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Research Article

Physiological Evaluations of Maize Hybrids under Low Nitrogen

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A field experiment was conducted during 2014 and 2016 rainy season at Tudun Wada, Kano and Shika, Zaria in the Northern Guinea Savanna of Nigeria in order to study the physiological responses of maize hybrids under low nitrogen. The experiment consisted of two nitrogen levels 0 and 120 N kg ha^{-1} as main plot and 8 drought-tolerant maize hybrids and 2 controls as subplot laid out in a randomized split plot design and replicated three times. Physiological parameters of hybrids were significantly affected by low nitrogen at both locations. Interaction between hybrids and nitrogen was significantly affected at both locations. Based on these results, application of nitrogen significantly increased the physiological growth indices of maize hybrids. The extent of increment in physiological reactions was additionally higher in Zaria in view of higher soil natural carbon and nitrogen and higher precipitation was better dispersed at this area. However recent hybrids were more tolerant to nitrogen stress and out-yielded the older hybrids. Therefore the recently released hybrids were more adapted to abiotic stresses.

1. Introduction

Maize is a major important cereal crop being cultivated in the savanna zones of Nigeria. It has been in the diet of Nigerians for centuries. It started as a subsistence crop and has gradually become more important crop. Maize thrives best in a warm climate and is now grown in most of the countries that have suitable climatic conditions [1]. Maize is an important crop for security, serving as cash and food crop and recently replacing some crops, such as sorghum in Nigeria, as the most consumed cereal. It is consumed as a vegetable although it is a grain crop [2]. Maize is the most widely grown staple crop in Africa; more than 300 million Africans depend on it as their main food source. Improving maize grain yield is a substantial challenge given the reliance on maize for food, feed, fiber, and fuel [3]. The moist savannas of West Africa have great potential for maize production. Higher radiation levels, lower night temperatures, and reduced incidence of diseases and insect pests increase yield potential in comparison with the traditional area (forest zone) for maize cultivation [4]. Recently, researchers have linked maize grain yield to both high nitrogen uptake and high ability to utilize nitrogen accumulated in the plant in grain production. Nitrogen is the most important element required for plant growth and development. It is a key component in the manufacture of tissues and plays a major role in photosynthetic activity and crop yield [5].

Nitrogen being the most yield constraining supplement, its pressure diminishes grain yield by deferring plant development and improvement. Normally for ideal yield generation nitrogen fertilization has by and large been resolved from field experimentation keeping distinctive rates of nitrogen compost application [3]. Henceforth, use of nitrogen has been outstanding among other methods for supplying nitrogen to convene this high demand. At low nitrogen supply, crop growth rate slows down causing reproductive structures to decline, as a result lower physiological components and maize grain yield and its components are achieved. Similarly the deficiency of nitrogen is evident in the reduction of light interception by decreasing leaf area index, which results in lower grain yield [6]. A deeper understanding of the physiological determinants of maize endurance to the applied nitrogen may play a pivotal role to accomplish greater yield plateau by revealing ways to achieve a better resource use and capture in the next decades. The study was therefore conducted to determine the physiological responses of maize-hybrids under low nitrogen.

2. Materials and Methods

The experiment was conducted in two locations at Tudun Wada, Kano (11°11′N, 8°24′E) and Shika, Zaria (11°11′N and 7°38′E) in the Northern Guinea Savanna of Nigeria. Ten recently developed maize hybrids were evaluated at two nitrogen levels 0 and 120 kg N ha^{-1}. Eight hybrids were (M0826-7, M0926-8, M1026-10, M1026-13, M1124-4, M1124-10, M1227-12, and M1227-14) and two widely cultivated maize hybrids (Oba-98 and Oba super-1). In both years, the trials were laid out in a split plot design with three replications. Two nitrogen levels 0 and 120 kg N ha^{-1} were main plots, whereas the ten hybrids were the subplots within each main plot.

