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Full Length Research Paper

Influence of nitrogen, phosphorus and potassium application on the yield of maize in the savanna zone of Nigeria

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Field trials testing the effects of five rates each of N, P and K application on three hybrid and two open-pollinated maize varieties were conducted in three separate experiments on an Arenic haplustalf (USDA) at Ilora in the derived savanna and Typic paleustalf (USDA) at Mokwa in the southern guinea savanna of Nigeria. The hybrid maize varieties planted were 8516-12, 8321-18 and 8329-15 and were compared with the open-pollinated maize, TZSR-Y and TZSR-W. Nitrogen was applied at rates 0-200 kg ha^{-1} in the first trial, while P and K were supplied as basal nutrients. In the second trial, P was applied at rates 0- 80 kg P_2O_5 ha^{-1} using basal N and K fertilizers. In another trial, K was applied at rates 0-120 kg ha^{-1} with blanket application of N and P. The hybrid maize gave higher yields and used N and P more efficiently than the open pollinated at both trial locations. The yield of maize was higher in the southern guinea savanna than in the derived savanna. The performance of the hybrid varieties followed in the ascending order of 8516-12, 8321-18 and 8329-15. The optimum rates of N and P for maize grown in the derived savanna were 100 and 40 kg ha^{-1}respectively. In the southern guinea savanna the open pollinated and hybrid varieties responded up to 150 and 200 kg N ha^{-1} respectively. The 8516-12 showed higher N and P use efficiency than other varieties. Consequently, planting such variety could be advantageous, using minimal dose of fertilizer most especially, where farmers have less access to fertilizer.

Key words: Hybrid maize, open pollinated maize, nitrogen use efficiency, phosphorus use efficiency.

INTRODUCTION

Maize production has become very popular and the crop is widely grown in many countries in the world. In recent times, production of hybrid maize has been given wide publicity among maize farmers in Nigeria. However, hybrid maize is well known for its high demand for plant nutrients and other production inputs. The farmer has been indoctrinated with the belief that all conditions required for maximum performance of hybrid maize have to be fulfilled to letters before the desired economic returns can be obtained. This extra production cost discourages most farmers engaging in hybrid maize production in the country.

The yield of maize however, varies from variety to variety, location to location and also depends on the availability of essential factors such as soil nutrient status and application of fertilizers. Nitrogen is a vital plant nutrient and a major yield-determining factor required for maize production (Adediran and Banjoko, 1995; Shanti et al., 1997). Its availability in sufficient quantity throughout the growing season is essential for optimum maize growth. Most farmers in developing countries usually rely on the natural soil fertility for crop production. Opening up of a long fallow land may provide adequate nutrient to food crop. But cropping of such land is only successful

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within few years after opening of the fallowed land. Afterwards, subsequent cropping requires additional fertilizer input, most importantly that of nitrogen to maintain good yields.

Phosphorus (P) is another limiting nutrient in maize production. Various factors could be responsible for P availability to crop plants. These include the form of native soil P, the type of P applied to the soil, and soil reaction. It has been reported that total P was higher in forest soils than in the savanna (Adepetu, 1970; Adepetu and Corey, 1975). Also, agricultural crops show different response to P fertilization.

The results of various fertilizer experiments carried out in Nigeria have led to fertilizer recommendations that gave blanket nutrient requirements for maize in ecologies having varying soil conditions and under varying levels of soil management (FPDD, 1990). This practice is aimed at giving farmers a fairly appreciable economic return from the fertilizer input. For example, hybrid maize cultivation was found to require high fertilizer rate for optimum yield. Findings from these research work indicated, that maize responded to nitrogen better in the savanna than in the forest ecology (Sobulo, 1980). It was further suggested, that 60-70 kg N ha^{-1} served as economic rate for maize in the rainforest, and over 100 kg N ha^{-1} in the savanna. The difference between the two zones was, however, attributed to the presence of higher insulation in the savanna (Sobulo, 1980). Some work earlier carried out with phosphorus fertilizer indicated positive response of maize to low rates of P (Amon, 1965; Amon and Adetunji, 1970). Application of high rate was reported to be capable of causing nutrient imbalance and consequently yield depression of western yellow maize (Osiname, 1979).

