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Nitrogen Use Efficiency and Grain Yield in a Diallelic Cross of Maize Populations

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Abstract The high cost of inorganic fertilizer in West and Central Africa has necessitated an investigation into the nitrogen optimum fertilizer rate for profitable maize production. The performance of ten early open pollinated varieties (OPVs) and their F_1 hybrids for grain yield and nitrogen use efficiency (NUE) was assessed, and productive cultivars under low N fertilizer regimes were also quantified. The trials (ten OPVs and their F_1 hybrids) were set up in a split plot arrangement with three N fertilizer levels (0, 45 and 90 kg N ha^{-1}) as main plot and the genotypes as sub-plot. Each plot was four-row, laid out in a randomized complete block design (RCBD) of four replications. Field experiments were conducted at the teaching Research (T and R) farm of the University of Ilorin, in the southern Guinea savanna of Nigeria. Planting was carried out during the growing season on 20th July, 2005 and 2nd July, 2006. Ten open pollinated maize cultivars were crossed in a half diallel to generate 45 F_1 hybrids during 2004 and 2005 growing seasons. Observed agronomic characteristics were grain yield, establishment plant count, days to 50% tasselling and silking as well as plant and ear heights. All observed characteristics amongst all the genotypes during growing season in 2005 were better than those in 2006. Expressions of all characteristics in the selected hybrids including the grain yield were relatively higher than the OPVs. The total increase in grain yield was 1.72 t ha-^{1} and 1.95 t ha-^{1} for OPVs and hybrids respectively on application of 90 kg N ha^{-1} over no N-application. However, nitrogen use efficiency (NUE) was optimum at 45 kg N ha^{-1} in both groups. Grain yield and NUE correlated positively with growth characters measured except for days to 50% silking. Higher genetic gains were recorded for plant and ear heights. The hybrids Acr 90 Pool 16-Dt × Ak 95 Dmr-Esrw, Tze Comp4 C2 × Ak 95 Dmr-Esrw and Tze Comp 4 C2 × Tze Comp 3 C2 had higher grain yield with superiority for NUE ($P< 0.05$). It suggested that the hybrid combinations can further be tested under commercial growing conditions or can be introgressed with other released cultivars to develop low N-tolerant varieties in the in the Nigeria's savanna ecologies.

Keywords Nitrogen use efficiency, diallel crosses, maize cultivars, open pollinated varieties

1. Introduction

Maize (*Zea mays* L.) is an important staple food crops and provides bulk of raw materials for the livestock and many agro-allied industries in the world[1,2]. Maize has a wide range of uses than any other cereals because of its world-wide distribution, high yielding nature, ease of processing, readily digestible and relatively lower price of the grain. In recent times, importance of maize production has been widely publicized among farmers of Nigeria. The Nigerian savanna soils however, are fragile, primarily of kaolinitic Alfisols with low organic matter, effective cation exchange capacity (ECEC) and plant nutrients[3] creates low yield problems in this agro-climate condition. The attendant problems of the soils frequently deficient in nitrogen (N) due to high rate of leaching, denitrification, decomposition of organic matter and erosive action of rainfall had not only made nitrogen the most limiting nutrient to maize production in Nigeria[3,4] but also enhanced low soil moisture retention. Despite the soil being low in plant available nutrients, N deficiency is further exacerbated from its continual depletion from the soil pool by removal of N-containing crop residues from the farm. Nitrogen depletion in maize-based systems in some farmers' fields in West African savannah is estimated to be 36-80 kg N ha^{-1} per year[5]. The resource poor farmers lack cash or access to credit. In view of the fact that farmers hardly adopt option that could provide supplemental N to maize crops (perhaps manuring, mulching, crop rotation and fallowing schemes), the outcome is that maize production by

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smallholder farmers is normally at a lower capacity (with decrease in the total maize yield) and at a subsistence level solely to meet family consumption. Despite fertilizers recommendations (60 to 120 kg N ha^{-1}) for resource poor farmers in the West Africa moist savannah[2,3], less than 20 kg N ha^{-1} used in Nigeria was considered grossly inadequate and 50 kg nutrient ha^{-1} fertilizer use was recommended across sub-Saharan Africa by African Heads of States at the Fertilizer Summit held in 2006 at Abuja, Nigeria. Therefore, research is required to increase judicious use of fertilizer and develop sustainable management practices in response to continually increasing economic and environmental pressures[2,6].

