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Evaluation of the Relationship between Nitrogen Fertilization and Agronomic Performance of Maize (*Zea mays* L.) Varieties

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Abstract

The significance of nitrogen fertilizer in maize (*Zea mays* L.) cultivation cannot be underestimated. Therefore the aim of the study is to assess the responsiveness of maize varieties to four rates of nitrogen fertilization in the formation of grain yield and other agronomic traits. The study area was at the Teaching and Research Farm of Ladoke Akintola University of Technology, Ogbomoso, Nigeria. The test period was between 2021 and 2022 where six varieties of maize (sub-plot factor) were included in an experiment with four rates (0, 30, 90 and 150 kg N/ha) of nitrogen fertilizer (main plot factor) laid down in a randomized complete block design with six replicates. Analysis of variance indicated that there were significant ($P < 0.01$) differences among maize varieties, nitrogen fertilizer rates, variety × year interaction as well as between the years of evaluation for grain yield and other agronomic traits. Growth parameters and grain yields differed significantly ($P < 0.05$) between varieties at all nitrogen fertilizer rates. SC 719 produced the highest yield (2512.03 kg/ha), whereas the lowest yield (1721.41 kg/ha) was found in SAMMAZ 27. The shortest anthesis-silking interval (2.4 days), lowest ear aspect score (4.9), highest grain yield (2734.6 kg/ha), plant (167.3 cm) and ear (72.3 cm) heights was recorded from plots fertilized with 150 kg N/ha. All the maize varieties performed better than the widely grown adapted local check (Oba super 6) under 0 kg N/ha. The application of nitrogen fertilizer improves yield and other agronomic traits of the maize varieties. Treatment of 90 kg N/ha gave comparable performance with 150 kg N/ha for most traits. Moreover, judicious nitrogen fertilizer management could ensure high grain yield production and profit.

Keywords: Agronomic Traits; Grain Yield; Maize Variety; Nitrogen Fertilizer

Abbreviations: ASI: Anthesis-Silking Interval; SAS: Statistical Analysis System; ANOVA: Analysis of Variance; LSD: Least Significant Difference; MLRM: Multiple Linear Regression Model.

Introduction

Maize (*Zea mays* L.) is an economic important cereal crop with global consumption in various forms. In Nigeria, it holds a prominent position as a staple food and is cultivated extensively. However, about 90% of cultivatable lands are susceptible to either biotic or abiotic stresses [1]. These stress factors disrupt plant growth and have the potential to result in substantial yield reduction, with major food crops possibly experiencing up to a 70% decrease in yields [2]. Low soil nitrogen is one of the major abiotic stresses limiting maize production leading to substantial annual losses in grain yield ranging from 10 and 50% [3].

In most maize growing areas, continuous cropping alongside limited utilization of organic and inorganic fertilizers, coupled with soil erosion and leaching, leads to the depletion of soil nitrogen and nutrient losses [4]. The primary approach for preserving or replenishing depleted soil nutrients and enhancing crop productivity involves the use of fertilizers [5]. Fertilizers are useful for soil enrichment to promote plant growth [6]. The three most commonly required synthetic fertilizers in maize production are nitrogen (N), phosphorus (P) and potassium (K) [7]. Nitrogen is vital in the utilization of P and K [8]. It plays a major role in photosynthesis and other biological activities whereas its deficiency results in a phenotype characterized by a pale, yellowish-green appearance and slender stalks [9].

Within Nigeria's derived savanna agroecology, maize stands out as the crop with the greatest need for N fertilizer. This agroecology has the potential for maize production [10], but grain yield is usually low due to poor soil fertility [11]. In an effort to address this, numerous maize varieties possessing characteristics such as tolerance to low soil N and other desirable traits originally developed in different agro-ecological regions, have been introduced to this specific zone. However, the adoption rate among farmers has remained low, primarily due to insufficient awareness regarding the potential advantages associated with these maize varieties, coupled with the unavailability of N fertilizer needed to enhance their performance.

Different maize varieties exhibit varying responses to N fertilizer application when it comes to the uptake and utilization of this essential nutrient [12]. Smallholder farmers with limited access to credit facilities often face scarcity of both organic and inorganic fertilizers. One of the efficient approaches to decrease the quantity of N fertilizer used by farmers is by identifying maize varieties with superior grain yield potential across various N fertilizer rates. Consequently, information regarding maize varieties that exhibit the potential for high grain yields and enhanced agronomic performance under moderate N fertilizer application becomes of utmost importance. The aim of the study is to assess the responsiveness of maize varieties to four rates of N fertilization in the formation of grain yield and other agronomic traits.