There has been no sufficient information on the fertilizer requirement of hybrid maize introduced to farmers in Nigeria. Farmers mainly rely on the blanket recommendation for maize production. However, new high-yielding maize varieties are continually being released for farmers' use. And there is need to determine their nutrient requirements. Also, changes in soil fertility levels with continued cultivation necessitate the reassessment of fertilizer application. This paper examines the effect of N, P and K application on the yield of hybrid maize in the derived and southern guinea savanna of Nigeria.

MATERIALS AND METHODS

Field trials were carried out at Ilora in the derived savanna (savanna-forest mosaic) and at Mokwa in the southern guinea savanna of Nigeria for three years. The soil at Ilora was classified as Arenic haplustalf (United State Department of Agriculture, USDA) and that at Mokwa was Typic paleustalf (USDA). Soils at the trial sites were loamy sand Alfisol with moderate pH values. The exception was the sandy loam texture at Ilora and Mokwa observed on the potassium and nitrogen experimental sites, respectively. The sites in both locations had been under cultivation for three to four years before establishing the trials and the soils therefore showed low nutrient status, with the exception of K, which was generally adequate (Table 1).

The hybrid maize (HBM) varieties planted were 8321-18, 8516-12, and 8329-15, which were recently introduced and have become popular in the zones of the experiments. Two open pollinated (OP) varieties (TZSR-W and TZSR-Y) commonly grown in the zones of the experiments were also planted for comparison. In the first trial, nitrogen fertilizer in the form of granular urea was applied to maize at 0, 50, 100, 150 and 200 kg N ha^{-1} two weeks after planting using drilling method. Phosphorus and potassium were applied at 40 kg P_20_5 and 60 kg K_20ha^{-1} as basal fertilizers. In the second trial, P was applied at rates 0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1} while, N and K were supplied as basal fertilizers at 100 kg and 60 kg K_2O ha^{-1}, respectively. Whereas in the third trial, K application was done at 0, 30, 60, 90 and 120 kg K_20 ha^{-1} using urea and single super phosphate at 100 kg N and 40 kg P_2O_5 ha^{-1}, respectively as basal fertilizers. For all the trials, the control consists of treatment with only basal fertilizer application. Nitrogen (NUE) or phosphorus use efficiency (PUE) was calculated as the yield obtained from the N (Yn) or P (Yp) fertilized plot minus control (Yc), divided by a unit weight of the applied fertilizer (Nw for nitrogen and Pw for phosphorus):

$$NUE = (Yn-Yc)/Nw$$

$$PUE = (Yp-Yc)/Pw$$

Table 1. Selected physical and chemical characteristics of the soil before cropping of maize.

Soil Properties	**Ilora**			**Mokwa**		
	N	P	K	N	P	K
Texture	Loamy Sand	Loamy Sand	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand
pH	6.07	6.08	6.33	6.10	6.18	6.32
Organic C (%)	0.67	0.80	0.75	0.37	0.62	0.46
Exchangeable Bases						
Ca (C. mol kg^{-1})	3.10	2.58	4.93	2.04	3.19	1.89
Mg, (C. mol kg^{-1})	0.88	1.21	2.13	0.56	1.12	0.67
K (C. mol kg^{-1})	0.22	0.21	0.34	0.19	0.17	0.12
Total N (g kg^{-1})	0.80	0.80	0.60	0.40	0.60	0.05
Available P (mg kg^{-1})	5.70	6.18	6.81	3.63	5.90	6.13
Available Zn (mg kg^{-1})	2.52	1.64	3.37	2.70	1.53	1.59

Soil samples were collected from the trial sites before cropping and were analyzed in the laboratory for selected physical and chemical properties. The plot size was 5.00 m X 5.25 m and planting space was 75 cm X 25 cm. The treatments were randomized within the block and replicated four times. Maize was harvested at maturity and grain yield was calculated at 12% moisture content. The data were subjected to analysis of variance and the means separation was performed by the Least Significant Difference (LSD) method utilizing the procedures of Gomez and Gomez (1984).

