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ASSESSMENT OF MAIZE (*Zea mays* L.) VARIETIES FOR TOLERANCE TO CONTRASTING SOIL-NITROGEN ENVIRONMENTS IN OGBOMOSO, NIGERIA

A. O. KOLAWOLE *, I. A. RAJI, S. A. OYEKALE

Department of Crop Production and Soil Science, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Oyo State, Nigeria
***Corresponding Author**: aokolawole@lautech.edu.ng **Tel**: +2348033880394

ABSTRACT

Millions of resource-limited farmers cultivate maize under low-soil nitrogen (N), which is a major constraint to maize production in Nigeria. Therefore, the objectives of this study were to: (i) assess the existence of genetic variation among some maize varieties for grain yield and other agronomic traits under varying N conditions, (ii) identify maize varieties with favourable alleles for tolerance to low-soil N and superior performance for grain yield across N environments. Eight maize varieties were evaluated under four (0, 30, 90 and 150 kg N ha^{-1}) N environments at the Teaching and Research Farm of Ladoke Akintola University of Technology, Ogbomoso, in 2021. The experiment was laid down in a randomized complete block design with six replicates. Data obtained were subjected to analysis of variance for each N level. Rank summation index was used to select superior variety. Significant (P < 0.01) mean squares were observed for grain yield and other agronomic traits of the maize varieties, across the (N) environments. Mean grain yields under low and optimal N environments were 2.8 t ha^{-1} and 3.8 t ha^{-1}, respectively. Outstanding varieties (Pioneer KMK (30Y87); Kapam 10 and Sammaz 52) were identified by rank summation index and low-N tolerant base index, indicating that the varieties possess favourable alleles for tolerance to soil-nitrogen stress.

Keywords: Agronomic traits, Grain yield, Low-N tolerance, N-environments, Rank summation index, Superior variety.

INTRODUCTION

Maize (*Zea mays* L.) is an important annual cereal crop grown for grain and forage in sub-Saharan Africa (SSA). It serves as staple food for more than 300 million people in the developing countries (Raheem *et al.*, 2021) and a major source of income to farmers in the sub-region (Tandzi and Mutengwa, 2019). Maize is grown throughout the world, although with huge yield discrepancies (Tigchelaar *et al.*, 2018). In West Africa, production of maize has been soaring over the years with the average total maize production of 10.2, 13.7 and 17.6 million tonnes in 2001-2005, 2006-2010 and 2011-2015, respectively (FAOSTAT, 2016). Considering the climatic and edaphic requirements of maize, there is a greater potential for its production and productivity in the savanna belt of SSA due to the low night temperatures, low pests and diseases occurrence and high influx of solar radiation (Anbessa *et al.*, 2010). However, maize grain yield on farmers' fields in SSA has been consistently low, averaging 1.7 t ha^{-1} compared to 10.7 t ha^{-1} obtainable in other parts of the world (FAOSTAT, 2016). The low yields have been attributed mainly to low soil fertility and acidity constraints. Several studies (Kamara *et al.*, 2005; Badu-Apraku *et al.*, 2016; Talabi *et al.,* 2017) have pointed out low-soil nitrogen (N) as an important abiotic stress reducing maize production in SSA.

Nitrogen (N) is essential for maize production and it is vital in the utilization of phosphorus and potassium, which are principal plant nutrients (Adediran and Banjoko, 1995). However, N is easily lost from the soil through leaching beneath the plant root zone during rainfall periods and volatilization (Ige *et al.*, 2021). In SSA, maize production occurs mostly on soils with inherent low N due to poor weed control, total removal of crop residues after harvest and continuous cropping with little or no use of N fertilizer (Oikeh and Horst, 2001). In spite of the awareness on the importance of application of N fertilizer to maize plant, many resource-limited farmers' still apply nitrogen fertilizer at sub-optimum rates. This may be attributed to high cost of fertilizers, which makes it uneconomical, lack of technical knowledge about its application and non-availability/scarcity of fertilizers when needed (Mi *et al.*, 2012). Several approaches at mitigating the low-soil N problem have been uneconomical. Low-N thus remains a great challenge to maize production on farmers' fields (Weber *et al.*, 2012). Therefore, the identification and promotion of superior maize hybrids with low-N tolerance is crucial for an increased maize production and productivity in SSA.

