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Influence of Nitrogen Levels and Plant Density on Agronomic Traits of Maize (*Zea mays L.*) Hybrids in a Forest Location

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Abstract

This study investigated the response of two maize (*Zea mays L.*) hybrids to four levels of nitrogen (N) (0, 100, 200 and 300 kg/ha) at two plant densities (53,300 and 66,600 plants/ha). The experiment was conducted at the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria in the early and late cropping seasons of 1985. Design was a randomized complete block (RCBD) with split-split plot arrangement. N was the main plot while varieties and spacing constituted the sub-plots, and sub-sub plots, respectively.

Grain yields increased up to 200 kg/ha of applied N while at higher N levels, yield tended to ceil off. Yield of the hybrids varied from 3.0 t/ha at OkgN/ha to 5.4 t/ha at 300kg N/ha. N at 200 kg/ha was found adequate for grain yield during the early season while a lower rate (100 kg N/ha) appeared sufficient for the late season. The effects of N on grain yield were due to an increase in ear length, ear diameter, and number of kernel rows per ear. No significant yield difference was obtained between the two (normal and high) densities used indicating that the normal density of 53,300 plants/ha is adequate for the hybrids used.

Introduction

Acute shortage of maize (*Zea mays L.*) in Nigeria is brought about partially by low levels of production. Nigeria's average grain yield of about 1 tonne/ha compares adversely with the world average of over 3 tonnes/ha (Fajemisin, 1985). The problems of low maize yield are attributable to extensive use of traditional low yielding cultivars, planting at irregular and wide spacings and inadequate use of fertilizers. With the introduction of maize hybrids to replace low-yielding local, open-pollinated varieties, there is need to evaluate their agronomic performance with respect to their response to fertilizer and planting density. Nitrogen (N) is, perhaps, the most critical element essential for the growth of plants and this

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element has been found to be commonly deficient in tropical soils (Agboola and Corey, 1976; Adepetu *et al.*, 1979).

A plant population of 53,300 plants/ha is widely used by maize researchers in Nigeria (Fakorede and Ayoola, 1980). Traditional farmers often plant at lower densities at irregular and wide spacings. It is important at this stage of hybrid maize technology in Nigeria to find out if hybrids being released can tolerate higher densities than the recommended one. This study was, therefore, designed to investigate the response of maize hybrids to N fertilizer at two plant densities.

Materials and Methods

The study was conducted at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, on longitude 04° 33'E and latitude 7°28'N, 244 m above sea level.

Three maize cultivars (two hybrids and one open-pollinated check) were used for this study. The two hybrids, 8338-2 and 8329-15 are both F_1 single cross hybrids developed at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Hybrid 8338-2 is white-grained, while 8329-15 is yellow. Both of them are late maturing (about 120 days) and resistant to maize diseases like rust fungus, blight and streak virus (Fajemisin, 1985). The check cultivar was TZSR- W -1. This is an improved open-pollinated (O.P.) maize cultivar derived from TZSR - W. It is also a white-grained and late maturing cultivar (Obilana and Fajemisin, 1977).

The experiment was a randomized complete block design (RCBD) with split-split plot arrangement. N - levels formed the main plot, and spacing and variety constituted the sub-plots and sub-sub plots, respectively. The sub-sub-plot was whole or split N application. Each sub-plot consisted of eight rows, 5m long, and measured 6.0m X 5m (30m^2). Each replication consisted of plots laid out in four blocks each containing 12 sub-plots.

The field was disc ploughed and harrowed. Weed control was carried out by using a mixture of paraquat (1, 1'-dimethyl 4, 4'-bipyridinium) and metolachlor (2 - chloro - N - (2-methoxy-1 methyl acetamine) as pre-emergence herbicide one day after sowing at the recommended rate of 3.0 kg ai/ha.

Early season planting was done on May 1st, and the late season planting on September 2. Two spacings designated as 'normal' and 'high' were used. The normal density was planted at 75cm X 25cm spacing, at one seed per hill. This corresponds to 21 plants per row or 168 plants/plot (53,300 plants/ha). The high density was sown at 75cm X 20cm spacing, at one seed per hill. This corresponds to 26 plants/row or 208 plants/plot (66,600 plants/ha). Emergence counts were very high (99%) hence no supplying was done.