The southern Guinea savannah (SGS) of Nigeria has great potential for the expansion of maize production beyond the present level due to its bimodal rainfall pattern, high solar radiation and favourable temperature during the growing season. However, the zone is mitigated with problems such as erratic nature of rainfall pattern, low soil nutrient status and water holding capacity due to fragility of the soil that consistently prone to drought[7-9]. Hybrid maize is well known in the region for its high demand for plant nutrients and other production inputs. The farmers have been indoctrinated with the belief that required amount of inorganic fertilizers need to be applied for maximum performance of hybrid maize and good economic returns. This extra production cost discourages most farmers engaging in hybrid maize production in the country[10]. However, as a result of increasing cost of N fertilizer due to reduction in government subsidy, poor infrastructure for production and distribution, resulted to inadequate or untimely supply of fertilizers to farmers. Lack of cash or access to credit and perception of cost-benefit ratio also made N fertilizers sometimes unavailable or are too expensive and often beyond the reach of resource poor farmers who constitute the bulk of maize growers in the moist savannah of West Africa[9]. Maize cultivars that are productive under conditions of low N availability are therefore highly desirable.

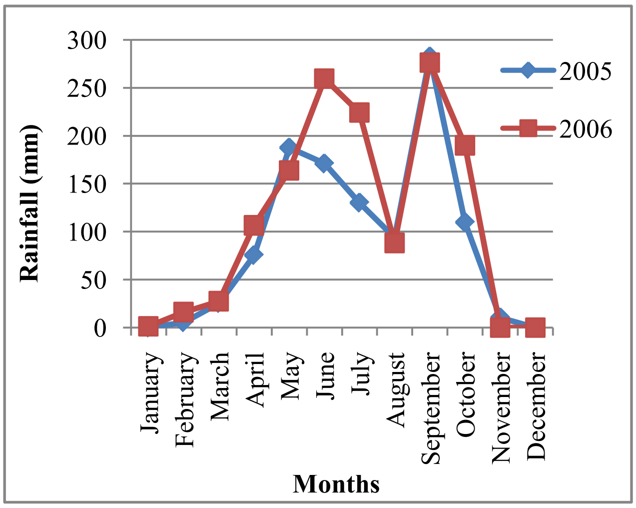
In the development of improved maize productivity in a sustainable fashion in areas with low N fertility, two basic approaches can be taken. The first, approach is to develop innovative agronomic practices that efficiently utilized N from organic matter and N inputs from biological fixation and atmospheric deposition. The second approach is to work with population with the reservoir of genes for low N tolerance[11]. One strategy for improving the productivity of maize under sub-optimal N fertility is to use the second approach. The low N tolerance cultivars are superior in the utilization of available N, either due to enhanced N- uptake capacity or because of more efficient use of absorbed N for grain production[12-15]. On the other hand, combination with the first approach will lead to high maize yields. Evaluation of open pollination maize varieties (OPVs) and their F_1 hybrids in a diallel cross however could provide a worthwhile knowledge on those genotypes that could be used either directly for cultivation or for extraction of inbred lines for low N tolerant hybrid development. A corollary is that these genotypes can readily fit into environment with erratic rainfall and low water holding capacity, since they are bred for marginal environments of West and Central Africa. Thus, development of early maturing maize cultivars that remain productive under low N fertilizer farming system, consistent with the farmers' technologies is therefore a prerequisite to improving adoption of new varieties without increasing production cost in this agro-ecology. This may eventually enhance economic returns of the resource-poor farmers with the proviso that the reductions in fertilizer expenditures are greater than the value of any reduction in saleable maize, resulting from reduced N fertilizer usage. The objectives of this research therefore was to assess the performance of ten early OPVs and their F_1 hybrids under low N fertilizer regimes with the view to identify those that could be cultivated either as varieties per se under the farmers' practices or those that could be introgressed with other released cultivars to develop low N-tolerant varieties in the SGS ecology of Nigeria.