Materials and Methods

Planting Material, Experimental Design and Cultural Practices

Seeds of six maize varieties (SAMMAZ 27, SC 719, SAMMAZ 52, OBA 98, KAPAM 6 and OBA SUPER 6 - used as local check) sourced from the major maize producing agroecologies in Nigeria including the locally cultivated maize variety in Ogbomoso, were evaluated at the Teaching and Research Farm of Ladoke Akintola University of Technology, Ogbomoso (8^0 10'N, 4^0 10'E and altitude 341 m above sea level), Oyo State, Nigeria. The location experiences an annual precipitation range of 1,000 to 1,200 mm and daily temperature fluctuations typically falling between 28 and 30°C. The soils at the research site are generally deficient in N and have been categorized as alfisols [13,14].

The field used for this study had a history of consistent maize cultivation for several years, during which there was minimal or no application of N fertilizer. After each harvest, all remaining crop residues were thoroughly cleared from the field to prepare it for the upcoming planting season, leading to a continuous depletion of nitrogen in the soil. Before the establishment of this trial, soil samples were taken at the experimental site and the nutrient composition of the soil was determined at the soil science laboratory of the Department of Agronomy, University of Ibadan, Ibadan, Nigeria. The land was mechanically prepared using a tractor mounted plough and the field was subsequently partitioned into four N environments (0, 30, 90 and 150 kg N/ha). Each environment was separated by a 3 m alley and a gutter was used to break the lateral movement of nitrogen in the soil. The trial was structured as a split-plot within a randomized complete block design with the four different N fertilizer rates as the main plot factor and the six maize varieties were considered as sub-plot factor. The trial had six replications over the course of two years (2021 and 2022). An experimental unit consisted of a single-row plot, 5m long spaced at 0.75m apart with 0.50m spacing between hills within a row. Three seeds were sown per hole to ascertain that at least two seeds germinate and where the three seeds were viable they were thinned to two plant stands per hill two weeks after sowing to obtain a plant density of 53,333 plants per hectare. Basal fertilizer application of P in the form of single super phosphate and K in the form of Muriate of potash were applied at the rate of 60 kg/ha each at the 0 and 30 kg N/ha. No N fertilizer was applied under 0 kg N/ha. For the other rates, N was applied in two split doses for efficiency; the first application was done at two weeks after sowing and the second dose was applied two weeks later. In order to ensure a weed-free field, a combination of Gramoxone and Primextra were administered as pre- and post-emergence herbicides at the rate of 5.0 liters per hectare during sowing. Afterward, manual weeding was implemented to sustain a weed-free environment in the field.

Data Collection and Analysis

Data were recorded on the following traits on plot basis: number of days to 50% anthesis and silking was estimated as the numbers of days from planting to the day that 50% of plants had tassels shedding pollen and silk, respectively. The anthesis-silking interval (ASI) was calculated as the difference between the number of days to 50% anthesis and silking. Plant and ear height were measured from the base of the plant to the first tassel branch and the node bearing the uppermost ear, respectively. Plant aspect scores were obtained using a scale of 1-9, where 1 denoted excellent overall phenotypic appearance of plants and 9 extremely poor overall appearance of plant. Ear aspect was also rated on a 1-9 scale, where 1 indicated well-filled ears with no insect and disease damages and 9 represented plots with ears having only one or no kernel. Root and stalk lodging was estimated as the proportion of plants that fell from the root or with stalk bending more than 45^0 from the vertical position and broken stalk below the upper ear, respectively. Husk cover was rated on a scale of 1-5; where, 1 = very tight husk extending beyond the tip and 5 = exposed ear tip. The number of ears per plant was calculated as the ratio of harvested cobs per plot to the number plants at harvest. Grain yield was measured in kilograms per hectare (kg/ha) and adjusted to 15 % moisture content, from grain weight and percent moisture as described by Kolawole AO, et al. [15] using the following equation:

$$GY\left(kgha^{-1}\right)=GWT\left(\text{kg plot}^{-1}\right)\times\frac{100-MC}{100-15}\times\frac{10,000m^2}{\text{plot size m}^2}$$

Where: GWT = grain weight of harvested area, MC = moisture content of grains at harvest, moisture content for storage = 15 %, 1 hectare = $10,000\text{m}^2$ and plot size = 3.75 m^2.