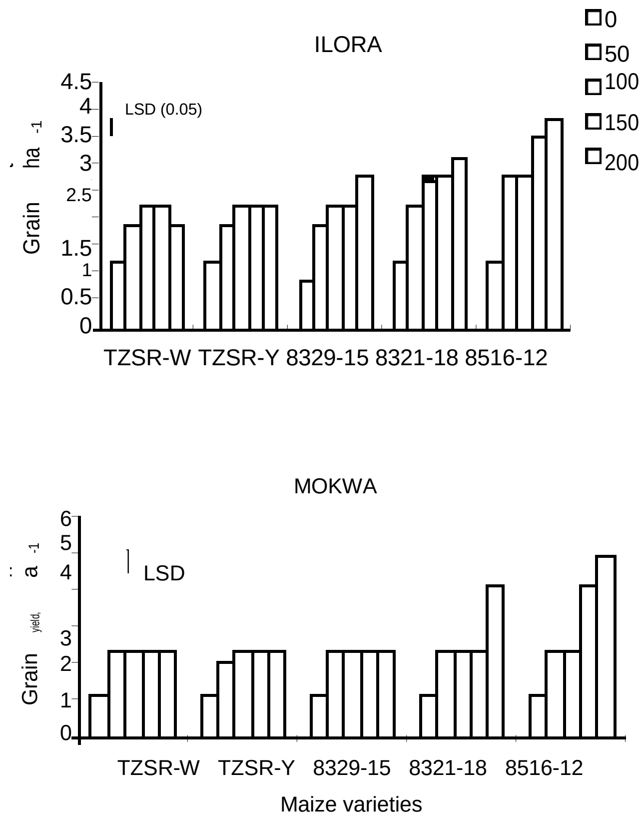

Figure 1. Effect of nitrogen rates (0, 50, 100, 150 and 200 kg ha^{-1}) on maize yield in the derived and southern guinea savanna zones of Nigeria.

RESULTS

Figure 1 shows the yield response of maize with respect to applied nitrogen rates. The yield of hybrid maize increased with rise in nitrogen rates at Ilora and Mokwa representing the derived savanna and southern guinea savanna respectively. At Ilora, the hybrid maize showed significant yield increase (p = 0.05) at rates above 100 kg N ha^{-1}. On the other hand, application of 100 kg N ha^{-1} to open pollinated maize (OP) was not significantly different from using 150 kg N ha^{-1}. The yield declined at rates above 100 kg Nha^{-1}. Whereas, increased yield of hybrid maize (HBM) was observed at higher rates. The exception was for 8329-15, which showed a little yield decrease at these rates. Regardless of the maize varieties, the yield obtained from the southern guinea savanna was higher than from the derived savanna. For example, in the former location, application of 50 kg N ha^{-1} to both OP and HBM gave higher yield than applying up to 200 kg N ha^{-1} in the later.

The highest yield was obtained from 8516-12 and was followed by 8321-18. On the average, (8516-12) produced 17.5-33.5% grain yield more than other maize varieties in the southern guinea savanna. It also yielded more than other varieties by 23.6-57.6% in the derived savanna. The nitrogen use efficiency (NUE) of both maize types is indicated in Table 2. Mostly, the NUE values decreased with increase in nitrogen rates. The HBM utilized nitrogen more efficiently than the OP. On the average, every kilogram of N applied to 8516-12 produced 25.9 kg grain, while TZSR-W gave 19.7 kg grain, which showed the highest NUE among the different maize types, respectively. The NUE, however, was considerably higher in the southern guinea savanna than in the derived savanna. The OP and HBM grown in the southern guinea savanna gave 49-93% and 13-51% NUE, respectively higher than in the later.

On the whole, at 50 and 100kg N ha^{-1} maize efficiently utilized nitrogen resulting into yields close to those obtained at higher rates. Optimum N application rate appeared to be 100 kg ha^{-1} in the derived savanna. The HBM however, responded well to higher levels such as 150 and at times 200kg N ha^{-1} in the southern guinea savanna. The best performance was shown by 8516-12 and was followed by 8321-18. Also, application of 100 kg Nha^{-1} appeared to be optimum for the OP in this zone.