Table 1. Selected physical and chemical characteristics of the soil before growing maize in 2005 and 2006

Physical characteristics	Amount in 2005	Amount in 2006
Texture	Loamy sand	Loamy sand
pH 1:1 (H2O)	5.4	5.30
Sand %	84.1	84.0
Clay %	8.02	8.01
Silt %	6.42	6.40
Chemical characteristics		
Exchangeable Ca^{2+} (Cmol kg -1)	1.12	1.10
Exchangeable Mg^{2+} (Cmol kg -1)	1.62	1.61
Exchangeable Na^{+} (Cmol kg -1)	0.19	0.18
Exchangeable K^{+} (Cmol kg -1)	0.01	0.01
Total acidity $H+^{+}$ (Cmol kg -1)	0.05	0.04
Cation exchange capacity (Cmol kg -1)	2.83	2.82
Organic Carbon %	0.24	0.26
Soil organic matter %	1.03	1.04
Total Nitrogen %	0.24	0.26
Available Phosphorus (mg kg-1)	20.31	20.30

2. Materials and Methods

Field experiments were conducted at the Teaching and Research (T and R) farm of the University of Ilorin (Latitude 8^0 29'N, Longitude 4^0 35'E and annual rainfall of 945mm) in the southern Guinea savanna of Nigeria. The soil is classified as Typic paleustalf (United State Department of Agriculture, USDA soil taxonomy). Composite soil samples were collected randomly from the trial site at the depth of 0-15cm with an auger prior to planting in 2005 and 2006 .The samples were analyzed in the Soil, Water and Material Testing Laboratory of Lower Niger River Basin Development Authority, Ilorin, Nigeria for physico-chemical analysis (Table 1). The collected samples were air-dried and passed through 2mm sieve to remove large particles, debris and stones. The sieved samples were analyzed for pH in 1:1 soil to water ratio using the Coleman pH meter. Organic carbon was determined by Walkley and Black procedure[16]. Total Nitrogen was determined by the micro Kjeldahl method[17], while available phosphorus was extracted by Bray's P_1 method[18] and read from the atomic absorption spectrometer. Exchangeable Ca, Mg, K, Na and effective cation exchangeable capacity (ECEC) were analyzed using Atomic Absorption Spectrophotometery[19], while textural analysis was by hydrometer method. However, rainfall distribution data for the year 2005 and 2006 were also collected (Fig. 1). Rainfall distribution data for the year 2005 and 2006 were also collected at the Lower Niger River Basin Development Authority, Ilorin, Nigeria.



Source: Lower Niger River Basin Development Authority, Ilorin, Nigeria

Figure 1. Monthly rainfall distribution pattern for Ilorin in 2005 and 2006

The genetic materials used were ten open pollinated varieties of maize, selected for grain yield and adaptation to abiotic (drought) and biotic (Stalk rot, Striga and Downy mildew) stress factors. They were early to medium maturing white cultivars with maturity period of 90 to 100 days. The cultivars were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan. The origin, genetic background, breeding emphasis and ecological adaptation of the maize parents are presented in Table 2. The ten varieties were crossed in a half diallel to generate 45 F_1 hybrids during 2004 and 2005 cropping seasons. It is worthwhile to mention that the ultimate goal is not diallel analysis in which using pure lines as parents is necessary. Planting of the ten varieties and their F_1 hybrids were carried out during the growing seasons on 20th July, 2005 in the first year and 2nd July, 2006 in the second year. The resultant hybrids were harvested, processed and stored in the cold room prior to field evaluation. The trials were set up in a split plot arrangement with N-level as main plot and the genotypes as sub-plot. Each plot was four-row, laid out in a randomized complete block design (RCBD) of four replications at spacing of 0.75m between and 0.50m within the rows. Each stand was planted to three seeds but was later thinned to two plants per stand to give a plant population of approximately 53,333 per hectare. Nitrogen fertilizer in form of granular urea was applied at 0, 45, 90 kg N ha^{-1}, while phosphorus and potassium obtained from single super phosphate (SSP) and murate of potash (MOP) were applied at 40 kg P_20_5 and 60 kg K_20 ha^{-1}. All the SSP and MOP fertilizers were applied once at planting with 60% of the rate urea at two weeks after planting (WAP), while the remaining 40% of urea was applied at six WAP by spot placement. Weed control was undertaken by applying 5 liters per hectare of pre-emergence herbicides (3 kg l^{-1} Metolachlor and 170 g l^{-1} Atrazine). The field borders were also weeded to minimize encroachment by insects and rodents. The chemical weed control was supplemented by a regime of hand weeding at six WAP. Data were collected from the two middle rows in each plot. Agronomic parameters recorded in each cropping seasons were establishment plant count (EPC), ; plants and ear heights were measured as the distance from the ground level to the flag leaf and the node bearing the uppermost ear, respectively using a measuring tape. Days to 50% tasselling (TS) and silking (SK) were taken as the date when 50% of the plants in a plot had tasselled and extruded silk respectively. The anthesis-silking interval was estimated as the difference between days to pollen shed and silking. Moisture at harvest was determined by collection of 500 grain samples from each plot. The samples were first weighed to obtain initial weight, followed by drying to a constant weight in the oven at 80^{0}C, and the difference between the two weights were recorded as the moisture at harvest. Grain yield was obtained from ear weight per plot (assuming 80% shelling percentage) and converted to tonnes per hectare after adjusting to 12.5% moisture content. Nitrogen use efficiency (NUE) was estimated as grain yield per unit of available soil N as described below.