Data were subjected to analysis of variance (ANOVA) to test for treatment effects and interactions using the statistical analysis system (SAS) computer software package version 9.4 [16]. A combined ANOVA was conducted on plot means for all traits across years and N fertilizer rates due to the insignificance of the homogeneity of variances test. Significant differences between varieties were compared using the Fisher's least significant difference (LSD) at 5% probability level [17]. Afterwards, Multiple Linear Regression Model (MLRM) was used to establish the linear relationship of dependent and independent variable [18] using PROC REG in SAS. The general linear model for MLRM in which response is related to a set of independent variable (X1) is given:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\ldots..\beta_kX_k+\varepsilon_i$$

Where Y = dependent variable, β0 is the intercept, β1, β2 … βk are coefficients of the variables, X_1, X_2 … X_k are kth independent variables and ε_i error term.

The maximum likelihood was used to estimate parameters of regression model and the general linear regressions model was tested by ANOVA. All regression coefficients were tested for statistical significance (t-test) at α = 0.05. Furthermore, correlation analysis was computed to determine the relationship between traits. The assessment of statistical significant differences of grain yield and other agronomic traits cultivated under low (0 and 30 kg N/ha) and high (90 and 150 kg N/ha) N fertilizer rates was carried out using the Student's t-test.

Results and Discussion

The mean squares of years of evaluation and likewise the interaction between variety and year (V × Y) were highly significant ($P < 0.01$) for all traits (Table 1). This implied that the maize varieties performed differently across years and there is a need to ascertain the stability of these varieties. The performance of the varieties across replications for all traits except for the number of days to anthesis signifies that the differences in organic matter, soil pH and moisture on the field did not affect the response of the varieties. The maize varieties mean squares showed significant ($P < 0.01$) differences for grain yield and all other measured traits. Variation in response to N fertilizer application among maize varieties indicated that superior variety with potential grain yield and other desirable traits can be identified for commercialization. The N Fertilizer rates have a significant ($P < 0.01$) effect on grain yield and other agronomic traits measured. The V × N rate interaction mean squares were not significant for all traits indicating similarly response to the contrasting N fertilizer rates. However, the interaction effects over years were significant only for number of days to anthesis, anthesis-silking interval and ear height.

Across the two years of evaluation, the pairwise comparisons of N fertilizer rates showed that application of either 90 or 150 kg N/ha gives the ASI which was significantly ($P < 0.05$) different from applying 0 or 30 kg N/ha (Table 2). Anthesis-silking interval is a useful indicator in screening for tolerance to stress because it is a measure of synchronization between maize pollen and silk. Short ASI implies longer grain filling periods, a phenomenon which contributes to increase in grain yield. There was a rapid significant ($P < 0.05$) increase in grain yield with increments of N fertilizer which ranged from as low as 266.7 to 5597.0 kg/ha. This further indicated that one or more N fertilizer rates were statistically different as observed earlier from ANOVA. The application of 150 kg N/ha gave the highest grain yield in consonance with the report of Sharma R, et al. [19]. The lowest N fertilizer rate (30 kg N/ha) shows a significant ($P < 0.05$) yield difference from the zero (0) N fertilizer rate which was approximately 25.7% of the maximum grain yield (5597 kg/ha). Likewise, the ear aspect, number of ears per plant, ear and plant heights of the maize varieties had better performance as N fertilizer rates increases. Although the pattern was inconsistent for other traits measured, but increment in N fertilizer rate resulted into improved performance. The observed effects of N fertilizer rates on agronomic and yield traits confirmed that N stress was a major factor limiting maize production and productivity [20]. The higher N fertilizer rates extended the vegetative growth period of the maize varieties, enhancing the production of photosynthetic assimilate and their allocation to stems [21]. This had a beneficial effect on the other agronomic traits that were assessed, ultimately leading to an increase in grain yield consistent with the findings of Akintoye HA, et al. [22], Bänziger M, et al. [23]. Both genetic and environmental factors may have contributed to the increase in maize yield under varied N fertilizer rate.