In Nigeria, maize varieties that are tolerant to N stress are constantly being released for different agro-ecological zones. However, the varieties being cultivated by farmers' in the derived savanna agro-ecology are mostly those released for either the rain forest zones or the northern savanna zones. The derived savanna is a zone extending southwards from the Southern Guinea savanna zone into the rainforest zone of Nigeria with an estimated 10% of the country's land area (Adebayo *et al.*, 2017; Kolawole *et al.*, 2021). Thus, the zone combines the characteristics of both the rain forest and savanna zones. Hence, maize genotypes that are tolerant to N stress must be selected for the zone. It is therefore important that efforts be intensified towards the identification of potential maize genotypes that are adapted to low-N in the derived savanna agro-ecology in a bid to abate the impact of high nitrogenous fertilizer costs and the endemic low nitrogen nature of the savanna soil on maize production. This study aimed at assessing the existence of genetic variation among some maize varieties for grain yield and other agronomic traits under varying nitrogen conditions, (ii) identify maize varieties with favourable alleles for tolerance to low-soil N and superior performance for grain yield across N environments in the derived savanna agro-ecology of Nigeria.

MATERIALS AND METHODS

Planting material, experimental design and cultural practices

Seeds of seven maize varieties sourced from the major maize producing agro-ecologies in Nigeria and one locally cultivated maize variety in Ogbomoso (Table 1), were evaluated at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso (8^o 10'N, 4^o 10'E and altitude 341 m above sea level). The site is characterized by annual rainfall ranging between 1,000 and 1,200 mm and daily temperature ranges between 28 and 30°C. Soils of the experimental site are generally low in N and were classified as Alfisols (Adebayo *et al.,* 2017).

The experimental site used for this study had been under continuous maize cultivation over the years with little or no N fertilizer application. After each harvest, the residuals were completely removed from the field in preparation for the next planting season thereby depleting the soil of N incessantly. 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 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^{-1}). 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 a split-plot, with the four N environments as main plot factor while the eight maize varieties were considered as sub-plot factor with six replications. 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^{-1} each at the 0 and 30 kg N ha^{-1}. No N was applied under 0 kg N environments. For the other environments, the nitrogen was applied in two split doses for the efficient use of nitrogen; the first application was done at two weeks after sowing and the second dose was applied 2 weeks later. A mixture of Gramoxone and Primextra were applied as pre- and post-emergence herbicides at the rate of 5.0 l ha^{-1} at sowing and manual weeding was subsequently done to keep the plot weed-free.

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 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.

Table: 1 List and characteristics of maize varieties evaluated in this study

Variety	Type of genotype	Ecology	Breeding emphasis	Year of release
Sammaz 52	Open pollinated variety	Northern guinea and Sudan Savanna	Intermediate maturity, PVA content (9.8 g/g)	2007
Sammaz 27	Open pollinated variety	Lowland tropics	Drought and *Striga* resistant	2009
SC 719	Open pollinated variety	Southern and Northern Guinea Savanna	Drought tolerant, high yield potential and good husk cover	2014
Oba 98	Hybrid	Forest and Savanna	Quality protein maize	2001
Oba Super 6 (Check)	Single-cross hybrid	Forest and Savanna	Nitrogen use efficiency	2018
Kapam 6	Open pollinated variety	Savanna	Drought tolerant and Pro-vitamin *A*	2018
Kapam 10	Open pollinated variety	Savanna	Drought tolerant and Pro-vitamin *A*	2019
Pioneer KMK (30Y87)	Hybrid	Forest, transition, Southern and Guinea Savannah	Stay green characteristics	2014

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. Stay-green scores were recorded on low-N plots (0 and 30 kg N ha^{-1} environments) on a scale of 1 to 9; where 1 = almost all leaves below the ear were green and 9 = virtually all leaves below the ear were dead (Kamara *et al.*, 2005). 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^{-1}) and adjusted to 15 % moisture content, from grain weight and percent moisture as described by Kolawole *et al.* (2018) using the following equation:

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

Where: GWT = grain weight of harvested area, MC = moisture content of grains at harvest, moisture content for storage = 15 %, 1 hectare = 10,000m² and plot size = 3.75 m².