Regardless of type, maize responded positively well to P application. The control (0 kg P_2O_5 ha^{-1}) gave the least yield that was significantly lower than other application rates (Figure 2). Application of 40 kg P_2O_5 ha^{-1} appeared to be optimum. Since, at higher rates, the yield was depressed. At Mokwa however, there was steady increase in grain yield of the HBM up to 60 kg P_2O_5 ha^{-1}. The yield at this rate was significantly (p = 0.05) higher than applying 20 kg P_20_5 ha^{-1}, but not different from 40 kg P_20_5 ha^{-1}. Application of 80 kg depressed yield. The grain

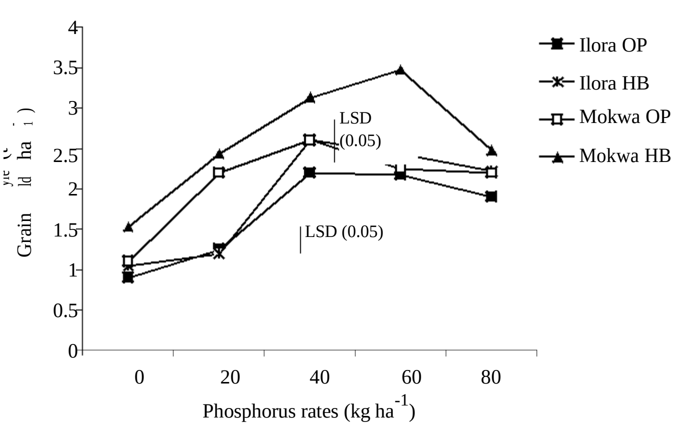

Figure 2. Influence of phosphorus rates on maize yield in the derived and southern guinea savanna zones of Nigeria.

Table 2. Nitrogen use efficiency of maize (kg grain kg N^{-1}) as influenced by different rates of N application.

N rate, kg ha^{-1}	TZSR-Y	TZSR-W	8321-18	8516-12	8329-15
ILORA					
50	12.4	15.6	24.0	28.0	19.8
100	14.2	14.4	14.5	14.1	16.5
150	8.07	7.3	10.3	14.3	8.7
200	5.85	3.5	8.9	12.4	9.5
MOKWA					
50	17.0	30.2	22.8	40.2	21.0
100	17.5	21.0	19.9	25.6	15.5
150	13.7	14.3	14.9	19.4	12.3
200	12.2	13.2	14.7	18.5	12.5

Table 3. Phosphorus use efficiency (kg grain kg P^{-1}) as influenced by different rates of P application.

P rate, kg ha^{-1}	ILORA		MOKWA	
	Open Pollinated	Hybrid	Open Pollinated	Hybrid
20	7.0	3.0	18.0	18.0
40	13.0	15.5	13.0	16.0
60	8.5	9.2	6.3	12.9
80	5.0	5.8	4.5	4.7
LSD (5%)	3.45	3.76	5.62	3.7

LSD: Least Significant Difference.

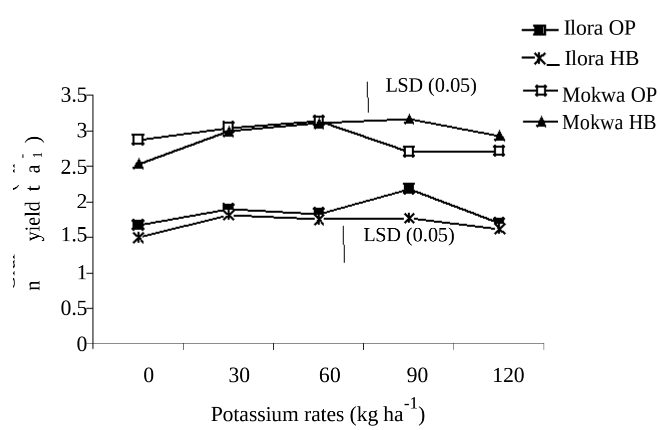

Figure 3. Influence of potassium rates on maize yield in the derived and southern guinea savanna zones of Nigeria.

yield response of the OP to the different P rates was obtained only at 40 kg P_2O_5 ha^{-1}. Higher rates resulted in yield decline.

The phosphorus use efficiency (PUE) of both open pollinated and hybrid maize is shown in Table 3. The higher the rate of P application, the lower the PUE. This indicates that the efficiency of maize in P utilization decreased as the P fertilizer rate was increased. On the average, every kilogram of P applied to maize at Ilora produced 8.4 kg and at Mokwa 10-13 kg of grain. The highest PUE was observed at 40 kg and 20 kg P_2O_5 ha^{-1} at Ilora and Mokwa, respectively. Additional use of 20 kg P_2O_5 ha^{-1} reduced the grain weight produced from every kilogram P by 35-40% at Ilora and 11-18% at Mokwa.