Source	df	Days to Anthesis (Days)	Days to Silking (Days)	Anthesis-silking interval (Days)	Plant Height (cm)	Ear Height (cm)	Plant Aspect (1-9)	Husk Cover (1-5)	Ear per Plant	Ear Aspect (1-9)	Grain Yield (kg/ha)
Year (Y)	1	364.50***	9.75	493.50***	9762.70***	3703.02***	76.06***	3.56**	0	41.25***	9598904.65***
Replication	5	16.09***	17.86	4.73	201.04	133.61	0.74	0.28	0.03	0.8	972818.45
Variety (V)	5	503.49***	624.81***	19.58**	5803.57***	3055.22***	4.54***	1.38**	0.08***	8.13***	3517837.17***
N rate	3	39.25***	47.21**	140.69***	2205.89***	752.42***	2.49**	1.28*	0.67***	7.57***	21329445.37***
V × N rate	15	5.18	6.4	7.07	265.81	133.77	0.66	0.24	0.03	1.6	1192114.57
V × Y	5	89.66***	164.31***	13.69	1703.00***	889.17***	7.82***	2.12***	0.10***	7.85***	14706299.58***
V × N rate × Year	18	19.17***	16.9	11.78*	516.25	208.97*	1.11	0.36	0.02	1.17	1033900.43
Error	235	4.15	11.63	6.63	326.49	120.44	0.71	0.38	0.02	1.06	721701.1
CV		3.29	5.23	75.15	11.28	16.13	16.17	21.79	17.24	20.19	38.78
R^2		0.8	0.63	0.48	0.47	0.53	0.52	0.29	0.45	0.44	0.55

*, **, *** = Significant at 0.05, 0.01 and 0.001 probability levels, respectively
N rate = Nitrogen fertilizer rate.

Table 1: Combined mean squares from ANOVA for grain yield and other agronomic traits of maize variety in response to N fertilizer rates.

N Rate (kg/ha)	Days to Anthesis (Days)	Days to Silking (Days)	Anthesis-Silking Interval (Days)	Plant Height (Cm)	Ear Height (Cm)	Plant Aspect (1-9)	Husk Cover (1-5)	Ear Per Plant	Ear Aspect (1-9)	Grain Yield (kg/ha)
0	60.9	66.3	5.4	153.8	64.6	5.3	3	0.7	5.6	1436.1
30	61.8	65.3	3.4	159.4	66.8	5.3	2.7	0.8	5.1	2267.6
90	61.9	64.3	2.4	160	68.4	5	2.8	0.9	4.9	2323.4
150	62.7	65.2	2.4	167.3	72.3	5.4	2.9	0.9	4.9	2734.6
Minimum	54	53	-10	99	22.6	2	2	1	2	266.7
Maximum	71	78	16	288	112	9	5	1.3	8	5597
Mean	61.8	65.3	3.4	160.1	68	5.2	2.8	0.8	5.1	2190
LSD (0.05)	0.8	1.2	0.9	6.1	3.8	0.3	0.2	0.1	0.4	332.3
Std. Dev.	4.1	5.1	3.2	22.5	14.5	1.1	0.7	0.2	1.2	1144

N rate = Nitrogen fertilizer rate, Std. Dev. = Standard deviation.

Table 2: Grain Yield and Other Agronomic Traits of Evaluated Maize Varieties Across Years Depending on Nitrogen Fertilizer Rates.

The six maize varieties evaluated under each of the four N fertilizer rates (0, 30, 90 and150 kg N/ha), showed variations in the mean performance for grain yield and other agronomic traits as a result of variation in their genetic makeup (Table 3). Consistent with the findings of Presterl T, et al. [24], it was observed that N stress significantly impacted grain yield due to a reduction in the plant's photosynthetic capacity, resulting in lower yields. At 0 kg N/ha, SAMMAZ 52 had the highest number of ears per plant, highest grain yield (2043.14 kg/ha), the shortest ASI with desirable phenotypic appeal. At 30 kg N/ha, OBA 98 had the shortest number of days to silking, shortest ASI, improved phenotypic appeal and the highest grain yield (2627.29 kg/ha). At 90 kg N/ha, KAPAM 6 had the highest grain yield (2724.21 kg/ha) with other desirable traits while SC 719 was the tallest with better husk cover and the highest grain yield (3176.85 kg/ha) at 150 kg N/ha.

