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Evaluation of nitrogen fertilizer rates on growth and yield of commercially grown maize genotypes in southwestern Nigeria

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Abstract

Experiments were designed to estimate the nitrogen requirements of some commercially grown maize genotypes and those under research trials. The first experiment consisted of four rates of nitrogen fertilizer (N 0, 25, 75 and 100 kg/ha) with three maize genotypes: single-cross hybrid (Oba Super1), and two open pollinated genotypes, I-WDC3Syn and ACR-91Suwan1-SRC1, while in the second experiment, six fertilizer rates were used (N 0, 50, 75,100,150 and 200 kg/ha) and two additional maize genotypes (STR double cross and STR 3 way cross) were included. Experimental designs were split plot with fertilizer rates as the main plots and maize genotypes as subplots. Data were taken on morphological parameters, growth rates, dry matter production, yield and components of yield. No consistent differences were recorded for most growth and morphological parameters; though the parameters increased with increasing nitrogen. Grain yield of maize genotypes significantly (P = 0.05) increased with response up to N 200 kg/ha; however, no significant increase was obtained above N 75 kg/ha. Grain yield increase of 18.1, 64.8 and 71.8% were recorded at N 25, 75 and 100 kg/ha, respectively, in the first experiment, while increase of 37.5, 42.6, 60.5, 59.3 and 73.4% were recorded at N 50, 75, 100, 150 and 200 kg/ha, respectively, for second experiment. Grain yield of commercial hybrid was higher than that of the open pollinated genotypes in all the nitrogen fertilizer rates. Hybrid maize genotype (Oba super1) outyielded the open pollinated genotypes ACR-91Suwan1-SRC1 and I-WDC3Syn by 13.4 and 20.4%, respectively, in the first experiment and 17.6 and 32.8%, respectively, in the second experiment. In conclusion, hybrid maize genotypes were superior to open pollinated genotypes, indicating that hybrid maize does not require more nitrogen fertilizer than open pollinated in exhibiting their potential yield, also, additional maize grain increase with respect to fertilizer cost was not profitable above N 100 kg/ha.

Key words: Maize, genotypes, nitrogen fertilizer, grain yield.

Introduction

Maize is the major food item in the diet of many tropical people and the main grain used for animal feed. In Nigeria, maize is the most widely grown cereal crop which is prepared and consumed boiled, baked, fermented or roasted and large quantities for livestock feeds. However, in spite of efforts at promoting maize production in Nigeria, there is no substantial progress in terms of average yield/ha. Reported yields were 1.27 and 1.85 tons/ha in 1986 and 2010, respectively, which is an increase of 0.6 tons/ha in 14 years. Thus, maize yield in Nigeria is still very low compared to the United States of America, where the mean yield was over 10 tons/ha in year 2009 [1]. Low maize yield in Nigeria is due to the fact that maize production in Nigeria, as in many other sub-Saharan countries, is faced by many constraints which mainly include low soil fertility, especially nitrogen, pests and diseases infestation, and unavailability of improved germplasm. Increase in maize production in Nigeria came about from large area devoted to the maize cultivation rather than yield produced per unit area of land, such that area devoted to maize production increased from over 3 million hectares in year 2000 to over 6 million hectares in 2011 [1]. Pressure on land for other purposes has, however, prevented continued increase in area devoted to maize production. Attention on increasing productivity is therefore now focused on increasing yield per unit area by the use of high yielding improved genotypes (open pollinated and hybrids) in addition to proper agronomic practices.

Nitrogen fertilization is an important agronomic practice for maize production. Better farm practices, optimal use and management of nitrogen fertilizer and improved variety technology are among the agronomic factors that may contribute to increase in maize grain production. Various studies have been carried out on nitrogen requirements and factors that enhance higher nitrogen use efficiency in maize genotypes which include optimum N rate required, method and time of N fertilizer application, nitrogen and planting densities in the forest and savannah ecological zones of Nigeria, genetic variations for nitrogen use efficiency etc.[2-6].

Earlier nitrogen recommendation for the old NS series in Nigeria was N 75kg/ha [7] while on FARZ series 150 kg/ha was recommended based on profit margin although statistically similar to grain yield at N 75 kg/ha [8]. Responses of up to N 70, 40 and 210 kg/ha for Ikenne, Mokwa and Kaduna representing the forest, southern and northern guinea savanna zones of Nigeria were reported [3]. Optimum yield at N 100 kg/ha was obtained for open pollinated genotypes and response up to N 150 kg/ha for hybrids in derived and southern guinea ecological zones while N 120kg/ha was recommended for forest zone [9, 10].