N was applied as calcium ammonium nitrate (CAN, 26% N) at the rates of O N, 100kgN, 200KgN, 300kgN/ha. The N - rates were applied either whole at planting to plots receivng whole N application, or in two equal splits, half at planting and the other half six weeks after planting. A basal application of 20kg Mg/ha as amgnesium sulphate, 60kg P/ha as single super phosphate and 90kg K/ha as muriate of potash was made by broadcasting at the time of first N application. The N-topdress in the split N-treatment plots was applied by banding.

Data were taken from the four middle rows (net plot) of each sub-plot on the following parameters: days-to-silking, plant height, ear height, stem and root lodging scores, plant stand at harvest, number of ears harvested, grain yield and yield components.

Stem lodging Score: Plants with broken stems below the ear or leaning at an angle of less than 45^0 but with roots not exposed were taken as stem - lodged. The rating score was assigned as follows.

No lodging	=	1;
Less than 20% lodging	=	2;
20 - 50% lodging	=	3;
50 - 70% lodging	=	4;
Greater than 70% lodging	=	5;

Root Lodging Score: Plants with exposed brace roots and with stems bent acutely towards the ground were regarded as root-lodged. The rating was as for stem lodging, above.

Plant Stands at Harvest: This was determined by counting the number of plants in the net plot, not lodged, at the time of harvest.

Ears Harvested: This is the number of ears harvested within the net plot.

Grain Yield and Yield Components: A one-meter margin was discarded from both ends of the four middle rows, leaving a net row length of 3m and a four - row width of 3m (net plot harvested = 9m^2) for grain yield determinations. The ears harvested within the net plot were weighed to obtain field weight per plot. Samples were obtained from grains in each plot and sample moisture content was determined using Dickey John Automatic Moisture Tester. Grain weight per plot was adjusted to 15% moisture and converted to tonnes per hectare (t/ha). After harvesting, five ears were randomly picked from the net plot for yield component determinations. The following yield components were determined: ear length, ear and cob diameters, number of kernel rows per ear, number of kernels per row, kernel depth, 1000 - kernel weight and shelling percentage.

Statistical Analyses: Data were subjected to analyses of variance to determine the effects of the treatments on the parameters measured. The treatment means were separated using the least significant difference (LSD) method (Steel and Torrie, 1980). Trend comparisons were also carried out to determine the nature of response of grain yield to N rates.

Results

Effects of Seasons, Planting Densities and Nitrogen Levels on Agronomic Traits of Maize Hybrids

The number of plants and ears harvested were influenced by plant density. Significantly more ears were harvested at the 'normal' density (53,300 plants/ha) than at the 'high' density (66,600 plants/ha). Number of plants and ears harvested during the early season were significantly higher than in the late season

TABLE 1: EFFECTS OF PLANT DENSITY AND SEASON ON AGRONOMIC TRAITS OF TWO MAIZE HYBRIDS

	Varieties				Densities (plant/ha)			Seasons		
Agronomic traits	**8338-2**	**8329-15**	**TZSR-W**	**LSD 0.05**	**66,600**	**53,300**	**LSD 0.05**	**Early**	**Late**	**LSD 0.05**
No. of Plants harvested	40	43	41	2.5	38	45	1.5	43	40	1.90
No. of ears harvested	30	32	31	1.6	29	32	1.3	32	30	1.42
Days-to-silking	59	58	61	0.4	59	60	0.4	59	59	0.43
Plant height (cm)	223.4	217.1	226.3	6.3	222.2	222.2	4.3	262.8	181.6	5.70
Ear height (cm)	102.3	106.4	110.2	4.2	105.7	107.0	2.7	121.2	91.5	3.60
Shelling percentage	77.2	75.0	77.0	0.8	76.2	76.2	0.0	80.7	71.7	0.04
Kernel moisture percentage	16.2	16.4	17.0	0.6	16.6	16.8	0.5	17.8	15.7	0.45
Stem lodging	2.1	1.9	2.1	0.2	1.2	2.0	0.1	2.1	2.0	0.21
Root lodging	1.2	1.2	1.3	0.1	1.2	1.3	0.1	1.4	1.0	0.12

The hybrids silked earlier than the O.P. check, with hybrid 8338-2 and 8329-15 silking 2 and 3 days earlier, respectively, than the O.P. Irrespective of season, days-to-silking were the same (Table 1). Hybrid 8329-15 was significantly shorter than 8338-2. The O.P. check and 8338-2 were not significantly different from each other in average height. However, no significant differences existed in the ear heights of the hybrids. The ear height of the O. P. variety (110.2 cm) was also significantly different from that of 8338-2 (102.3cm). Virtually all the agronomic traits except days-to-silking varied with season (Table 1).