Combined ANOVA was conducted across the nitrogen environments using the Procedures for General Linear Model (PROC GLM) in SAS (SAS Institute, 2011). The means for each trait was computed and the specific differences between pairs of means were estimated with the Duncan's Multiple Range test (DMRT) at 0.05 probability level (Duncan, 1955). Performance of the maize varieties across low nitrogen environments was determined using the low-N base index as described by Badu-Apraku *et al.* (2011a) as follows:

Low nitrogen base index = 2YIELD + EPP – ASI – PASP – EASP – SG

Where: YIELD = Grain yield (kg ha^{-1}), EPP = number of ears per plant, ASI = anthesis-silking interval, PASP = plant aspect, EASP = ear aspect, SG = stay-green characteristic.

Least square mean for each trait was standardized to reduce the effects of the different scales used to measure them. The standardized values were used in the base index; a positive base index value for any maize variety indicated that the variety was tolerant to low-soil N while a negative value revealed the susceptibility of the variety to the stress (Badu-Apraku *et al.*, 2011b). To select superior variety, the rank summation index (RSI) was constructed by ranking five traits for each variety in order of preference (Mulumba and Mock, 1978; Kolawole and Olayinka, 2022). For grain yield, the higher the values, the better, while for other traits, the lower the values, the better. The ranks for each entry for the five traits were then summed up to obtain an index as:

$$RSI_1 = \sum_j^m = n^{ij}$$

Where n^{ij} is the rank of variety i in relation to trait j

Pearson correlation coefficients (r) between every pair of measured trait were calculated to determine the degree of association among traits.

RESULTS AND DISCUSSION

The combined analysis of variance revealed that the mean squares for nitrogen (N) environment and the variety were significantly ($P < 0.01$) different for all traits measured except r the number of days to silking and plant aspect for the N environment as well as stalk lodging and husk cover for the variety (Table 2). However, the variety × environment interaction was not significant for most of the traits except for root lodging.

The observed significant mean squares for most measured traits of the varieties indicated the existence of variability. Hence, there is a potential for selection of a variety suitable for production in the test environment (Obeng-Bio *et al*., 2020). The highly significant N environment implied that selection for a suitable variety for specific N environment is feasible. The non-significant interactions between the variety × environments for all traits measured except root lodging indicated that the environmental variation did not affect the expression of most traits and their expression would be consistent in varying N environment. On the other hand, the significant mean square of variety × environments detected for only root lodging indicated that environmental variations controlled its expression. Consequently, more evaluations across multiple N environments may be needed to validate the standability of the maize varieties. Earlier studies have based genotype selection on the absence of significant interaction between genotype and environment (Derera *et al*., 2008; Adebayo, 2014; Badu-Apraku *et al*., 2016).

Across the low-N environments (0 and 30kg N ha^{-1}), the mean grain yield was 2.8 t ha^{-1} and ranged between 2.1 t ha^{-1} for Kapam 6 to 4.0 t ha^{-1} for Pioneer KMK (30Y87), which also had the significantly highest grain yield (Table 3). Across the optimal N-environments (90 and 150 kg N ha^{-1}) the mean grain yield was 3.8 t ha^{-1}. The lowest yield was 2.6 t/ha^{-1} for Sc 719 and Pioneer KMK (30Y87) had the significantly highest (5.7 t ha^{-1}) grain yield (Table 4). Comparing the grain yield under low-N input and optimal N conditions revealed yield reduction ranging from 7% for Sc 719 to 39% for Kapam 6, with a mean of 21%. The decline in grain yield observed may be as a result of reduction in the photosynthesis capacity of the plant (Settinni and Maranville, 1998) and kernel abortion due to nitrogen stress (Amegbor *et al*., 2017). Thus, the increased grain yield under optimal N conditions was a response to increase in N fertilizer which is in consonance with previous report of Adu *et al.* (2018).