There is much to be done on nitrogen requirements of maize in

Nigeria, especially with the commercial maize genotypes; since maize genotypes that produce significantly higher quantity of grain yield per unit of N applied to the soil than any others will increase farmer's profit margin. Moreover, nitrogen fertilizer should be applied at the rate that will enhance more efficient use by the crop. This will not only increase farmer's profit but will prevent possible nutrient imbalance that can reduce yield potential of maize and possible environmental pollution.

The study is therefore set up to evaluate nitrogen requirements of some open pollinated and hybrids of maize, as well as those under research trials in Ibadan, southwestern Nigeria, as part of the program to evolve agronomic packages for optimum grain yield in maize production.

Materials and Methods

Field experiments were conducted at the Teaching and Research farm, University of Ibadan, Nigeria (7^{0}20'N, 3^{0}54'E) during 2012 and 2013 growing seasons. Soil of the experimental location is dominated by Alfisols and belongs to Egbeda series [11]. In each year, the experimental field was cleared, ploughed and harrowed, and before planting, representative soil samples were taken at different parts of the field, thoroughly mixed to form a composite sample, which was air-dried and passed through 2 and 0.5 mm sieve for soil physical and chemical analyses. Experimental design in each year was split plot replicated three times, while fertilizer rate was main plot and maize genotype the subplot treatment. In the first experiment, four nitrogen rates (N 0, 25, 75 and 100 kg/ha) were used with three maize genotypes: single cross hybrid (Oba Super1), and two open pollinated genotypes (I-WDC3Syn and ACR-91Suwan1-SRC1), while in the second experiment, six fertilizer rates (N 0, 50, 75,100,150 and 200 kg/ha) and two additional maize genotypes (STR double cross and STR 3 way cross) were included. Maize genotypes single cross hybrid (Oba Super1) and open pollinated ACR-91Suwan1-SRC1 are commercially available to farmers while the remaining four are still under research trials. All experimental seeds were obtained from International Institute of Tropical Agriculture (IITA), Nigeria, and treated with Apron Plus before planting at two seeds per hole and thinned at three weeks to one plant per stand at a spacing of 75 cm by 25 cm to give plant population of 53,333 plants/ha. Plot size was 4 m by 5 m and plots were separated from each other by distance of 1 m. Weeds were controlled by application of Gramaxone, i.e. paraquat (1,1-dimethyl 1-4,-4-bipyridinium) at 0.56 kg/ha and supplemented by two manual weeding operations. Basal application of phosphorus and potassium fertilizers in the form of muriate of potash and single super phosphate respectively at 60 kg/ha each was applied to all plots, while urea was the source of nitrogen, split applied at two and four weeks after sowing.

For each experiment, samples were taken biweekly until plant reached physiological maturity starting from 5 weeks after planting. On each sampling occasion, data on plant height, number of leaves and leaf chlorophyll, using SPAD, were recorded for four plants, after which the plants were cut to the ground level. Plant parts were separated in the laboratory into leaves, stem, roots, tassel and ear depending on the stage of growth for dry matter yield. Leaf area measurement was done using the LICOR 3000 leaf area meter, while dry weights were determined after the plant parts were dried for 48 hours at 75^{0}C in a force drought oven to constant weight. From the dry weight and the leaf area measurements, the growth analysis variables (leaf area index (LAI), leaf area duration (LAD), leaf area ratio (LAR) and crop growth rate(CGR) were computed [12].

Grain yield at maturity was determined by harvesting all plant within an area of 1 m by 1 m, and yield component parameters were also determined at harvest. The data collected were subjected to Generalized Linear Model (GLM) procedure [13]. Significant means were separated by the Least Significant Difference (LSD) at 5% probability.

Results

Soil analysis of the experimental field in each year revealed that the textural class of the soil was sandy loam, slightly acidic with very low nitrogen content.