Variety	Days to Anthesis (Days)	Days to Silking (Days)	Anthesis-Silking Interval (Days)	Plant Height (cm)	Ear Height (cm)	Plant Aspect (1-5)	Husk Cover (1-5)	Ear Per Plant	Ear Aspect (1-5)	Grain Yield (kg/ha)
0 kg N/ha										
SAMMAZ 27	56.5	61.08	4.58	144.56	58.7	5.33	3.08	0.65	5.58	1189.64
SC 719	64.83	71.25	6.42	170.08	77.53	5.17	2.42	0.69	5.58	1675.22
SAMMAZ 52	61.33	64.5	3.17	152.17	62.88	4.92	2.83	0.75	4.92	2043.14
OBA 98	60.33	65.92	5.58	148.12	66.01	5.42	3.25	0.67	5.67	1408.18
KAPAM 6	59.92	65.92	6	160.75	61.2	5.17	3.08	0.61	5.58	1229.43
Local check	62.58	69.25	6.67	147.08	61.52	5.5	3.08	0.67	6	1071.22
LSD (0.05)	1.32	3.11	2.71	33.54	14.39	0.85	0.66	0.19	1.34	816.47
30 kg N/ha										
SAMMAZ 27	56.42	59.83	3.42	149.83	59.42	6	2.83	0.78	5.83	1971.14
SC 719	66.33	70.33	4	182.63	82.75	5.25	2.42	0.73	5.33	2587.45
SAMMAZ 52	61.58	64.67	3.08	157.1	65.73	5.08	2.67	0.88	4.5	2223.99
OBA 98	60.92	63.5	2.58	155.77	63.02	5	2.83	0.83	4.75	2627.29
KAPAM 6	62	65.42	3.42	152.25	62.68	5.08	2.67	0.8	5.25	1998.13
Local check	63.67	67.75	4.08	158.97	67.28	5.25	2.5	0.89	5	2197.58
LSD (0.05)	1.93	2.12	1.69	11.21	9.54	1.09	0.54	0.15	1.17	647.85
90 kg N/ha										
SAMMAZ 27	56.08	57.42	1.33	145.03	60.12	5.75	3	0.82	5.83	1866.37
SC 719	67.67	68.92	1.25	182.3	85.13	5.17	2.67	0.8	5	2608.59
SAMMAZ 52	61.33	63.25	1.92	165.15	69.69	4.42	2.67	0.91	4.08	2573.73
OBA 98	61.33	64.33	3	152.73	60.2	5	3.08	0.93	5.33	1996.47
KAPAM 6	61.33	64.5	3.17	158.42	69.02	4.42	2.67	0.95	4.58	2724.21
Local check	63.67	67.67	4	156.6	66.43	5.08	2.83	0.84	4.42	2170.97
LSD (0.05)	1.93	2.28	1.49	14.97	8.84	0.9	0.74	0.14	0.85	914.77
150 kg N/ha										
SAMMAZ 27	57	59.17	2.17	158.5	65.47	6	3.17	0.86	5.67	1858.52
SC 719	66.25	68.75	2.5	190.65	89.13	5.58	2.75	0.79	5.08	3176.85
SAMMAZ 52	63.25	65.58	2.33	158.93	64.75	5.33	2.83	0.9	4.5	2640.7
OBA 98	61.75	64.25	2.5	162.4	71.48	5.25	2.83	0.86	5	3015.53
KAPAM 6	63	65.08	2.08	162.27	66.02	5.08	3	0.87	4.92	2567.41
Local check	65.08	68.08	3	170.98	76.95	5.25	2.83	0.98	4	3148.65
LSD (0.05)	2	2.13	1.71	11.23	13.75	0.89	0.86	0.11	0.99	1049.4

Table 3: Effects of Four Rates of N Fertilizer on Grain Yield and other Agronomic Traits of Maize Varieties Evaluated in the 2021 and 2022 Cropping Seasons.

Across the contrasting N fertilizer rates in the two years of evaluation, SC 719 had 14.5% yield increase over the local check, followed by SAMMAZ 52 (9.42%) which also had the shortest ASI, desirable number of ears per plant and general phenotypic appeal. This result corroborates the report of Kandel BP, et al. [25], who found considerable differences in grain yield between maize varieties. The variety (SC 719) with the highest grain yield (2512.03 kg/ha) was the tallest with firm husk cover, making it less susceptible to insects and birds attack (Table 4). The consistent improved performance of SAMMAZ 52 and SC 719 indicates the possession of good root systems, which enabled them to take up N fertilizer from deeper layers of the soil [20].