Among the top performing varieties under low-N conditions, Pioneer KMK (30Y87), Kapam 10 and Sammaz 52 had higher grain yield than the commercial check (Oba Super 6). However, only two maize varieties Pioneer KMK (30Y87) and Kapam 10 were superior than the commercial check for grain yield under optimal N conditions. The consistency in performance of these varieties across N environments implies the possession of some desirable genes for N-stress tolerance and further emphasizes their potential in all growing conditions.

Table 2: Mean squares of grain yield and other agronomic traits of maize varieties evaluated across four nitrogen environments

Source	df	Grain yield (kg ha^{-1})	Numbers of ears per plant	Days to anthesis	Days to silking	Anthesis -silking interval (days)	Plant height (cm)	Ear height (cm)	Plant as- pect (1-9)	Ear as- pect (1-9)	Root lodg- ing (%)	Stalk lodging (%)	Husk cover (1-5)
Replicate (R)	5	1369232.6	0.0	22.7**	62.8	24.1	353.1	176.3	1.4	1.1	19.7*	56.5	0.9*
Environment (E)	3	42076503.7***	0.2***	119.5***	54.4	186.7***	3614.2***	791.6***	0.2	5.1**	67.4***	211.9***	0.7
R×E	15	1473434.1	0.0	9.3*	60.5*	40.1	413.7	149.7	1.1	1.2	13.9*	52.3*	0.8**
Variety (V)	7	14129227.5***	0.1***	194.9***	365.9***	67.5**	1872.4***	529.3***	10.8***	10.6***	27.1**	27.9	0.5
V×E	21	1344510.8	0.0	6.6	27.3	24.2	142.1	90.9	0.9	1.2	12.31*	23.6	0.4
Error	140	1083105.2	0.0	5.2	28.6	23.6	275.1	106.9	0.7	1.1	7.3	26.5	0.3
CV (%)		31.7	16.5	3.8	8.3	120.7	10.1	14.6	15.4	20.3	98.5	152.5	20.6

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

Table 3: Means of grain yield and other selected agronomic traits of maize varieties evaluated in low nitrogen environments

Variety	Grain yield (kg ha^{-1})	Numbers of ears per plant	Days to anthesis	Days to silking	Anthesis-silking interval	Plant height (cm)	Ear height (cm)	Plant aspect (1-9)	Ear aspect (1-9)	Root lodging (%)	Stalk lodging (%)	Husk cover (1-5)	Stay green charac-teristics (1 - 9)
Pioneer KMK (30Y87)	4035.56a	0.86ab	58.75c	62.92c	4.17bc	150.75b	69.33b	4.50d	4.25d	4.69b	2.37ab	2.50ab	3.83b
Kapam 10	3431.11ab	0.91a	58.92c	62.08c	3.17bc	158.08b	71.33ab	5.17bcd	4.58cd	21.00a	5.30ab	2.33b	4.58ab
Sammaz 52	3066.67bc	0.85ab	57.92c	61.92c	4.00cd	165.17b	72.00ab	5.08cd	4.83bcd	16.91a	6.66a	2.67ab	4.75a
Sammaz 27	2862.22bcd	0.81abc	56.83c	63.33c	6.50abc	165.67b	72.50ab	5.83ab	5.58abc	16.09a	4.64ab	2.42ab	5.25a
Oba 98	2640.00bcd	0.78abc	57.33c	62.33c	5.00bcd	161.00b	66.92b	5.58abc	5.58abc	20.85a	2.11ab	2.92a	4.50ab
Sc 719	2453.33bcd	0.64d	64.67a	72.42a	7.75a	180.50a	80.67a	5.92a	6.33a	10.61ab	2.24ab	2.67ab	3.83b
Kapam 6	2124.44cd	0.76bc	58.00c	64.58c	6.58abc	157.08b	65.83b	5.58abc	5.75ab	15.75a	3.49ab	2.67ab	5.25a
Oba Super 6 (Check)	1893.33d	0.72cd	61.25b	68.25b	7.00ab	152.75b	68.08b	6.17a	6.25a	15.85a	0.00b	2.92a	4.58ab
Mean	2813.33	0.79	59.20	64.70	5.50	161.40	70.80	5.50	5.40	15.20	3.40	2.60	4.60