Morphological characters: Effect of different levels of nitrogen fertilizer on maximum plant heights and number of leaves on maize genotypes are presented in Tables 1 and 2. In both experiments, maximum values for both plant height and number of leaves were recorded nine weeks after planting. In the first experiment, plants treated with N 75 kg\ha produced significantly higher mean value than the control and nitrogen treatment at N 25 kg\ha but similar to value recorded for N 100 kg\ha. The highest mean value for plant height (173.3cm) was recorded for Oba super1 genotype followed by ACR-91Suwan1-SRC1 (167.9 cm) while I-WDC3Syn gave the least value (166.3 cm). In the second experiment, no significant differences were obtained in plant height but highest plants were recorded at N 200 kg/ha rate (176.3 cm) statistically similar to plant height at N 150 kg/ha (175.4 cm) and N 100 kg/ha (169.2 cm) also, no significant differences in plant height were obtained among the genotypes. There were significant interactions between N fertilizer and maize genotypes in both years. Maximum number of leaves were not significantly different from each other except in the second year when hybrid genotypes gave significantly higher values than open pollinated I-WDC3Syn and no interaction between genotypes and N fertilizer rates.

Table 1. Effect of N fertilizer levels on maximum plant height (cm) and maximum number of leaves (9 weeks after planting) on maize genotypes grown in Ibadan (Experiment 1).

Nitrogen rates (kg/ha)	ACR-91 Suwan1-SRC1	I-WDC3Syn	Oba Super 1	**Mean**
	Maximum plant height (cm)			
0	143.1	139.5	144.2	**142.3**
25	161.4	156.3	158.2	**158.6**
75	177.0	190.5	199.6	**189.0**
100	190.0	179.0	190.8	**186.6**
Mean	**167.9**	**166.3**	**173.3**	
LSD (5%)				
Nitrogen (N)	13.8			
Genotypes(G)	ns			
N x G	*			
	Number of leaves/plants			
0	14.6	13.8	14.7	**14.4**
25	14.8	14.6	14.7	**14.7**
75	14.7	14.5	14.7	**14.6**
100	14.7	14.6	14.9	**14.7**
Mean	**14.7**	**14.4**	**14.8**	
LSD (5%)				
Nitrogen (N)	ns			
Genotypes(G)	ns			
N x G	ns			

Table 2. Effect N fertilizer levels on maximum plant height (cm) and maximum number of leaves (9 weeks after planting) on maize genotypes grown in Ibadan (Experiment 2).

Nitrogen rates (kg/ha)	Acr-91 suwan 1-SRG	1WD C3 Syn	Oba Super 1	STR Double cross	STR 3 way cross	**Mean**
			Maximum plant height (cm)			
0	144.3	157.2	141.3	180.5	165.2	**157.7**
50	175.3	153.0	179.8	171.5	151.5	**166.3**
75	182.2	133.8	161.0	164.3	177.2	**163.7**
100	172.8	150.5	167.0	194.3	161.2	**169.2**
150	172.1	171.0	189.7	180.8	163.7	**175.4**
200	146.8	189.0	191.2	160.8	194.0	**176.3**
Mean	**165.6**	**159.1**	**171.7**	**175.4**	**168.8**	
LSD (5%)						
Nitrogen (N)			ns			
Genotypes (G)			ns			
N x G			*			
			Number of leaves/plant			
0	15.0	13.7	12.7	15.0	15.8	**14.4**
50	13.5	14.7	15.0	14.7	15.0	**14.6**
75	14.5	12.3	14.7	14.2	15.2	**14.2**
100	15.2	13.7	15.5	15.2	14.8	**14.9**
150	14.2	13.7	15.3	15.4	14.2	**14.6**
200	13.8	14.2	15.7	14.3	15.8	**14.8**
Mean	**14.4**	**13.7**	**14.8**	**14.8**	**15.1**	
LSD (5%)						
Nitrogen (N)	ns					
Genotypes (G)	0.8					
N x G	ns					

Growth rates: Effects of nitrogen levels and genotypes on LAI, LAD and LAR of maize for the second experiment are presented in Table 3. The values for these parameters increased with time but peaked nine weeks after planting. The highest LAI was obtained at N 150 kg/ha (4.1) and was similar to LAI obtained at N 200 kg/ha (3.8) which was significantly similar to values at N 100 and 75 kg/ha while least value was recorded for 0 kg/ha. Oba Super 1 had the highest LAI value, significantly higher than LAI values obtained from other N-rates. LAD and LAR values were not significantly different among genotypes ($p<0.05$). However, among maize genotypes, Oba Super 1 had the highest LAD and LAR (50.86 days and 49.35 cm^2/g, respectively) values while open pollinated genotype I-WDC3Syn had the lowest LAD and LAR values (40.09 days and 46.69 cm^2/g).