$$NUE = \frac{\text{Grain yield (g/plant) at N rate applied} - \text{grain yield at 0 kg N ha}^{-1}}{\text{N applied (g Nf)}}$$

Where g Nf = Amount of N applied.

The data were subjected to analysis of variance and pertinent means were separated using Least Significant Difference (LSD) according to[20]. The phenotypic (rph), genotypic (rg) and environmental (re) correlation coefficients were estimated from the mean squares and mean across products as suggested by[21]. PROC GLM model of SAS[22] was used to compute simple linear correlation. Analysis of variance (ANOVA) on individual year basis was first computed before a combined ANOVA across the two years.

3. Results

3.1. Soil Analysis

Soil samples collected from the trial site before cropping in 2005 and 2006 were analyzed for selected physical and chemical properties (Table 1). The soil texture was loamy sand with similar values of soil properties in both years. The soil had a pH of 5.4 which is moderately acidic. The soil organic matter and total nitrogen content was low, while the soil available phosphate and the exchangeable cations (K, Na, Ca and Mg) were moderate for maize production in this area.

3.2. Effect of Cropping Season on Open Pollinated Varieties and their Selected F_1 Hybrids Performance

The rainfall in 2006 growing season was more favourable for the expression of all studied characters among the genotypes than 2005 (Fig. 1). Each of the cropping seasons had significant effect on all the characters measured in the open pollinated varieties and hybrids, except for nitrogen use efficiency (NUE) and grain yield in the hybrids (Table 3). The plants were significantly taller, with higher ear placement, subsequently higher grain yield, more efficient utilization of N and higher anthesis-silking interval. However, expressions of these traits in the hybrids were relatively higher than the OPVs.

3.3. Effect of N Fertilizer Rates on Grain Yield, NUE and other Agronomic Characters

Varying the N-fertilizer rate significantly (P< 0.05) affected the expression of the characteristics measured in both OPVs and hybrids (Table 3). Grain yield increased with the increase in N-dosage in the OPVs and hybrids but was higher in the hybrids relative to OPVs. The NUE of hybrids and OPVs increased significantly (P< 0.05) by increasing the N-level from 0 to 45 kg N ha^{-1}. Though the NUE showed consistent trends in both groups from 45 to 90 kg N ha^{-1}, the increament was significant (P< 0.05) only for hybrids. The grain yield increased significantly (P< 0.05) from 0.89 to 2.18 t ha^{-1} and 1.35 to 2.68 t ha-^{1} for OPVs and hybrids respectively by increasing N-application from 0 to 45 kg N ha^{-1}. The total increase in grain yield observed was 1.72 t ha-^{1} and 1.95 t ha-^{1} for OPVs and hybrids respectively on application of 90 kg ha-^{1} over no N-application. Days to 50% tasselling and silking decreased with increasing N application rate, while plant and ear heights increased with increasing N application rate in both groups. Plant and ear heights also differed significantly (P< 0.05) with increase in N-dosage.