Means with the same letter within the column are not significantly different at P = 0.05 by DMRT

Table 4: Means of grain yield and other selected agronomic traits of maize varieties evaluated in optimal nitrogen environment

Variety	Grain yield (kg/ha^{-1})	Numbers of ears per plant	Days to anthesis	Days to silking	Anthesis-silking interval	Plant height (cm)	Ear height (cm)	Plant aspect (1-9)	Ear aspect (1-9)	Root lodging (%)	Stalk lodging (%)	Husk cover (1-5)
Pioneer KMK (30Y87)	5706.67a	0.98a	60.00c	57.17d	-2.83b	154.08c	66.83b	3.92c	3.67c	7.98b	5.09a	2.83a
Kapam 10	4320.00b	0.92a	61.33c	64.33bc	3.00a	160.42bc	64.92b	5.25b	4.83b	8.51b	5.76a	2.58a
Sammaz 52	3617.78bc	0.88a	60.83c	63.58bc	2.75a	170.42b	72.00b	5.33b	5.00b	19.09ab	10.83a	2.75a
Oba 98	3591.11bc	0.88a	61.00c	64.17bc	3.17a	163.83bc	66.83b	5.50b	5.00b	22.64a	9.20a	2.75a
Kapam 6	3511.11bcd	0.92a	60.50c	63.58bc	3.08a	166.92bc	71.42b	5.25b	5.00b	23.48a	11.98a	2.75a
Sammaz 27	3253.33cd	0.86a	57.75d	60.50cd	2.75a	162.83bc	70.00b	5.75b	5.50ab	15.45ab	12.95a	2.67a
Sc 719	2648.89d	0.71b	68.25a	71.50a	3.25a	183.58a	82.50a	7.00a	6.00a	10.44ab	7.30a	2.58a
Oba Super 6 (Check)	3386.67cd	0.91a	64.25b	69.25ab	5.00a	161.75bc	70.83b	5.92b	4.92c	15.09ab	9.56a	2.92a
Mean	3754.40	0.88	61.70	64.30	2.50	165.50	70.70	5.50	5.00	15.30	9.10	2.70

Means with the same letter within the column are not significantly different at P = 0.05 by DMRT

Table 5: Traits means of the maize varieties evaluated across four nitrogen environments

Variety	Grain yield (kg ha^{-1})	Numbers of ears per plant	Days to anthesis	Days to silking	Anthesis-silking interval (days)	Plant height (cm)	Ear height (cm)	Plant aspect (1-9)	Ear aspect (1-9)	Root lodging (%)	Stalk lodging (%)	Husk cover (1-5)
Pioneer KMK (30Y87)	4871.1a	0.91a	59.4c	60.0d	0.7b	152.4c	68.1b	4.2e	4.0d	5.4c	2.1a	2.7abc
Kapam 10	3875.6b	0.91a	60.1c	63.2cd	3.1ab	159.3bc	68.1b	5.2d	4.7c	12.1abc	2.5a	2.5c
Sammaz 52	3342.2bc	0.86ab	59.4c	62.8cd	3.4ab	167.8b	72.0b	5.2d	4.9bc	15.8ab	4.5a	2.7abc
Oba 98	3115.6cd	0.83ab	59.2c	63.3cd	4.1a	162.4bc	66.9b	5.5bcd	5.3bc	19.8a	3.1a	2.8ab
Sammaz 27	3057.8cd	0.84ab	57.3d	61.9cd	4.6a	164.3b	71.3b	5.8bc	5.5ab	13.4abc	4.9a	2.5bc
Kapam 6	2817.8cd	0.84ab	59.3c	64.1c	4.8a	162.0bc	68.6b	5.4cd	5.4b	17.9a	4.5a	2.7abc
Sc 719	2551.1d	0.68c	66.5a	72.0a	5.5a	182.0a	81.6a	6.5a	6.2a	8.5bc	2.8a	2.6abc
Oba Super 6 (Check)	2640.0d	0.82b	62.8b	68.8b	6.0a	157.3bc	69.5b	6.0ab	5.6ab	12.9abc	2.6a	2.9a
Mean	3283.9	0.8	60.5	64.5	4.0	163.4	70.8	5.5	5.2	13.3	3.4	2.7