Maximum value of CGR was obtained in all the treatments between 9 and 11 weeks after planting as presented in Table 4. Among genotypes, highest CGR values were recorded for STR double cross (27.3 $g/m^2/day$) which was statistically similar to CGR value of Oba super 1 (26.4 $g/m^2/day$) while lowest were obtained from I-WDC3Syn. Plants that received N 100 kg/ha had highest maximum CGR (31.0 $g/m^2/day$) which was significantly similar to CGR values obtained at N 75 and 200 kg/ha (27.9 and 30.7 $g/m^2/day$).

SPAD readings: Chlorophyll readings of maize grown for experiment 2 were recorded and maximum values obtained nine weeks after planting (Table 4). SPAD values were highest in plants that received N 200 kg/ha (51.89) while lowest was obtained at 0 kg/ha (33.69). Among genotypes, ACR-91Suwan1-SRC1 had the highest chlorophyll value (48.42), which was significantly higher than values of the other genotypes.

Dry matter production, yield components and grain yield: The dry matter accumulation of maize increased with time and maximum was attained eleven weeks after planting. At the peak period maize grown with N 200 kg/ha gave the highest value closely followed by N 150 kg/ha which was statistically similar to values obtained at 100 and 75 kg/ha but significantly higher than N 50 and 0 kg/ha. Similar trend was obtained for maize genotypes averaged across N fertilizer, Oba super 1 gave the highest value, however, similar to values obtained for other genotypes (Figs 1 and 2).

Grain yield components of maize genotypes as influenced by different N-rates are as presented in Table 5. No differences were observed at all N-rates for cob diameter and kernel rows/cob ($p<0.05$). Other yield components (cob length, No of kernels/row, 100 kernel weight and shelling percentage) increased with increasing rates of nitrogen fertilizer with highest values recorded at N 200 kg/ha, though not significantly higher than values obtained at N 75, 100 and 150 kg/ha for these yield components. Among the maize genotypes, no significant differences were in cob length and shelling % ($p<0.05$), also no consistent trend in other yield components, but Oba Super 1 had highest values for cob diameter and number of kernels per row, though not significantly higher than values recorded for STR double cross hybrid.

There was very highly significant correlation between LAI and each of the yield components, similar trends were observed between chlorophyll readings and the yield components except for kernel/cob which had high significant correlation. There was also significant correlation between LAD and CGR with each of the cob length and number of kernels/row. Correlation coefficient among selected yield components and grain yield revealed very highly significant correlation among these traits and grain yield (Tables 6 and 7).

Table 3. Effects of nitrogen levels and genotype on leaf area index, leaf area duration (days) and leaf area ratio (cm^2/g) of maize grown in Ibadan (Experiment 2).

Nitrogen rates (kg/ha)	Maize genotypes					Mean
	ACR-91Suwan1 SRC1	1-WDC3Syn	Oba Super1	STR Double cross	STR 3 way cross	
			Leaf area index			
0	2.05	2.29	2.30	2.89	2.54	**2.41**
50	2.44	3.32	3.68	3.56	3.00	**3.20**
75	3.84	2.00	3.94	3.57	3.55	**3.38**
100	3.98	2.97	4.24	3.60	2.93	**3.55**
150	4.25	4.38	4.72	3.91	3.23	**4.10**
200	3.90	3.71	4.44	3.09	3.82	**3.79**
Mean	**3.41**	**3.11**	**3.89**	**3.44**	**3.18**	
LSD (5%)						
Nitrogen (N)			0.48			
Genotype(G)			0.44			
N x G			*			
			Leaf area duration (days)			
0	39.03	37.08	40.58	44.06	40.08	**40.17**
50	42.36	35.19	51.37	46.68	39.62	**45.04**
75	41.80	37.39	56.58	48.36	43.96	**47.62**
100	45.35	38.67	57.54	36.11	43.29	**46.19**
150	45.56	46.99	53.37	31.81	42.37	**42.02**
200	40.06	45.22	45.77	35.21	50.51	**40.36**
Mean	**42.45**	**40.09**	**50.87**	**40.37**	**43.31**	
LSD (5%)						
Nitrogen (N)			ns			
Genotypes(G)			4.56			
N x G			**			
			Leaf area ratio (cm^2/g)			
0	43.27	48.80	54.09	63.69	50.46	**52.06**
50	40.11	47.59	45.67	43.57	49.24	**45.24**
75	52.39	33.06	53.47	40.46	57.84	**47.44**
100	46.76	47.98	45.51	42.22	47.15	**45.93**
150	59.93	55.29	51.83	44.33	43.58	**50.99**
200	51.71	47.45	45.53	51.85	44.71	**48.25**
Mean	**49.03**	**46.69**	**49.35**	**47.69**	**48.83**	
LSD (5%)						
Nitrogen (N)			ns			
Genotypes(G)			ns			
N x G			ns			

