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Research Article

Agronomic Performance and Grain Yield of Low-Nitrogen-Tolerant Maize Varieties in Two Different Agro-Ecologies

Olatuyi, O. A., Okonji, C. J., Adewale, B. D., Baiyeri, S. O. and Osundare, O. T.
Department of Crop Science and Horticulture, Federal University Oye-Ekiti

Correspondence e-mail: olatuyiopeyemi72@gmail.com

Abstract
The soil of Ekiti State is low in nitrogen due to continuous cropping, erosion and leaching, which has led to decrease in crop yield. An effective approach to increasing maize yield in nitrogen-deficient soils is the use of low-nitrogen-tolerant maize varieties. Experiments were conducted in two locations: Ikole-Ekiti and Ikere-Ekiti in Ekiti State, Nigeria. Four low nitrogen tolerant maize varieties, *TZEE-W Pop STR* C_5, *TZEE-W Pop HDT* C_3 *STR* C_5, *2017 TZEE-W HDT STR* and 2016 *TZEE-W Syn Pop DT STR* F_2 from the International Institute of Tropical Agriculture Ibadan, Nigeria were used. Three rates of nitrogen fertilizer, 0 kg N/ha, 30 kg N/ha and 60 kg N/ha were applied. The three factors experiments were laid out in split-split plot design. Days to silking, anthesis-silking interval, flag leaf height, plant height and grain yield significantly ($p \leq 0.05$) varied with the locations, nitrogen rates and varieties. The results indicated that 60 kg N/ha reduced the grain yield of maize compared to 30 kg N/ha which improved the grain yield of the maize varieties in the two locations (Ikole-Ekiti: 1506.04 kg/ha and Ikere-Ekiti: 952.82 kg/ha). This could be because high nitrogen level reduced nitrogen use efficiency of the maize varieties. Thus, low nitrogen level such as 30 kg N/ha is favourable for higher grain yield of low nitrogen tolerant maize varieties. *TZEE-W Pop HDT* C_3 *STR* C_5 significantly had the highest grain yield among the varieties in Ikole-Ekiti and Ikere-Ekiti.

Keywords: *Location, agronomic traits, grain yield, maize, nitrogen levels*

Introduction
Maize (*Zea mays*) belongs to the grass family Poaceae. It originated from South and Central America. Maize is among the most important grains in Nigeria because of its numerous usage domestically, commercially and industrially (Adetunji *et al*., 2017). Maize is a highly adaptable crop grown across diverse agro-ecological zones, it has a short growth duration, rapid development, and significant yield potential (Begam *et al*., 2018). Nitrogen is the most important, among the nutrients needed for maize growth and development because of its role for major activities during the growth and development of maize (Tanumihardjo *et al*., 2020). It is a macronutrient that has a decisive role in the improvement of maize production (Szulc *et al*., 2016). In recent years, climate change has been affecting the global agricultural productivity and its impacts negatively affect crop production (Boonwichai *et al*., 2019). Soil is another key factor which determines the growth and productivity of maize crop (Zhang *et al*., 2018). Nitrogen is the key element for maize production due to its impact on the plant growth and development (Basso *et al*., 2020).

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Maize grown on soils deficient in nitrogen shows nitrogen deficiency symptoms such as poor growth, chlorosis and causes disorderliness in many physiological or biochemical characteristics of maize plants (Wei *et al*., 2016). Low nitrogen in soils may be due to continuous cropping, erosion and leaching, which could result to decrease in maize yield (Abubakar and Manga, 2017). Previous research on maize in Ekiti state revealed the analysis of productive resources in maize relating to input use, maximization and profit margin (Owoeye *et al*., 2017) but few reported the actual growth and yield performance of low nitrogen tolerant maize varieties in the different agro-ecologies in Ekiti state. Ikole is in the northern part of Ekiti state and Ikere is located on the southern part of Ekiti state respectively. Akinola *et al*. (2021) reported low nitrogen in the northern part of Ekiti State and this poses a great concern among farmers on maize production in the region. Low soil fertility is among the abiotic constraints affecting maize production, especially nitrogen deficiency which is the main factors that mostly limit maize productivity (Olaniyan, 2015). In addition, unavailability of fertilizer and the high prices results to low production of maize among smallholder farmers (Jama *et al.,* 2017). Tofa *et al,* (2022) also reported that factors that mostly limit maize production in all the agro-ecological zones, especially the savanna zone, is low soil fertility. In spite of the availability of high-yielding varieties in Nigeria, maize yields are still low in Nigeria savannas. This is due to declination in soil fertility combined with low use of fertilizer or no fertilizer application. Shorter fallow periods and continuous cropping arising from rapid population expansion have also resulted in nitrogen deficiency in soil (Maja and Ayano, 2021).