Variety	Days to Anthesis (Days)	Days to Silking (Days)	Anthesis-Silking Interval (Days)	Plant Height (cm)	Ear Height (cm)	Plant Aspect (1-5)	Husk Cover (1-5)	Ear Per Plant	Ear Aspect (1-5)	Grain Yield (kg/ha)	Yield Increase Over Check (%)
SAMMAZ 27	56.5	59.38	2.88	149.48	60.93	5.77	3.02	0.78	5.73	1721.41	-24.73
SC 719	66.27	69.81	3.54	181.42	83.64	5.29	2.56	0.75	5.25	2512.03	14.53
SAMMAZ 52	61.88	64.5	2.63	158.34	65.76	4.94	2.75	0.86	4.5	2370.39	9.42
OBA 98	61.08	64.5	3.42	154.75	65.18	5.17	3	0.82	5.19	2261.87	5.07
KAPAM 6	61.56	65.23	3.67	158.42	64.73	4.94	2.85	0.81	5.08	2129.79	-0.81
Local check	63.75	68.19	4.44	158.41	68.05	5.27	2.81	0.84	4.85	2147.1	
Mean	61.84	65.27	3.43	160.14	68.05	5.23	2.83	0.81	5.1	2190.43	
LSD (0.05)	0.97	1.51	1.06	7.45	4.65	0.37	0.26	0.06	0.44	407.02	
Std. Dev.	3.24	3.61	0.64	11	7.98	0.31	0.17	0.04	0.41	270.72	

Table 4: Combined Mean Performance of the Evaluated Maize Varieties for Grain Yield and Other Agronomic Traits across N Fertilizer Rates in 2021 and 2022.

The evaluated maize varieties appear to vary in their capacity to take up N fertilizer and utilize it efficiently. Under high (90 and 150 kg N/ha) N fertilizer rates, maize varieties yielded significantly ($P < 0.01$) more (677 kg/ha) and had taller plants with more ears per plant than the performance under low (0 and 30 kg N/ha) N fertilizer rates (Table 5). On the other hand, the performance of the maize varieties under high N fertilizer rates showed a significant ($P < 0.01$) decrease in ASI and ear aspect. The maize varieties did not show changes in the number of days to silking, plant aspect and husk cover irrespective of the N fertilizer rates.

Traits	Mean		Minimum	Maximum	Difference
	0 and 30 Kg N/ha (Low N)	90 and 150 kg N/ha (High N)			
Days to anthesis (days)	61.4	62.3	54	71	0.9*
Days to Silking (days)	65.8	64.8	53	78	1
Anthesis-silking interval (days)	4.4	2.4	-1	16	1.9***
Plant height (cm)	156.6	163.7	99	288	7.1**
Ear height (cm)	65.7	70.4	22.6	112	4.6**
Plant aspect (1-5)	5.3	5.2	2	9	0.1
Husk cover (1-5)	2.8	2.9	2	5	0.1
Ear per plant	0.7	0.9	0.2	1.1	0.1***
Ear aspect (1-5)	5.3	4.9	2	8	0.5***
Grain yield (kg/ha)	1851.9	2529	266.7	5597.5	677.1***

*,**, *** Low N rate significantly different from High N rate at the 0.05, 0.01 and 0.001 probability levels, respectively, using T test.

Table 5: Mean comparison of grain yield and agronomic performance of maize varieties based on low and high N fertilizer rates using T test.

Furthermore, correlation between all measured traits and N fertilizer rates were significant (P < 0.01) except for the number of days to anthesis (Table 6). There were significant positive associations between N fertilizer rates and grain yield (r = 0.36), number of ears per plant (r = 0.48), plant and ear heights (r = 0.49 and 0.54). The number of days to silking (r = -0.17), anthesis-silking interval (r = -0.26), husk cover (r = -0.27), plant and ear aspects (r = -0.37 and r = -0.57) correlated negatively with N fertilizer rates. In addition, strong positive significant (P < 0.001) correlation was found between the number of days to silking and anthesis-silking interval (r = 0.58). On the other hand, ear aspect and grain yield had a strong negative significant (P < 0.001) correlation (r = -0.57). These maize varieties can be improved indirectly by considering traits which had a strong correlation with grain yield.