Final grain yield of maize genotypes as influenced by N-fertilizer rates is presented in Tables 8 and 9 for experiments 1 and 2, respectively. Lowest grain yield was recorded at N 0 kg/ha in both years. In the first experiment, highest grain yield was obtained at N 100kg/ha (3.71 tons/ha) which was similar to value obtained at N 75kg/ha (3.56 tons/ha) but significantly higher than values at N 25kg/ha (2.55 tons/ha) and 0 kg/ha (2.16 tons/ha); while in the second experiment, highest final grain yield was obtained at N 200 kg\ha (4.44 tons/ha) followed by 100 kg\ha (4.11 tons/ha), 150 kg\ha (4.08 tons/ha), 75 kg/ha (3.65 tons/ha), 50 kg/ha (3.52 tons/ha) and 0 kg\ha (2.56 tons/ha). Although application of nitrogen fertilizer substantially promoted grain yield, successive increases in fertilizer rate from N 75 kg/ha did not produce any significant increase in grain yield. Additional increase in grain yields from N 75 kg/ha are 0.46, 0.43 and 0.79 tons/ha for N 100,150 and 200 kg/ha with the corresponding increase in nitrogen of 25, 75 and 150 kg/ha, respectively.

With regards to maize genotypes, no significant differences were obtained in the first experiment, however, Oba super1 (single cross genotype) gave the highest grain yield, followed by ACR-91Suwan1-SRC1 and I-WDC3Syn. Single cross genotype produced 3.31 tons\ha while ACR-91Suwan1-SRC1 genotype gave 2.92 tons\ha and I-WDC3Syn gave 2.75 tons/ha. In the second experiment, the highest grain yield was also recorded for single cross hybrid (Oba Super 1) and was statistically similar to yield of ST double cross hybrid (4.29 tons/ha) while the lowest grain yield was recorded for STR 3 way cross hybrid. There was a significant genotype by nitrogen rate interaction for grain yield ($p<0.05$).

Discussion

Nitrogen (N) is the most important and limiting nutrient in corn production being one of the essential constituents of enzymes, amino acids (proteins), nucleotides (nucleic acids), hormones and chlorophyll molecules [14, 15]. However, maize has a high and relatively rapid nutrient requirement [16], such that it requires high amount of N for high yields and every megagram of grain produced removes approximately 20-25 kg of N from the soil [17].

Nitrogen rates used in the experiments of the current study is, however, within the recommended rates for various cultivars of maize in different ecological zones of Nigeria. Response of maize genotypes to nitrogen applied confirmed the low soil nitrogen. Genotypes and N fertilizer did not give much difference with regards to measured morphological parameters but results from this study show that plant height was lowest among plots that received 0 kgN/ha since the plants had to rely on native fertility of the soil.

Table 4. Effects of nitrogen levels and genotypes on crop growth rate (g/m²/day) and SPAD chlorophyll readings of maize grown in Ibadan (Experiment 2).