N levels significantly affected the number of plants and ears harvested from the net plot (Table 2). The number of plants harvested at 100kg N/ha was significantly higher than at other N levels, while N-levels higher than 100kg/ha did not significantly increase the number of ears.

TABLE 2: EFFECTS OF NITROGEN LEVELS ON AGRONOMIC TRAITS OF TWO MAIZE HYBRIDS

	Nitrogen levels (kg/ha)				
Agronomic Traits	**0**	**100**	**200**	**300**	**LSD 0.05**
No. of plants harvested	41	43	41	41	1.40
No. of ears harvested	28	33	32	31	2.55
Days-to-silking	61	59	59	59	0.33
Plant height (cm)	210.50	223.80	227.10	227.40	3.26
Ear height (cm)	97.40	108.10	109.30	110.40	4.10
Shelling percentage	76.19	76.19	76.19	76.19	0.07
Kernel moisture percentage	16.75	16.53	16.72	16.82	0.56
Stem lodging	2.00	1.90	2.00	2.20	0.28
Root lodging	1.1	1.22	1.23	1.24	0.08

Plants receiving N silked earlier than the control. Also, plant and ear heights were affected by N- rates. Thus, plants were taller at 200 and 300kg N/ha than at 100kg N/ha and the control. For ear height, the main difference was between the control and other N-levels. Ear placement at 300kg N/ha was not significantly higher than at 100 or 200kg N/ha. At 300kg N/ha, significantly more plants were root lodged than at 0 kg N/ha while the effects of the other N rates (100 and 200kg N/ha) were not significantly different from the control (Table 2). More plants suffered from root and stem lodging during the early than the late season (Table 1).

TABLE 3: ANALYSIS OF VARIANCE OF THE EFFECTS OF NITROGEN LEVELS ON GRAIN YIELD OF MAIZE HYBRIDS

Sorces of variation	DF	SS	MS	F
Replicates	3	9179275	3059758	6.5
Nitrogen levels	3	56688656	18896218	40.38*
N_L	1	36856516.8	36856516.8	78.0*
N_Q	1	17626776	17626776	37.6**
Residual	1	2199979.2	2199979.2	4.7
Error A	9	4224352	469372	
Variety	2	6397030	3198515	4.5*
Nitrogen x variety	6	8066714	1344452	1.9
N_L x V	2	6549183.1	3274591.0	4.6**
N_Q x V	2	504912	252456	0.4
Residual	2	1012328.9	506164.5	0.7
Error B	24	16935826	705659	

* ** *significant at P = 0.05 and 0.01 levels, respectively*

N and Grain Yield of Hybrids Figure

Grain yields were significantly affected by N levels (Table 3). The coefficient of determination (R^2) for the mean grain yield of the hybrids was 0.99 (fig..1). The response of 8329-15 was similar to the response obtained for the mean of the two hybrids, while 8338-2 increased with additions of N up to 300kg N/ha (R^2 = 0.54). Furthermore, the varieties differed significantly from one another in their responses to N (Table 4). Grain yields varied from 2.98 t/ha at 0 kg N/ha to 5.35 t/ha at 300kg N/ha for 8338-2. No statistically significant yield difference was obtained between 100 and 200kg N/ha for this hybrid, although yield at 300 kg N/ha was significantly higher than at 100kg N/ha.

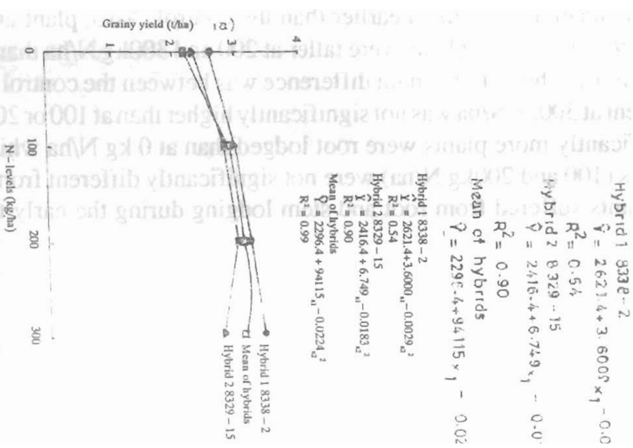

Fig. 1 Regression of nitrogen levels on grain yield of maize hybrids.