	N RATE	DA	DS	ASI	PH	EH	PA	HC	EPP	EA
DA	0.14**									
DS	-0.09	0.77***								
ASI	-0.32***	-0.08	0.58***							
PH	0.20***	0.15**	0.06	-0.1						
EH	0.19***	0.14*	0.08	-0.06	0.77***					
PA	0.03	-0.05	0.19***	0.37***	-0.17***	-0.18***				
HC	0.03	-0.16**	-0.14*	-0.02	-0.21***	-0.26***	0.06			
EPP	0.41***	-0.01	-0.13*	-0.18***	0.11*	0.17***	-0.22***	-0.11		
EA	-0.20***	-0.11*	0.14*	0.37***	-0.25***	-0.27***	0.56***	0.16**	-0.35***	
YLD	0.36***	-0.02	-0.18***	-0.26***	0.49***	0.54***	-0.37***	-0.27***	0.48***	-0.57***

*, **, *** = Significant at 0.05, 0.01 and 0.001 probability levels, respectively

N RATE = Nitrogen fertilizer rates, DA = Number of days to anthesis, DS = Number of days to silking, ASI = Anthesis-silking interval, PH = Plant height, EH = Ear height, PA = Plant aspect, HC = Husk cover, EPP = Number of ears plant, EA = Ear aspect, YLD = Grain yield.

Table 6: Correlation coefficient (r) of grain yield and other agronomic traits with N fertilizer rates.

Due to the significant effects of the N fertilizer rates, regression analysis further highlights the linear component and trends in the response of grain yield and other agronomic trait to the N fertilizer rates which is the explanatory variate. It was evident that the N fertilizer rates explained most of the variations in grain yield and other agronomic traits (R2 = 73-97) except for number of days to silking, husk cover and plant aspect (Table 7). Plant and ear heights had significant (P < 0.05 and 0.01 respectively) impact on the linear regression of N fertilizer rates. The number of days to silking, anthesis-silking interval and ear aspect score had negative effects. This signifies that a unit increase in N fertilizer rates will lead to a decrease in those three traits while a proportional increase in N fertilizer rates will likely lead to increase in grain yield, plant and ear heights.

Traits	Intercept (α)±S.E	Slope (β)	Standard Error	R^2
Days to anthesis (days)	61.14±0.25	0.0103	0.0029	0.87
Days to Silking (days)	65.78±0.60	-0.0076	0.0067	0.39
Anthesis-silking interval (days)	4.63±0.69	-0.0179	0.0078	0.73
Plant height (cm)	154.83±1.72	0.0785*	0.0194	0.89
Ear height (cm)	64.81±0.52	0.0479**	0.0059	0.97
Plant aspect (1-9)	5.20±0.17	0.0005	0.002	0.03
Husk cover (1-5)	2.81±0.12	0.0003	0.0014	0.02
Ear per plant	0.72±0.05	0.0012	0.0006	0.7
Ear aspect (1-9)	5.38±0.15	-0.0042	0.0017	0.75
Grain yield (kg/ha)	1702.77±241.01	7.2247	2.7158	0.78

*, ** = Significant at 0.05 and 0.01 probability levels, respectively

R2 = Coefficient of determination; S.E = standard error.

Table 7: Contributions of N fertilizer rates to response in grain yield and other agronomic traits of maize varieties based on stepwise regression.

Conclusion

This study reveals significant variations in the response of maize varieties to N fertilizer rates. All the varieties performed better than the widely grown Oba super 6 used as local check at 0 kg N/ha. Nitrogen fertilization exerted high influence on productivity of maize. Diverse maize varieties were outstanding for each of the N fertilizer rate. In all, the outstanding varieties exhibited tolerance to low soil N apparently, due to high grain yields, early flowering as well as desirable phenotypic appeal. Regardless of the quantity of N fertilizer utilized in the soil, SAMMAZ 52 exhibited grain yields ranging from 2043.14 to 2640.70 kg/ha, whereas the least productive variety, SAMMAZ 27, showed grain yields ranging from 1189.64 to 1971.14 kg/ha. For enhancing maize grain yield under low N fertilizer rate, SAMMAZ 52 is the recommended choice, while under high N fertilizer cultivation; SC 719 (1675.22 – 3176.85 kg/ha) is the suggested option. These findings hold significant importance for farmers in the derived savanna agroecology of Nigeria, where the soil are inherently low in N.

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