Means with the same letter within the column are not significantly different at P = 0.05 by DMRT

Table 6: Grain yield and other agronomic traits of maize varieties evaluated across low-N input and variety mean performance ranking across N-environments.

			Low-N index				
Variety	**Grain yield (kg ha^{-1})**	**Ears per plant**	**Anthesis-silking interval (day)**	**Plant aspect (1-9)**	**Stay-green characteristic (1-9)**	**Ear aspect (1-9)**	**Low-N index**
Pioneer KMK (30Y87)	4035.6	0.9	4	4.5	3.8	4.3	10.4
Kapam 10	3431.1	0.9	3	5.2	4.6	4.6	6.6
Sammaz 52	3066.7	0.9	4	5.1	4.8	4.8	3.8
Oba 98	2640.0	0.8	5	5.6	4.5	5.6	-0.7
Sammaz 27	2862.2	0.8	7	5.8	5.3	5.6	-2.6
Sc 719	2453.3	0.6	8	5.9	3.8	6.3	-5.2
Kapam 6	2124.4	0.8	7	5.6	5.3	5.8	-5.2
Oba Super 6 (Check)	1893.3	0.7	7	6.2	4.6	6.3	-7.2
Mean	2813.3	0.8	6	5.5	4.6	5.4	

			Rank Summation Index			
Variety	Grain yield (kg ha^{-1})	Anthesis-silking interval (days)	Plant aspect (1-9)	Ear aspect (1-9)	Root lodging (%)	Rank sum
Pioneer KMK (30Y87)	4871.1	1	4.2	4	5.4	5
Kapam 10	3875.6	3	5.2	4.7	12.1	11
Sammaz 52	3342.2	3	5.2	4.9	15.8	18
Oba 98	3115.6	4	5.5	5.3	19.8	25
Sammaz 27	3057.8	5	5.8	5.5	13.4	27
Kapam 6	2817.8	5	5.4	5.4	17.9	28
SC 719	2551.1	6	6.5	6.2	8.5	32
Mean	3375.9	4	5.4	5.1	13.3	
Standard Error	294.7	1	0.3	0.3	1.9	
Minimum	2551.1	1	4.2	4.0	5.4	
Maximum	4871.1	6	6.5	6.2	19.8	
Oba Super 6 (Check)	2640.0	6	6.0	5.6	12.9	34

Table 7: Correlation coefficient (r) between grain yield and other agronomic traits of the maize varieties evaluated

Parameter	Grain yield (kg ha^{-1})
Numbers of ears per plant	0.53^{***}
Days to anthesis	-0.18^{*}
Days to silking	-0.39^{***}
Anthesis-silking interval (days)	-0.35^{***}
Plant height (cm)	0.41^{***}
Ear height (cm)	0.40^{***}
Plant aspect (1-9)	-0.60^{***}
Ear Aspect (1-9)	-0.76^{***}
Root lodging (%)	0.07
Stalk lodging (%)	0.15^{*}
Husk cover (1-5)	-0.18^{*}

As a result of the morphological and physiological responses of the maize varieties to soil N, the increase in grain yield under optimal N conditions was accompanied with higher numbers of ears per plant, shorter anthesis-silking interval and lower ear aspect score which is in consonance with the report of Matusso and Materusse (2016).