TABLE 4: GRAIN YIELD OF TWO MAIZE HYBRIDS AND ONE OPEN-POL LINATED MAIZE CULTIVAR

	Grain Yield (t/ha)					
	Early Season			Late Season		
N-Levels	8338-2	8329-15	TZSR-W	8338-2	8329-15	TZSR-W
	Grain Yield (t/ha)					
0 kg/ha	2.98	3.07	2.60	1.37	1.70	1.58
100 kg/ha	4.38	3.70	3.96	1.89	2.32	2.08
200 kg/ha	5.10	3.86	3.82	1.94	2.50	2.06
300 kg/ha	5.35	3.20	4.23	1.49	2.47	1.94

LSD: 0.05	0.740
SE+	0.329
CV%	25.8

The response of the O.P. check during the early season shows significant difference between grain yield at 0 kg N/ha (2.60 t/ha) and at 100kg N/ha (3.96 t/ha). A significantly higher yield response was obtained for 8329-15 at 200kg N/ha. However, 8329-15 performed better than the other varieties during the late season and showed significant yield differences between 100kg N/ha and 200 or 300kg N/ha.

Variety, Density and N - level effects on Yield Componentsm

The difference between the hybrids and the O.P. cultivar in the overall yield performance was reflected in significant differences in their yield components. The hybrids had significantly longer ears than the O.P. (Table 5). However, the kernel row number per ear and kernel depth of 8338-2 were not significantly different from the O.P. check while 8329-15 had more kernel rows per ear. The weight of the kernels (measured as 1,000 kernel weight) for the white hybrid and the O.P. check, were not significantly different, while the yellow hybrid had significantly lighter kernels than the white hybrid and the O.P. check.

Average ear length and kernel number per row were higher at the high density than at the normal density (Table 5). In addition, ear diameter was wider at the high than at the normal density while the weight of 1,000 kernels was greater at the high than at the normal density.

Discussion

The number of maize ears harvested per unit area of land was significantly affected by planting density. The total number of plant stands at the time of harvest in the net plot was 20% higher at the high density than at the normal density (data not shown). Significantly more ears were harvested under normal density (53,300 plants/ha) than at high density (66,600 plants/ha). This is similar to the results of Bolton (1971) who observed considerable reduction in the number of ears harvested per unit area as density increased beyond 49,500 plants/ha. Reminson and Lucas (1982) obtained significant increase in ear number up to 53,300 plants/ha with significant reduction beyond this level. The increase in the number of ears per unit area at 53,300 plants/ha; in this study, was however, not reflected in the ultimate grain yield. The main effect of spacing on yield is believed to be a change in the radiant energy distribution within the crop canopy (Yao and Shaw, 1964). With closer and more uniform spacing of plants, light distribution and interception within the canopy is more uniform and more leaves are exposed to direct light (Egharevba, 1977). Crop growth rates increase with percent light interception, resulting in increased rate of dry matter production. Spatial distribution of plants were shown to have a large effect on the amount of energy absorbed by plants (Aubertin and Peters, 1961). Although net radiation over the populations used in this study was not measured, some other studies have given opposite effects of spacing on net radiation in maize. (Linvill and Dale, 1975). The authors observed that maize population density in the range from 42,000 to 62,000 plants/ha had no significant effect upon net radiation. this may have accounted for the non-significant difference in grain yield obtained in this study at the two densities used. Only 8329-15 gave a significant response at these densities by producing significantly more ears than the other hybrid 8338-2, but the number of ears produced by 8329-15 was not significantly higher than that produced by the O.P. check.

N - rate increased (Kamprath et al., 1982). These workers observed a significant linear correlation between N concentration of hybrids at silking and the number of ears per plant. Since no difference occurred in ear number between 100 and 300kg N/ha the level of 100kg N/ha appeared enough for the hybrids to develop their ears. However, higher levels of N would be needed for high dry matter accumulation in the developed grains.