Nitrogen rates (kg/ha)	Maize genotypes					
	ACR-91Suwan 1-SRC1	1-WD C3Syn	Oba Super1	STR Double cross	STR 3 way cross	**Mean**
			Crop growth rate (g/m²/day)			
0	10.0	14.9	6.9	18.2	18.3	**13.7**
50	17.0	10.7	16.9	21.3	13.7	**15.9**
75	26.6	25.3	30.4	38.8	18.3	**27.9**
100	29.2	31.4	42.5	30.8	20.9	**31.0**
150	16.7	10.9	37.9	24.0	15.8	**21.1**
200	44.7	22.8	23.8	30.8	31.5	**30.7**
Mean	**24.0**	**19.3**	**26.4**	**27.3**	**19.8**	
LSD (5%)						
Nitrogen (N)			8.48			
Genotype(G)			ns			
N x G			ns			
			SPAD chlorophyll readings			
0	37.40	32.33	30.63	34.53	33.57	**33.69**
50	47.53	41.93	40.17	46.53	34.67	**42.17**
75	46.87	42.90	50.03	43.20	38.93	**44.39**
100	54.33	43.53	43.73	47.67	41.73	**46.20**
150	53.10	43.93	50.00	43.53	42.67	**46.65**
200	51.27	52.13	56.20	48.73	51.13	**51.89**
Mean	**48.42**	**42.79**	**45.13**	**44.03**	**40.45**	
LSD (5%)						
Nitrogen (N)			3.07			
Genotypes(G)			2.80			
N x G			*			

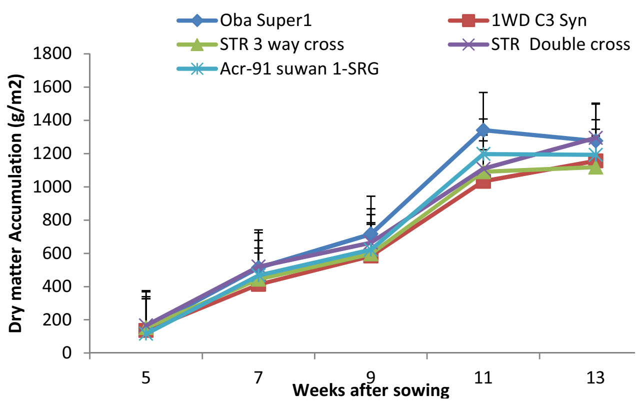

Figure 1. Effect of maize genotypes (averaged across nitrogen rates) on dry matter (g/m²) accumulation of maize grown in Ibadan (Experiment 1).

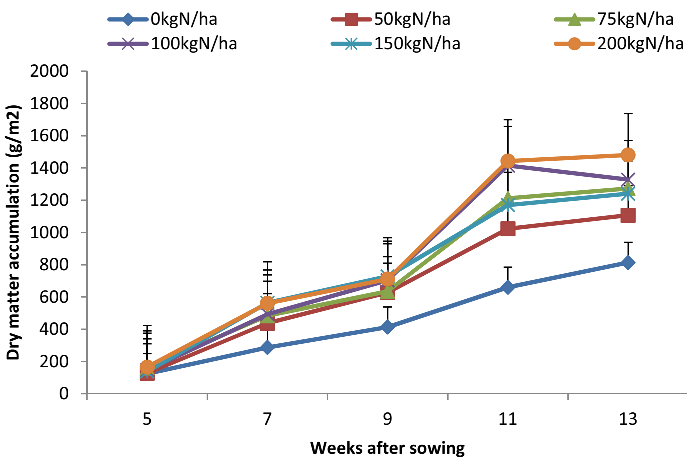

Figure 2. Effect of nitrogen rates (averaged across genotypes) on dry matter (g/m²) accumulation of maize grown in Ibadan (Experiment 1).

Growth analysis was carried out to ascertain the formation and accumulation of plant biomass as determined by nitrogen, maize genotypes or both [18]. Dry matter increased with increase in N fertilizer in the current study as a result of increase in photosynthetic capacity which mainly is due to increase in leaf area. Leaf area index, leaf area ratio and crop growth rates; all characterizes the relative sizes of assimilatory apparatus as a measure of growth differences that occur, while the values increased in response to increase in N-fertilizer applications. High significant correlation in LAI, LAD, CGR, chlorophyll readings and yield components and grain yield indicated that these physiological traits are good indicators of yield traits. Grain yield increased as N fertilizer levels increased with yielding peak at N 200 kg/ha, kernel weights and other yield components gave a similar response, this may be due to the influence of N on kernel endosperm starch and protein accumulation. Maize cultivars differ in grain yield response to N fertilization with differential ability of hybrids to utilize N more efficiently than open pollinated genotypes is documented for West and Central Africa [19]. Results from this study confirmed that single cross hybrid (Oba super 1) and double cross hybrid performed better than the open pollinated genotypes (I-WDC3Syn and ACR-91Suwan1-SRC1) used in this study, with the 3 way cross under research trials needs improvement to boost the yield.