A possible approach to increase maize yield even in soil with low nitrogen nutrient is the use of varieties that are tolerant to low nitrogen in soil (Badu-Apraku *et al*., 2017). The use of low nitrogen tolerant maize varieties in Ekiti State will reduce the cost of maize production due to fertilizer input. This study aims to evaluate the agronomic traits and yield performance of low-nitrogen-tolerant maize varieties in two agro-ecologies of Ekiti State, Nigeria..

Materials and Methods

Study area: The experiment was conducted in two locations within Ekiti State, Nigeria. The locations were Ikole-Ekiti (Ekiti north) and Ikere-Ekiti (Ekiti south), Ikole is located in the derived guinea savanna area while Ikere is located in the tropical rainforest (Talabi, 2018). Ekiti State is situated in the south western part of Nigeria between latitude 7.667° N and longitude 5.250° E (Salau *et al*., 2016). The soil in Ikere-Ekiti contain higher clay and lesser sand compared to that of Ikole-Ekiti (Table 1). The annual rainfall and temperature in Ikole-Ekiti range from 740 mm to 1220 mm and 24C to 28C respectively while, the annual rainfall in Ikere-Ekiti ranges from 1,200 mm to 1,500 mm and temperature ranges from 21^0 C to 32^0 C throughout the year (Olujobi, 2015).

Experimental layout and planting materials: The experiment used a split-split plot design with three replications, incorporating three treatment factors: locations, nitrogen levels, and maize varieties. The main plot treatment was the location, the sub-plot treatment was different levels of Urea fertilizers, 0 kg N/ha, 30 kg N/ha and 60 kg N/ha while the maize varieties were in the sub-sub-plot. The four low nitrogen tolerant maize varieties (*TZEE-W Pop STR C_5, TZEE-W Pop HDT C_3 STR C_5, 2017 TZEE-W HDT STR and 2016 TZEE-W Syn Pop DT STR F_2)* used for the study were sourced from the International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria.

Field preparation and soil sampling: The experimental fields were ploughed and harrowed; soil sample was afterward collected for routine soil analysis before ridging was done in the two locations. The soil samples collected from the two locations were differently analyzed in the Soil Science and Land Management Resources Laboratory, Federal University Oye-Ekiti. Ikole-Ekiti Campus, Nigeria (Table 1).

Sowing and cultural practices: The plot size was 3 m × 1.5 m and inter and intra row spacing was 0.75 m × 0.5 m. Cultural practices such as weeding, pest control and fertilizer application were carried out. Pre-emergence herbicide such as atrazine and weed crusher were applied at 500ml per 15 litres of water after sowing before emergence for weed control. Manual weeding was further carried out regularly during the growth of maize. Caterpilar force was sprayed on maize plants regularly from two weeks after planting to prevent army worm attack on the maize plants. Nitrogen fertilizer (urea) was applied randomly at 0 kg N/ha, 30 kg N/ha and 60 kg N/ha in two split applications. For 30 kg N/ha and 60 kg N/ha, 3 g and 6 g of nitrogen fertilizer were applied to each maize plant respectively using band placement method (hill placement) at 5 cm away from the plant.

Data collection: Agronomic traits and grain yield of maize plants were measured to evaluate the performance of each variety in the two locations. Eight (8) plants were sampled per plot. The agronomic traits measured include days to 50% anthesis, days to 50% silking, anthesis-silking interval, flag leaf height (cm), plant height (cm), ear height (cm), plant aspect and grain yield (kg/ha). Days to 50% anthesis: Number of days to anthesis was determined by counting from the day of planting to the time when 50 % of the plants in the plot sheds their pollen grain. Days to 50% silking: Number of days to silking was determined by counting from the day of planting to time when 50 % of the plants in the plot produce silk.