Across the nitrogen environments, number of days to anthesis ranged from 57 to 66 days while the number of days to silking was between 60 and 72 days with an average anthesis-silking interval of 4 days (Table 5). The short anthesis-silking interval which depicts early synchronization of the pollen and silk exhibited by Pioneer KMK (30Y87), Kapam 10 and Sammaz 52 indicates tolerance to stress (Edmeades *et al*., 2000; Adebayo, 2014). The varieties displayed sizeable tolerance to stalk and root lodging (mean of 3.4 and 13.3%, respectively). Plant height ranged from 152.4 to 182.0 cm, with an average height of 157.3 cm and having ears placed at an average of 69.5 cm above ground level. The plants produced an average of 1 ear per plant across the nitrogen environments. Plant and ear aspect ratings were averagely 6.0 and 5.6, respectively. The overall maize grain yield (3.3 t.ha^{-1}) across N environments, was comparable to the report of Adu *et al.* (2018) and higher than the average yield of 1.8 to 2.0 t.ha^{-1} obtained by farmers in the derived savanna agro-ecology (Tofa *et al*., 2021). All the evaluated maize varieties, except for SC 719 out-yielded the commercial check (2640 kg ha^{-1}). However, only two varieties (Pioneer KMK (30Y87) and Kapam 10) had a yield advantage of > 25% over the commercial check. This indicates that some of the varieties can adapt in the derived savanna and produce sustainable yields compared to the locally cultivated Oba super 6.

The low-N base index identified Pioneer KMK (30Y87), as outstanding and it out-yielded the commercial check (Oba Super 6) by 53 % under low-N environments (Table 6). Other two varieties (Kapam 10 and Sammaz 52) were also identified as exhibiting tolerance to low soil nitrogen. The results obtained from ranking the performance of the varieties using RSI and low-N base index were similar. For RSI, the varieties with lower ranks had higher grain yield coupled with other desirable agronomic traits whereas, a positive base index value for any maize variety indicate that the variety was tolerant to low soil nitrogen. In general, the two approaches identified Pioneer KMK (30Y87), Kapam 10 and Sammaz 52 as superior varieties. Pioneer KMK (30Y87) had the maximum yield performance across N- environments irrespective of the selection method employed. It is therefore a promising variety that can be exploited in low-input agricultural systems.

The association between traits observed from Pearson's correlation coefficient (r) revealed that the number of ears per plant had strong positive and significant ($P < 0.01$) correlation with grain yield (r = 0.53**) whereas strong negative and significant ($P < 0.01$) correlation existed between grain yield and each of ear and plant aspect (r = -0.76** and -0.60**)Table 7. Overall, grain yield had either positive (number of ears per plant, stalk lodging, plant and ear heights) or negative (number of days to anthesis and silking, anthesis-silking interval husk cover, plant and ear aspect) significant correlations with all measured traits except for percent root lodging, implying that grain yield was associated with many agronomic traits. In the selection for improved grain yield which is quantitative in nature, other agronomic traits related to yield and growth are equally important for adaptability.

However, breeding maize for height in the derived savanna agro-ecology is not a priority, because tall plants have been reported to be susceptible to lodging due to strong winds and have been found to reduce yield (Izge *et al.*, 2007).

CONCLUSION

This study revealed exploitable genetic variation among the evaluated maize varieties across the N environments. Similar varieties (Pioneer KMK (30Y87), Kapam 10 and Sammaz 52) were outstanding in the low-N input, optimal N input and across the N environments. These maize varieties exhibited tolerance to low soil N, with high grain yields, early flowering as well as desirable phenotypic with tolerance to stalk and root lodging. With the low rate of fertilizer use by resource-limited farmers' in Nigeria, these varieties can be recommended to farmers' in the derived savanna agro-ecology to boost maize production.

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