Increased grain yield observed in response to increased nitrogen fertilizer rates are in accordance with earlier studies [2, 6, 9]. From this study, the average yield varied from 2.16 to 3.71 and 2.56 to 4.11 tons/ha between N 0 to 100 kg/ha for Experiments 1 and 2,

Table 5. Effects of variety and fertilizer on some yield components of maize varieties grown in Ibadan, Nigeria.

Nitrogen levels (kg/ha)	Genotypes	Cob diameter (cm)	Cob length (cm)	Kernel rows/cob	No. of kernels/ row	100 kernel weight (g)	Shelling percentage (%)
0	ACR-91Suwan 1-SRC1	4.64	9.27	12.47	16.10	19.52	70.50
	1-WDC3Syn	3.66	10.72	12.10	21.20	23.60	70.25
	Oba Super 1	3.74	10.29	12.47	21.00	20.97	70.03
	STR Double cross	3.91	11.00	14.11	23.05	23.07	66.50
	STR 3 way cross	3.85	12.79	13.29	23.69	20.90	69.40
	Mean	**3.96**	**10.81**	**12.89**	**21.01**	**21.61**	**69.33**
50	ACR-91Suwan 1-SRC1	4.04	10.24	13.57	24.93	23.87	75.30
	1-WDC3Syn	4.42	13.18	14.80	18.42	20.50	71.20
	Oba Super 1	4.26	12.84	13.53	30.63	21.70	75.20
	STR Double cross	4.09	13.95	14.66	27.74	22.13	68.90
	STR 3 way cross	3.80	13.23	12.50	21.37	22.53	75.20
	Mean	**4.12**	**12.69**	**13.81**	**24.62**	**22.15**	**73.16**
75	ACR-91Suwan 1-SRC1	4.36	13.69	13.18	24.93	26.33	75.64
	1-WDC3Syn	3.84	10.53	12.83	22.40	21.20	76.40
	Oba Super 1	4.50	13.69	14.55	31.47	24.70	80.40
	STR Double cross	4.10	13.52	15.13	27.74	22.60	81.22
	STR 3 way cross	3.30	12.05	12.08	27.31	17.97	78.34
	Mean	**4.02**	**12.70**	**13.55**	**26.77**	**22.56**	**78.40**
100	ACR-91Suwan 1-SRC1	5.04	12.59	14.71	25.76	24.03	72.60
	1-WDC3Syn	4.28	12.10	13.46	25.83	21.73	72.30
	Oba Super 1	4.29	13.25	14.17	31.30	23.07	80.50
	STR Double cross	4.11	13.15	15.18	27.79	21.83	71.80
	STR 3 way cross	3.68	13.11	12.88	24.21	19.73	79.23
	Mean	**4.28**	**12.84**	**14.08**	**26.98**	**22.08**	**75.29**
150	ACR-91Suwan 1-SRC1	4.39	14.67	13.22	29.22	28.07	70.20
	1-WDC3Syn	4.13	13.11	13.70	27.20	24.20	73.80
	Oba Super 1	4.39	13.96	14.02	32.12	23.93	82.90
	STR Double cross	3.97	12.02	14.39	28.73	22.66	78.50
	STR 3 way cross	3.53	11.90	11.95	23.36	18.90	75.60
	Mean	**4.08**	**13.13**	**13.46**	**28.13**	**23.55**	**76.14**
200	ACR-91Suwan 1-SRC1	4.43	14.18	14.41	28.21	23.60	74.30
	1-WDC3Syn	4.30	12.90	13.53	27.62	24.87	76.20
	Oba Super 1	4.54	14.44	14.53	31.32	24.73	83.45
	STR Double cross	3.98	12.13	14.36	26.73	21.73	78.90
	STR 3 way cross	3.93	14.72	13.13	28.48	21.40	73.54
	Mean	**4.24**	**13.67**	**13.99**	**28.47**	**23.27**	**77.28**
	LSD (0.05)						
	Nitrogen (N)	ns	1.16	ns	3.04	1.21	4.70
	Genotype (G)	0.24	ns	0.80	2.79	1.11	ns
	N x G	ns	*	ns	ns	*	ns

Table 6. Correlation coefficients among selected yield traits of five maize genotypes evaluated under varying nitrogen fertilizer levels in Ibadan, Nigeria.