Anthesis-silking interval: It was calculated as the difference between days to 50 % anthesis and days to 50 % silking. It is the interval between the first day 50 % of maize plant shed there pollen grains and the first day 50 % of maize plants brought out silk. Flag leaf height (cm): It was determined by measuring eight maize plants from the base of the plant to the flag leaf per plot. The average was calculated and recorded per plot.
Plant height (cm): It was determined by measuring eight plants from the base of the plants to the tassel branch. The average was calculated and recorded per plot. Ear height (cm): It was determined by measuring eight maize plants from the base of the plants to the node bearing the upper ear. The average was calculated and recorded per plot.

Plant aspect: It was recorded on a scale of 1-5 based on overall plant heights, plants uniformity, plant reaction to diseases, insect and lodging per plot. 1 rate means excellent maize plant performance and 5 rate means poor performance of maize plants. Grain yield (kg/ ha): It was calculated and recorded after determining the field weight and moisture content of maize per plot. A shelling percentage of 80 % was assumed and grain yield was adjusted to 15 % moisture content.

Data analysis: Data generated was subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS) version 9.3. Data by count was transformed using logarithm method. This improves the quality of the data, prepares it for analysis and makes it reliable to compare. Significance means were separated using Tukey's Honestly Significant Difference at 5% probability level.

Results and Discussion

As shown in Table 1**,** the pre-planting physico-Findings from this study in Table 2 revealed that location affected the flowering traits (days to silking and anthesis-silking interval), vegetative traits and grain yield. This is in accordance with Silva *et al*. (2022) who reported that location had significant effect on days to anthesis, anthesis-silking interval and grain yield of maize. Days to 50 % silking is earlier in Ikole-Ekiti than in Ikere-Ekiti, also vegetative traits had better performance in Ikole-Ekiti than Ikere-Ekiti, except for plant aspect and days to anthesis (Table 3). Maize produced higher grain yield in Ikole-Ekiti than in Ikere-Ekiti. Lesser grain yield production in Ikere-Ekiti may be due to low nitrogen nutrient in soil. According to Leghari *et al.* (2016), nitrogen deficiency in the soil could be as a result of erosion or leaching, also Fujisao *et al*. (2020) reported that low nitrogen in soil could be as a result of continuous cropping which consequently reduce the grain yield of maize. Sussy *et al.* (2019) also reported that chlorophyll values, maize height, depth to compact layer of soils as consistent factors affecting yield of maize in different locations.

The significant differences in the vegetative traits and grain yield of low nitrogen tolerant maize varieties in the two agro-ecologies are in agreement with the findings of Bello *et al.* (2012) who reported that variety had significant effect on vegetative traits due to genotypic differences among varieties which resulted to variation in plants height, flag leaf height, ear height, leaf length and biomass of maize.

The earliest days to 50 % anthesis across the locations was obtained from *TZEE-W Pop HDT C_3 STR C_5* which do not differ significantly from *TZEE-W Pop STR C_5* and the highest was gotten from *2016 TZEE-W Syn Pop DT STR F_2.* Most of the maize varieties do not differ significantly for days to silking except *2016 TZEE-W Syn Pop DT STR F_2* which had the highest days to 50 % silking. *2017 TZEE-W HDT STR* showed the highest flag leaf height, and the least was obtained from *TZEE-W Pop HDT C_3 STR C_5.* The highest plant height and ear height across the two locations were obtained from *2017 TZEE-W HDT STR* (206.21 cm and 78.75 cm respectively). Furthermore, the least plant height and ear height were obtained from *2016 TZEE-W Syn Pop DT STR F_2* (193.32 cm) and *TZEE-W Pop STR C_5* (69.83 cm) respectively (Table 4). *TZEE-W Pop HDT C_3 STR C_5* (1343.24 kg/ha) produced the highest grain yield and minimum grain yield production was obtained from *2016 TZEE-W Syn Pop DT STR F_2* (945.77 kg/ha) across the two locations (Table 4). Variety, *TZEE-W Pop HDT C_3 STR C_5* produced the highest grain yield among the varieties in both locations. This could be due to higher photosynthetic accumulation (assimilates) in *TZEE-W Pop HDT C_3 STR C_5* which result in high dry matter accumulation and increases in grain yield (Piao *et al*., 2016).