3.4. Interactive Effects of Year × Nitrogen on Grain Yield and NUE

The first order interaction of year × nitrogen was significant for both grain yield and NUE in the OPVs and hybrids (Table 4). Significantly (P< 0.05), higher grain yield was obtained at 90 kg N ha^{-1} in 2005 than 2006 in both genotypes. Grain yield increased significantly (P< 0.05) at every N level between 0 and 90 kg N ha^{-1} with a difference of 1.59 and 1.66 t ha^{-1} in OPVs and 2.22 and 2.11 t ha^{-1} in the hybrids at the first and second years respectively. However, NUE was best at 90 kg N ha^{-1} regardless of the growing season among the genotypes.

Table 2. Origin, genetic background, breeding emphasis and ecological adaptation of the maize parents

	Genotypes	Origin and genetic background	Breedingemphasis	Ecological adaptation
1.	Acr 90 Pool 16-Dt	Early white dent International Maize and Wheat Improvement Centre (CIMMYT) cultivar, derived from crosses among large numbers of early late white flint materials from Mexico, the Caribbean area, Central and South America. Selected for drought tolerance.	Stalk rot, *Striga* and drought tolerance.	Forest and savannah.
2.	Tze Comp 4-Dmr Srbc2	Early maturing white and semi dent cultivar, derived from diverse sources of early mid-altitude germplasm, intermatted with TZESR-W and DMR-ESRW.	Yield and *Striga* tolerance.	Forest and savannah.
3.	Tze Comp4 C2	Early maturing white and semi dent cultivar, derived from diverse sources of early mid-altitude germplasm, intermatted with EV 8430-SR and IK 8149 SR. It has synchronous male and female flowering, lower plant height and small tassel size.	Yield and *Striga* tolerance.	Forest and savannah.
4.	Acr 97 Tze Comp3 C4	Early white flint dent cultivar, derived from early mid-altitude germplasm with EV 8430-SR, DMR-ESRW, TZESR-W and IK 8149 SR intermatted.	Yield, downy mildew and *Striga* tolerance.	Forest and savannah.
5.	Hei 97 Tze Comp3 C4	Early white flint dent cultivar, derived from early mid-altitude germplasm with EV 8430-SR, DMR-ESRW, TZESR-W and IK 8149 SR intermatted.	Yield, downy mildew and *Striga* tolerance.	Forest and savannah.
6.	Acr 94 Tze Comp5	Early white flint dent cultivar, derived from early mid-altitude germplasm with Striga intermatted with TZE-WC3.	*Striga* tolerance.	Savannah.
7.	Tze Comp3 Dt	Early white flint dent cultivar, derived from diverse sources of early mid-altitude germplasm with drought tolerant cultivars, intermatted with TZESR-W and DMR-ESRW.	Drought tolerance.	Forest and savannah
8.	Tze Comp3 C2	Early white and flint dent cultivar, derived from diverse sources of early mid-altitude germplasm, produced by intermating TZESR-W and DMR-ESRW.	Downy mildew and *Striga* tolerance.	Forest and savannah.
9.	Ak 95 Dmr-Esrw	Early maturing and flint dent cultivar, developed from intermating diverse sources of early mid-altitude germplasm, produced by intermating DMR sources from Philippines with TZB, TZBP, TZSR and tropical late. Selected for earliness.	Downy mildew and *Striga* tolerance.	Forest.
10	Tze Msr-W	Early white semi dent cultivar, derived from early mid-altitude germplasm, developed from intermating local and early cultivars with TZSR.	Yield and *Striga* tolerance.	Forest and savannah.

Source: IITA Archival Report 1988-1992.

Table 3. Maize grain yield, NUE and agronomic characters in open pollinated maize varieties and their F_1 hybrids as affected by N fertilizer rates in 2005 and 2006 at Ilorin, Nigeria

Treatments	Grain yield (t ha^{-1})	NUE	Establishment plant count (EPC)	Days to 50% Tasselling (TS)	Days to 50% silking (SK)	Plant height (cm)	Ear height (cm)
			Open pollinated varieties				
Year							
2005	2.42	1.82	39	52	53	129	44
2006	2.10	1.06	35	50	51	113	40
LSD α 0.05	0.08**	0.66**	0.76*	0.75**	0.85*	3.42*	2.81*
N Levels (kg N ha^{-1})							
0	0.89	1.00	36	54	56	101	35
45	2.18	2.07	38	52	53	121	37
90	2.61	2.45	37	51	52	129	40
LSD α 0.05	0.67*	0.45*	NS	0.45*	0.91*	3.54*	2.75*
			F_1 Hybrids				
Year							
2005	3.71	2.57	37	53	54	129	44
2006	3.70	2.51	33	50	51	118	40
LSD α 0.05	NS	NS	0.43*	0.36*	0.97*	3.28*	2.81*
N Levels (kg N ha^{-1})							
0	1.35	1.0	36	54	56	110	39
45	2.68	2.14	37	51	54	122	40
90	3.30	2.71	36	50	52	130	41
LSD α 0.05	0.98*	0.51*	NS	0.38*	0.96*	3.11*	2.61*

*, **; Significant F test at 0.05 and 0.01 levels of probability respectively.