Plant and ear heights of the varieties were significantly affected by N. TZSR - W- 1 was significantly taller than the two hybrids. Tallness of plants usually encourages lodging, especially if the stalk is not correspondly strengthened and under severe wind, stalks may break. It is thus advantageous to breed for shortness in hybrids as well as in other maize varieties. The O.P. check suffered more from lodging, especially in N-treated plots, than the two hybrids.

Uniformity of plants and ear placement characteristics could also be assessed from the heights. The advantage of uniformity in ear placement is that hybrids, with average ear height of 102 - 106cm would be more suitable for mechanized harvesting because the ear heights varied little within this range for both hybrids than the O.P. Variety where ear heights varied more widely (Table 1).

The hybrids responded significantly to N in grain yield performance. There was no significant yield difference between 100kg N/ha and higher n - rates in this study in the late season, contrary to what had been reported by Lutz and Lillard (1973); Arnold et al. (1974); hart et al. (1982); and Alofe et al. (1986). However, alofe et al. (1986) obtained optimum grain yield at 200kg N/ha for the hybrids used in their study.

TABLE 5: EFFECTS OF PLANT DENSITY AND NITROGEN LEVEL ON YIELD COMPONENTS OF MAIZE

Agronomic	Varieties				Densities (plants/ha)			Nitrogen levels Kg/ha				
Traits	**8338-2**	**8329-15**	**TZSR W**	**LSD0.05**	**66,600**	**53,300**	**LSD0.05**	**0**	**100**	**200**	**300**	**LSD0.05**
Ear length (cm)	15.1	15.5	14.5	0.38	15.4	14.76	0.32	13.8	15.1	15.7	15.6	0.44
No. of kernel rows per Ear row number	14.0	14.6	13.9	0.26	14.3	14.1	0.24	14.0	14.2	14.3	14.2	0.03
Kernel row number per row	33.3	34.8	32.0	0.92	34.6	42.7	0.94	30.8	33.8	34.5	35.3	1.46
Ear diameter (cm)	4.4	4.2	4.2	0.06	4.3	4.2	0.06	4.1	4.3	4.3	4.3	0.09
Kernel depth (cm)	1.6	1.5	1.6	0.04	1.6	1.6	0.04	1.6	1.6	1.6	1.6	0.06
Wt. of 1000 Kernels	223.9	195.3	218.6	7.93	217.1	208.1	5.50	209.6	214.9	214.7	211.2	6.60
Grain yield (t/ha)	3.1	2.8	2.8	0.22	2.9	2.8	0.18	2.2	3.1	3.1	3.1	0.22

According to Murata (1961), higher N supply would not always result in higher photosynthetic activity and grain yield, although the photosynthetic capacity of the stand may be greatly enhanced. This is because under high N, growth and development of leaves are greatly stimulated, so that the N content of each leaf is 'diluted', making the difference of N content comparatively small. Also, at high N levels where maximum yield may be obtained, expansion of leaf area may play a dominant role. Frequently, excess leaf area caused by a heavy N application could lead to decreased grain yield due to mutual shading of the leaves. Thus, to avoid these obstacles, maize hybrids that can tolerate high N with resultant high yield response are desirable. The hybrids used in this study responded positively to N up to 200kg N/ha during the early season, while little response was obtained during the late season beyond 100kg N. Thus, during the early season, 200kg N/ha was adequate for maximum grain yield while the lower rate appeared sufficient for the late season.

Some yield components of the hybrids were significantly affected by N. N caused an increase in ear length, number of kernel rows per ear, number of kernels per row and ear diameter (Table 5). The productivity of a plant can be increased in terms of carbohydrate production. This could contribute to increased yields if the total storage capacity of the plant is adequate. thus, an adequate 'sink' is required that is capable of receiving the carbohydrates in excess of the metabolic needs of the plants. In non-cereals, a 'feed-back' mechanism exists because the size of the 'sink' affects the production and movement of carbohydrates in the plant (Thorne, 1966). It is, therefore, possible that in maize, also, too few grains, or their unsatisfactory development, may restrict the photosynthesis of the shoot. Thus, the number of grains per ear and weight of the individual grain are important determinants of grain yield. Any attempt to increase the components of yield, for example, ear length or number of kernel rows per ear, by cultural practices would result in higher yields by these varieties. The role of N in this respect is to raise the ceiling for the maximum yield potential achievable under a given environmental condition and in ensuring that each individual yield component contributes maximally to the realization of this maximum yield. this appears to have been achieved in this study.

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