2014 cropping season.

Fertilizer	Spacing			
	50 x 30cm	80 x 30cm	50 x 50cm	70 x 40cm
0kgha^{1}	2.58	2.63	2.61	3.52
60 kgha^{1}	4.72	4.56	4.66	4.93
90 kgha'^{1}	8.91	8.80	8.92	9.20
120 kgha^{1}	7.52	7.48	6.98	7.37
Prob of F LSD (0.05)	*	*	*	*

*Significant ($p<0.05$).

of adequate plant spacing and ideal rates of nutrients applications to crop if maximum yields are the object of farming. The interaction between spacing and NPK fertilizer in terms of maize grain yield (mean of two years) was significant (Table 5).

Conclusion

From this research we found that spacing and fertilizers had significant effect on maize growth grown in Akpabuyo area located in southern Nigeria. The result of this study showed that maize respond well to adequate spacing and NPK fertilizer application. The optimum spacing of 70 × 40 cm and the application of 90 kgha^{-1} fertilizer gave the highest yield of maize in this area. Thus, for greater economic returns and benefits, cultivation of maize plants with 70 × 40cm spacing and application of 90 kg ha^{-1} N:P:K: fertilizer is recommended.

Authors` declaration

We declare that this study is an original research by our research team and we agree to publish it in the Journal.

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