According to Jat *et al*, (2013) nitrogen is the most essential nutrient responsible for physiological function of maize resulting in growth and development. Application of nitrogen fertilizer significantly increases the growth indices of maize (Abubakar *et al*., 2019). The application of 60 kg N/ha, the highest level applied produced the best performance of flowering traits in the two locations. It reduced days to 50 % anthesis and days to 50 % silking across the locations than other nitrogen levels. A similar report has shown that high nitrogen level reduces days to 50 % anthesis and days to 50 % silking than low nitrogen level due to enhanced growth rate of maize (Molla *et al*., 2014). Based on the result of this study, high nitrogen level (60 kg N/ha) reduced days to 50 % anthesis and days to 50 % silking (Table 5). Ibraheem and Abdel-Moneam (2015), reported that earliness to flowering under high nitrogen application may be attributed induction of early and rapid growth of plant. Also, application of 60 kg N/ha produced tallest plant (202.42 cm) of low nitrogen tolerant maize across the location compared to other nitrogen levels (Table 5). These findings corroborated the report of Chen *et al*. (2015), he stated that high levels of nitrogen gave superior plant height compared to other two levels. This is because high soil nitrogen increases the rate of cell division, cell elongation and chlorophyll content of plant increasing photosynthetic rate and extension plant leaf which enhance the growth of maize plant (Gao *et al*., 2020). Iqba *et al*. (2016) reported that increase in vegetative traits may result in increased mutual shading and plant height.

The application of 60 kg N/ha reduced the production of grain yield (1004.75 kg/ha) across the two locations (Table 5). However, application of 30 kg N/ha to soil in Ikole-Ekiti and Ikere-Ekiti improved grain yield production of maize than other levels, 0 and 60 kg N/ha used for the study. This finding is similar to the report of Haegele *et al*. (2013) that high nitrogen level reduced grain yield of maize as a result of decrease in nitrogen use efficiency. Similar reports were made by Gheith *et al*. (2022) who stated that increasing nitrogen level reduced the nitrogen use efficiency of maize. Low nitrogen rate enhances nitrogen use efficiency which result to increase in grain production. Efficient use of nitrogen fertilizer potentially enhances agricultural productivity (Halvorson *et al.*, 2016).

Conclusion

Low nitrogen tolerant maize varieties performed better in Ikole-Ekiti. Among the selected maize varieties, *TZEE-W Pop HDT C_3 STR C_5* performed best in the two locations. Based on the above facts, *TZEE-W Pop HDT C_3 STR C_5* is recommended for higher agronomic traits (flag leaf height, plant height and ear height) and grain yield in the two locations.

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Table 1: Analysis of soil properties and nutrients of the two locations

Soil properties	Location	
	Ikole	Ikere
Ca (cmol/Kg)	4.32	2.83
Mg (cmol/Kg)	1.1	0.63
K (cmol/Kg)	0.28	0.24
Na (cmol/Kg)	0.21	0.06
P (cmol/Kg)	3.23	7.03
N (%)	0.198	0.08
pH	6.03	6.08
OM (%)	3.569	2.32
Silt (%)	8.4	15.39
Clay (%)	9.7	14.21
Sand (%)	81.9	70.4

Table 2: Mean squares for the various sources of variation for flowering, vegetative traits and grain yield

		Flowering Traits			Vegetative Traits				Grain yield
Source of Variance	DF	DA	DS	ASI	FL	PHT	EHT	PASP	GY
Replication	2	0.181	0.431	0.889	37.512	25.603	2.672	30.681	12167.2
Location (L)	1	0.347	68.056***	12.5***	2956.81***	4688.99***	3087.15***	213.556*	4153358.00***
Error (a)	2	1.347	1.847	0.167	26.888	175.121	65.936	38.597	22042.1
Nitrogen Level (NL)	2	17.056***	19.847***	0.51	134.081**	157.46*	148.960*	67.931	315559.00***
L × NL	2	3.722	27.181***	0.375	130.706**	347.279**	96.065	31.847	184384.00***
Error (b)	8	3.118	4.889	0.882	38.514	125.717	78.403	32.972	52553.7
Varieties	3	48.273***	24.148***	1.593*	89.045*	601.882***	245.707***	51.778	481927.00***
L × Varieties	3	11.199***	2.426	0.537	397.704***	569.61***	164.895**	70.889	97466.40**
NL ×Varieties	6	9.982***	26.829***	0.357	165.232***	339.793***	34.481	54.764	155607.00***
L × NL ×Varieties	6	8.019***	17.607***	1.023	259.939***	255.758***	327.820***	48.569	56606.40*
Error (c)	36	1.26	1.991	0.468	25.412	48.534	32.737	45.25	18390.9
Mean		57.681	60.944	2.889	153.992	200.439	74.628	5.278	1130.35
CV (%)		1.946	2.315	23.67	3.274	3.476	7.667	127.455	11.997