Table 4. Interactive effects of year × nitrogen for grain yield and NUE in open pollinated varieties and their selected F_1 hybrids in 2005 and 2006 at Ilorin, Nigeria

Treatments	Open pollinated varieties grain yield (t ha^{-1})		F_1 hybrids grain yield (t ha^{-1})	
	2005	2006	2005	2006
N Levels (kg N ha^{-1})				
0	1.09	0.88	1.35	1.34
45	2.23	2.13	2.71	2.65
90	2.68	2.54	3.56	3.45
LSD α 0.05	0.18**		0.12**	
	NUE			
N Levels (kg N ha^{-1})				
0	1.0	1.0	1.0	1.0
45	2.12	2.01	2.15	2.13
90	2.64	2.35	2.74	2.68
LSD α 0.05	0.65*		0.39*	

*, **; Significant F test at 0.05 and 0.01 levels of probability, respectively

Table 5. Genotypic means for maize grain yield, NUE and agronomic parameters in 10 open pollinated varieties and their selected F_1 hybrids in 2005 and 2006 at Ilorin, Nigeria

Genotypes	Grain yield (t ha^{-1})	NUE	Establishment plant count (EPC)	Days to 50% tasselling (TS)	Days to 50% silking (SK)	Plant Height (cm)	
Open pollinated varieties							
Acr 90 Pool 16-Dt	2.33	2.34	35	51	53	124	44
Tze Comp 4-Dmr Srbc2	2.29	1.16	38	50	54	122	35
Tze Comp4 C2	2.24	1.53	34	51	53	114	41
Acr 97 Tze Comp3 C4	2.21	1.24	37	51	54	114	42
Hei 97 Tze Comp3 C4	2.18	1.34	39	50	53	114	39
Acr 94 Tze Comp5	2.24	1.33	37	51	54	118	38
Tze Comp3 Dt	2.38	2.28	40	49	53	135	53
Tze Comp3 C2	2.22	1.34	37	51	53	117	42
Ak 95 Dmr-Esrw	2.27	1.56	36	51	54	122	44
Tze Msr-W	2,24	1.13	39	50	54	128	41
LSD α 005	0.14*	0.34*	0.45*	0.87*	0.56*	6.04**	4.42**
F_1 hybrids							
Acr 94 Tze Comp5 x Tze Comp4 C2	3.46	1.90	35	50	52	137	45
Acr 90 Pool 16-Dt x Tze Comp3 C2	3.48	1.46	38	50	53	129	51
Acr 97 Tze Comp3 C4 x Tze Comp3 Dt	3.34	1.28	34	51	54	128	52
Acr 90 Pool 16-Dt x Ak 95 Dmr-Esrw	3.48	1,98	37	49	53	137	49
Tze Comp3 Dt x Ak 95 Dmr-Esrw	3.43	1.51	39	50	53	129	44
Tze Comp 4-Dmr Srbc2 x Ak 95 Dmr-Esrw	3.38	1.36	37	51	54	135	40
Ak 95 Dmr-Esrw x Tze Msr-W	3.44	1.81	40	49	53	128	43
Tze Comp3 Dt x Tze Comp3 C2	3.36	1.56	37	50	54	134	50
Acr 94 Tze Comp5 x Tze Comp3 Dt	3.34	1.48	36	50	53	126	53
Acr 90 Pool 16-Dt x Tze Comp3 Dt	3.48	1.90	39	49	52	128	52
Acr 94 Tze Comp5 x Tze Msr-W	3.38	1.46	35	50	52	127	49
Tze Comp 4-Dmr Srbc2 x Tze Msr-W	3.43	1.58	38	51	53	129	44
Tze Comp4 C2 x Tze Comp3 Dt	3.48	1,98	34	50	52	135	40
Tze Comp4 C2 x Tze Comp3 C2	3.43	1.98	36	51	54	128	43
LSD α 005	0.17*	0.56*	0.67*	0.89*	0.66*	5.98**	4.30**