	Cob diameter (cm)	Kernel rows/cob	Kernels per row	100 kernel weight (g)	Grain yield (tons/ha)
Cob length (cm)	0.36***	0.49***	0.82***	0.49***	0.80***
Cob diameter (cm)		0.51***	0.39***	0.59***	0.59***
Kernel rows/cob			0.53***	0.70***	0.70***
Kernels/row				0.43***	0.83***
100 kernel weight (g)					0.66***

*, ***: significant at 0.05, 0.001 probability levels, respectively; ns: not significant, n = 90.

Table 7. Correlation coefficients between selected yield traits and physiological traits (at silking) of five maize genotypes grown under varying nitrogen levels in Ibadan.

	Cob length (cm)	Cob diameter (cm)	Kernel rows/cob	No. of kernels per row	100 kernel weight (g)	Grain yield (Mg/ha)
LAI	0.58***	0.37***	0.39***	0.68***	0.36***	0.59***
LAR (cm^2/g)	0.12ns	0.01ns	0.04ns	0.19ns	0.10ns	0.07ns
LAD (days)	0.22*	0.17ns	0.14ns	0.32**	0.09ns	0.19ns
CGR ($g/m^2/day$)	0.29**	0.21*	0.08ns	0.29**	0.29**	0.32**
RGR	-0.02ns	0.04ns	0.19ns	0.04ns	0.05ns	0.01ns
Leaf chlorophyll (SPAD)	0.41***	0.46***	0.29**	0.41***	0.39***	0.59***

*, **, ***: significant at 0.05, 0.01, 0.001 probability levels, respectively; ns: not significant, n = 90.

Table 8. Effect of different nitrogen fertilizer rates on final grain yield of three maize genotypes (tons/ha) in Ibadan, Nigeria (Experiment 1).

Nitrogen rates (kg/ha)	ACR-9ISuwan 1-SRC1	1-WDC3Syn	Oba Super 1	**Mean**
0	2.09	1.70	2.69	**2.16**
25	2.27	2.28	3.09	**2.55**
75	3.50	3.54	3.63	**3.56**
100	3.83	3.47	3.83	**3.71**
Mean	**2.92**	**2.75**	**3.31**	
LSD (5%)				
Nitrogen (N)	0.58			
Genotype	ns			
N X G	ns			

Table 9. Effect of different nitrogen fertilizer rates on final grain yield of five maize genotypes (tons/ha) in Ibadan, Nigeria (Experiment 2).

Nitrogen rates (kg/ha)	ACR-91Suwan 1-SRC1	1-WDC3Syn	Oba Super 1	STR Double cross	STR3 way cross	**Mean**
0	2.30	2.43	2.39	3.31	2.37	**2.56**
50	2.38	3.61	3.54	4.70	3.35	**3.52**
75	4.18	2.38	5.14	4.64	1.89	**3.65**
100	4.23	3.74	4.56	4.84	3.19	**4.11**
150	4.69	3.68	5.18	4.34	2.53	**4.08**
200	4.71	4.10	5.64	3.92	3.82	**4.44**
Mean	**3.75**	**3.32**	**4.41**	**4.29**	**2.86**	
LSD (5%)						
Nitrogen (N)	0.69					
Genotype	0.63					
N X G	**					

respectively, which suggested that N 100 kg/ha may be regarded as the optimum nutrient level since an increase to N 200kg/ha did not significantly increase yield. Nitrogen application above 100 kg/ha may not be profitable with the current price of maize (₦45/kg) and nitrogen (₦260/kg) as additional grain yield increase from N 75 kg/ha were 0.46, 0.43 and 0.79 tons/ha at N 100,150 and 200 kg/ha, respectively. Excessive inorganic fertilizer application can induce nutrient imbalance, acidity as well as of pollution of ground water resulting from leaching [20].

Conclusions

This study revealed that N fertilizer had a profound effect on the overall yield performance of maize and application of N fertilizer had a significant effect on the growth and yield of maize. Application of N-fertilizer at rates greater than N 100 kg/ha did not significantly increase yield, hence 100 kg/ha produced optimum yield. Single cross hybrid (Oba Super 1) performed best in terms of photosynthetic capacity and final grain yield though comparable to the performance of double cross hybrid.

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