*, **, ***: p≤ 0.05, 0.01, 0.001, respectively; DA: Days to anthesis, DS: Days to silking, ASI: Anthesis-silking interval, FL: Flag leaf height, PHT: Plant height, EHT: Ear height, PASP: Plant aspect, GY: Grain yield

Table 3: Performances of flowering, vegetative traits and the grain yield of nitrogen tolerant maize varieties in the two different agro-ecologies

Locations	Flowering traits			Vegetative traits				Grain yield
	DA (days)	DS (days)	ASI (days)	FL (cm)	PHT (cm)	EHT (cm)	PASP	GY (kg/ha)
Ikole-Ekiti	57.75a	59.97b	2.47b	160.40a	208.50a	81.18a	3.56b	1370.53a
Ikere-Ekiti	57.61a	61.92a	3.31a	147.58b	192.36b	68.08b	7.00a	890.17b

DA: Days to 50 % anthesis, DS: Days to 50 % silking, ASI: Anthesis-silking interval, FL: Flag leaf, PHT: Plant height, EHT: Ear height, PASP: Plant aspect, GY: Grain yield.

Means with the same alphabets are not significantly different from each other

Table 4: Performances of nitrogen tolerant maize varieties for the flowering, vegetative triats and grain yield

Varieties	Flowering Traits			Vegetative Traits				Grain yield
	DA (days)	DS (days)	ASI (days)	FL (cm)	PHT (cm)	EHT (cm)	PASP	GY (kg/ha)
TZEE-WPopSTRC$_5$	56.89c	60.06b	3.06a	153.13ab	198.33bc	69.83b	4.00a	1099.92b
TZEE-WPopHDTC$_3$STRC$_5$	55.94c	60.28b	2.44a	152.17b	203.89ab	74.05ab	4.67a	1343.24a
2017TZEE-WHDTSTR	58.17b	60.83b	3.00a	157.23a	206.21a	78.57a	4.67a	1132.48b
2016TZEE-WSynPopDTSTRF$_2$	59.72a	62.61a	3.06a	153.45ab	193.32c	76.06a	7.78a	945.77c

DA: Days to 50 % anthesis, DS: Days to 50 % silking, ASI: Anthesis-silking interval, FL: Flag leaf, PHT: Plant height, EHT: Ear height, PASP: Plant aspect and GY: Grain yield . Means with the same alphabets are not significantly different from each other

Table 5: Effect of the different nitrogen levels on the performance of flowering, vegetative traits and grain yield of maize across the two different agro-ecologies

	Flowering Traits			Vegetative Traits				Grain Yield
N Level	DA (days)	DS (days)	ASI (days)	FL (cm)	PHT (cm)	EHT (cm)	PASP	GY (kg/ha)
0 kg N/ha	58.21a	61.13a	2.96a	153.51a	197.55b	75.27a	4.13b	1156.88a
30 kg N/ha	58.13a	61.75a	2.71b	151.90b	201.35a	76.74a	7.21a	1229.43a
60 kg N/ha	56.71b	59.96b	3.00a	153.51a	202.42a	71.88b	4.50b	1004.75b
Mean	57.68	60.95	2.89	152.97	200.44	74.63	5.28	1130.35
% change_30 kg N/ha	0.14	-1.01	9.23	-1.05	1.89	1.92	42.72	5.9
% change_60 kg N/ha	2.65	1.95	-1.35	0	2.41	-4.72	8.22	-15.14

DA: Days to 50 % anthesis, DS: Days to 50 % silking, ASI: Anthesis-silking interval, FL: Flag leaf, PHT: Plant height, EHT: Ear height, PASP: Plant aspect, GY: Grain yield.

Means with the same alphabets are not significantly different from each other