*, **; Significant F test at 0.05 and 0.01 levels of probability respectively

Table 6. Simple linear correlation coefficient of grain yield, NUE and agronomic parameters in 10 open pollinated maize varieties in 2005 and 2006 at Ilorin, Nigeria

	Grain yield (t ha-1)	NUE
Establishment plant count	0.320**	0.315**
Days to 50% tasselling	0.235**	0.261**
Days to 50% silking	0.042	-0.016
Plant height	0.147**	0.140**
Ear height	0.235**	0.125*
NUE	0.521**	

*, **; Significant F test at 0.05 and 0.01 levels of probability respectively

Table 7. Simple linear correlation coefficient of maize grain yield, NUE and agronomic characteristics in selected F_1 hybrids in 2005 and 2006 at Ilorin, Nigeria

	Grain yield (t ha-1)	NUE
Establishment plant count	0.411**	0.325**
Days to 50% tasselling	0.387**	0.341**
Days to 50% silking	0.009	-0.076
Plant height	0.345**	0.134
Ear height	0.140*	0.110*
NUE	0.242**	

*, **; Significant F test at 0.05 and 0.01 levels of probability respectively

3.5. Genotypic Performance for Grain Yield, NUE and other Agronomic Characters

The hybrids differed significantly ($P< 0.05$) for all the traits and showed superiority with respect to grain yield than their respective OPVs (Table 5). There was no significant genotype × N fertilizer effects for grain yield and NUE in this study. Two drought tolerant varieties (Acr 90 Pool 16-Dt and Tze Comp3 Dt) not only had the highest grain yield and NUE among OPVs, but also specifically combined well with each other and some cultivars. While Acr 90 Pool 16-Dt favourable combined with Tze Comp3 Dt, Tze Comp3 C2 and Ak 95 Dmr-Esrw for grain yield, var. Tze Comp3 Dt combined well with Tze Comp4 C2. The genotypes were also taller with higher ear placement, increase in days to 50% tasselling and silking. Grain yield among the parents showed similar trends with the hybrids. However, correlation of grain with other traits among the parents and hybrids showed that grain yield correlated positively and significantly ($P< 0.05$) with growth characteristics measured except days to 50% silking (Table 6 and 7). NUE correlated positively and significantly ($P< 0.05$) with all agronomic characters except days to 50% silking in the OPVs. However, association of NUE with plant height and days to 50% silking was not significant among the hybrids.

3.6. Genotypic and Phenotypic Variances for Grain Yield and other Agronomic Characteristics

Estimates of genotypic and phenotypic variances as well as coefficients of genotypic and phenotypic variations, and genetic advance are presented in Table 8. The value for genotypic variances ranged from 3.2 for grain yield to 608.6 for plant height, while the phenotypic variances ranged from 17.4 for establishment plant count to 1062.5 for plant height. The coefficients of variations also showed that the phenotypic coefficients of variations (PCV) were higher than the genotypic coefficients of variations (GCV) for all the parameters measured. Plant height had the highest GCV (129.6) and PCV (252.9). Similarly, highest genetic gain of 1162.8% was recorded for plant height and the least genetic gain of 11.9 % for days to 50% silking.

Table 8. Estimates of genotypic and phenotypic variances, coefficients of genetic variability and genetic advance in agronomic characters among open pollinated maize varieties and their selected F_1 hybrids as affected by N fertilizer rates in 2005 and 2006 at Ilorin, Nigeria

Character	δ^2g	δ^2p	GCV	PCV	GA (%)
Establishment plant count	3.6	17.4	52.4	118.8	12.2
Days to 50% tasselling	32.7	156.3	74.1	159.8	27.0
Days to 50% silking	10.5	317.2	16.8	254.6	11.9
Plant height	608.6	1062.5	129.6	517.5	1162.8
Ear height	121.4	1054.6	128.7	213.6	175.8
Grain yield	3.2	3.5	71.6	75.3	95.0

δ^2g, Genotypic variance; δ^2p, phenotypic variance; GCV, genotypic coefficient of variation; PCV, phenotypic coefficient of variation; GA, genetic advance.