Figure 3 shows response of maize to K application. Application of 30 kg K ha^{-1} increased yield by 20% at Ilora and Mokwa when compared with the control. The results showed that there was no significant difference between the OP and HBM at rates below 90 kg ha^{-1}. Although slight variations in yields were observed from applying higher rate, the differences between them were not significant. On the whole, maize gave significantly higher yields at Mokwa in the southern guinea savanna than at Ilora in the derived savanna.

DISCUSSION

The results from these experiments showed that hybrid maize (HBM) efficiently utilized nitrogen better than the open pollinated (OP). At both trial locations, HBM gave higher yield than the OP even at low soil N status. However, maize yield increased with increasing nitrogen rates, with exception of the decline observed when over 100 kg N ha^{-1} was applied to some varieties grown in the derived savanna. All the maize varieties responded adequately well to nitrogen application in the southern guinea savanna and gave over 3 t ha^{-1} grain yield by applying as low as 50 kg N ha^{-1}. This could erase the fear, that without high N input, hybrid maize would not give some appreciable returns. Definitely, with the high cost of fertilizer input in the developing countries, farmers are tempted to use minimal dose instead of applying high N rate. Identification of varieties such as 8516-12 that has ability to use N efficiently and produce yield up to 3 t ha^{-1} at low N input is advantageous for maize production in the developing countries.

The results in Table 2 indicated that the varieties showed a gradual decline in or had almost similar values of NUE at increased nitrogen rates. Application of additional unit weight of N led to reduction or gave almost similar unit weight of maize grain. There is therefore much advantage to be derived from using economic rate that will enhance higher nitrogen use efficiency and maximize grain production. Based on the value of increased nitrogen input, the decline observed in NUE, however, discourages the use of rate above 200 kg N ha^{-1} at both trial locations.

It can be deduced from the results of the P trials, that application of P to maize both in the derived and southern guinea savanna becomes apparently significant in as much as the soils of the areas are inherently low in P (FPDD, 1990). In order to obtain desirable effect on maize performance, additional P input to the native soil P becomes highly important. This indicates that increase in P rate beyond 40 kg ha^{-1} would further depress yield and lead to low economic return. Yield depression at high P rate (60 kg P_2O_5 ha^{-1}) was more expressed with the open pollinated maize. The OP showed 51 and 34% decrease in PUE at Mokwa an Ilora, respectively, while in the same locations HBM showed 19 and 41% decrease. This apparently implies, that the HBM utilized P better than the OP varieties possibly due to genetic factors.

It was observed that sampling and analysis of soil for nutrient determination before fertilizer use was highly important. Reliance on blanket fertilizer recommendation may not be able to provide adequate measure for efficient use of fertilizer in crop production. Lack of response to potassium fertilizer at rates higher than 30 kg Kha^{-1} might be due to its adequate level in the soil used for the experiment. Additional use of K fertilizer on such soil would be a waste and could raise the K in the soil to undesirable level that would not give economic return. It would therefore save the farmer more money and reduce pollution of the environment when K was not applied on such soil. However, higher response of maize to K was obtained at Mokwa as compared to Ilora probably due to lower soil K level in the former location.

The results obtained from these studies showed more emphasis on the importance of N and P for maize production most especially where K is found to be adequate in the soil. High fertilizer input is one of the conditions required to obtain maximum yield of hybrid maize. Many farmers who dominate farming population in Africa have little or no access to fertilizer. Crop production output is generally low and on the average, maize yield is low. Recommendation for efficient fertilizer use for economic production of hybrid maize when given the same production inputs as for the open pollinated maize would go a long way in alleviating farmers' problem in the developing counties. This may promote production of hybrid maize most especially among the farmers in sub-saharan Africa.

We therefore conclude that in both derived and southern guinea savanna, application of N_{100} P_{40} K_{30} per hectare to open pollinated maize gave optimum grain yield, while optimum fertilizer rate for the hybrid maize was N_{150} P_{40} K_{30}. All the maize varieties gave higher grain yield in the southern guinea than in the derived savanna. The 8516-12 responded highly to N and P application and performed better than other varieties at both locations. On the other hand, there was no consistent response of maize to high level of K application. We propose that soil testing as an important tool for efficient use of fertilizer for sustainable maize production.

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