4. Discussion

The release of improved stress-tolerant maize varieties and hybrids has sparked optimism for increased maize productivity in Nigeria. These cultivars have the potential to provide farmers with opportunities to overcome the challenges to maize production. The cultivation of these cultivars in this agro-ecology could increase maize production and thereby enhance food security. Although rainfall distribution throughout the duration of these studies appeared favourable for crop growth and expression of studied traits in both OPVs and the F_1 hybrids, the second year precipitation was more beneficial (Fig. 1). The results from this experiment showed that hybrid maize efficiently utilized nitrogen better than OPVs as per earlier reports in Nigeria[9,10,23]. In both years, hybrids gave higher yield than the OPVs even at low soil N status[24-27]. Consequently, maize yield increased with increasing nitrogen availability and this is in agreement with previous reports by many workers[4,10,15,28-31]. Cultivars identified as less responsive to applied N sometimes perform better at low N than do N-responsive hybrids or OPVs[32]. The low N tolerant cultivars are superior in the utilization of available N, either due to enhanced uptake capacity or because of more efficient use of absorbed N in grain production[9,12,28,33]. However, number of days recorded in 2006 especially at anthesis was less than that recorded in 2005, which probably facilitated optimum utilization of available soil nutrients within the few days. This probably explains the higher grain yield and superiority in N utilization observed in the OPVs in 2005 relative to 2006 (Table 3), and also the significant year x nitrogen interaction for this character in both parents and hybrids (Table 4). Values for NUE, plant and ear heights were higher in 2005 compared to 2006 in both OPVs and hybrids. This observation tends to underscore the importance of moisture availability especially at anthesis in the accumulation of photo assimilates as well as its translocation for grain production in maize. Grain yield and NUE increased in a consistent manner with increasing N rate in both parents and hybrids (Table 3). This is in line with previous reports[9,14,24,26,28,34] that variation in N supply affects both growth and development of maize plants. The capacity to utilize N as measured by NUE and consequently grain yield in this study was optimum at 45 kg N ha^{-1} in both varieties and hybrids which were similar to the result obtained by[35] in the northern Guinea savannah of Nigeria in which the author reported a yield increase of 200% over the control at 40 kg N ha-1 in two maize varieties of different maturity periods. This result is also in support by earlier findings[4,12,31,36] on increase in grain yield and NUE at low N levels. Reference[10] similarly observed that maize varieties responded adequately well to nitrogen application in the southern Guinea savanna of Nigeria and gave over 3 t ha-1 grain yield by applying as low as 50 kg N ha-1. The authors suggested that this could erase producer fears that without high N input, hybrid maize would not give some appreciable returns. However, there was no significant genotype × N fertilizer effects for grain yield and NUE in this study similar to the findings of earlier workers[37,38], but contradicts- the findings of[39] who observed that maize differed in their capacity for N uptake, assimilation and redistribution of N from vegetative to reproductive tissues. The fact that the OPVs used in this study are of the same maturing group may be responsible for the difference in the two results.

High phenotypic coefficients of variations values observed in both OPVs and hybrids may indicate significant year× nitrogen interactions for all the characters measured (Table 8). This therefore affirmed that the populations used in this study showed a wide range of genetic variability under different N fertilizer rates. Genetic differences have been observed among maize genotypes (inbred lines, hybrids and OPVs) in response to N fertilizer application and efficient utilization of absorbed N for grain yield[12,13,40-43]. The high genetic gain of plant and ear heights signify broader genetic base for the two characteristics and could be selected for genetic improvement of maize under different N regimes, as earlier suggested[38,44]. Though low genetic gain was recorded for days to 50% silking and days for establishment count, there is a significant variability in these traits and hence may also be useful in maize breeding programme. Grain yield correlated positively with most of the parameters measured and this has also been reported by previous researchers[45,46].

5. Conclusions

Two drought tolerant varieties (Acr 90 Pool 16-Dt and Tze Comp3 Dt) that combined well with specific cultivars for grain yield and NUE probably have gene pools for low N tolerance. Therefore, these varieties can further be tried under farmers' growing conditions or could be hybridized for development of inbred lines in the development of N stress-tolerance varieties for cultivation in the southern Guinea savanna ecology.

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