Field data were collected from the two middle rows of each plot leaving the outside rows and a distance of 25 cm at the ends of each middle row to serve as borders. Each plot size measured 3 m × 5 m (15 m^2) consisting of 4 rows of 0.75 m apart and 5 m in length, while the net plot size measured 1.5 m × 4.5 m (6.75 m^2). Alley way of 0.75 m between plots and 2 m between replications giving a total area of 1848.75 m^2 per replication and 5981.25 m^2 for the gross experimental area. The land was ploughed and ridged with work bulls mounted with plough. The ridges were made 0.75 m apart and the plots were then laid out as per the number of treatment. Two seeds were planted per holes at a spacing of 25 cm intraraw and thinned to 1 plant per stand. At one week after planting (WAP), Phosphorus and potassium were applied to low nitrogen treatment plots using triple super phosphate (TSP) and muriate of potash (MOP) fertilizers at the rate of 60 kg ha^{-1}, respectively. NPK 15:15:15 was used to supply 60 kg ha^{-1} of N, P, and K at one week after planting for the optimal nitrogen application plots and was top dressed with urea at the rate of 60 kg N ha^{-1} at 5 WAP. After planting, the area was sprayed with preemergence herbicide Gramoxone (1:1-dimethyl-4, 4-bipyridinium dichloride, manufactured by Syngenta Crop protection AG, Switzerland) at the rate of 276 g a.i/liter and 2 liters/ha. Weeding was done at 3 WAP, using a hoe. At 6 WAP, weeding was done by hand pulling method. Pests and diseases attacks were treated using appropriate agrochemicals at the recommended rates. Harvesting was carried out when the cob reached maturity, from the net plot i.e., the two inner most middle rows in the plots. Soil samples from all the locations (Shika, Zaria, and Tudun Wada) were collected at 0-15 cm and 15 -30 cm depths prior to nitrogen application/planting and these were analyzed for physicochemical properties; texture, available P, total N, pH, organic carbon, and exchangeable bases. Data on rainfall was utilized in the two locations for the purpose of this study. This was determined using Weather Stations device (2000 Series, Spectrum Technologies, USA). Data was collected from the two middle rows and a distance of two stands at the ends of each middle row was allowed to serve as borders. Observations were made and data was collected for growth and physiological parameters.

Data was collected on the following parameters.

Plant Height. At maturity, five plants were selected randomly from each plot. Their plant height was measured in meters from the soil surface to the first tassel branch with the help of a meter rule and the average plant height was recorded.

Chlorophyll Content. Chlorophyll content was estimated using Minolta chlorophyll meter (SPAD 502, Illinois, USA). Soil-Plant-Analysis-Development (SPAD) readings were taken at two-thirds of the distance from the leaf tip (without the midrib) towards the stem of the ear leaf and leaf under ear (after silking). Five leaves were measured at random in the plot and a mean SPAD value was calculated and recorded for each plot.

Intercepted Photosynthetically Active Radiation (IPAR) and Leaf Area Index (LAI). Nondestructive IPAR and LAI were measured simultaneously at the full maize tasselling stages using AccuPAR model LP-80 PAR/LAI Ceptometer (Decagon Devices, Inc. Pullman, USA). Ceptometer measurements of incident light above and below the canopies were used to estimate IPAR. Five PAR measurements above and below the maize canopy were taken from each plot and the displayed average was recorded. The displayed LAI for each plot was also recorded. The sensor was placed diagonally across the two inner rows at ground level so that the ends of the sensor coincide with the line of the plants in each row. Observations were taking under cloud free conditions between 12:00 noon and 14:00 hours.

In each plot, the IPAR was calculated as

$$\text{IPAR} = \left[1.0 - \left(\frac{\text{PARb}}{\text{PARa}}\right)\right] \quad (1)$$

where
IPAR = intercepted PAR,
PARa = PAR μmol m^{-2} s^{-1} measured above maize canopy,
PARb = PAR μmol m^{-2} s^{-1} measured below maize canopy.

3. Data Analysis

The data thus obtained were subjected to the analysis of variance technique by using GenSTAT computer software and means were separated by $LSD_{5\%}$ test.

4. Results and Discussion

The two middle rows were considered as net plot and used for data collection.

Plant Height (cm). As shown in Table 1, the plant height of maize as affected by nitrogen, maize hybrids and their interaction, hybrids grown in 2014 showed significantly taller plants when compared with those grown in 2016 at Zaria but not significantly different at Tudun Wada. Nitrogen application was also observed to significantly affect plant height of maize. At Zaria, nitrogen applied at 120 kg N ha^{-1}

TABLE 1: Effect of nitrogen on plant height chlorophyll content, leaf area index, and intercepted photosynthetically active radiation (PAR) on maize-hybrids in 2014 and 2016 rainy season at Tudun and Zaria combined.

	Tudun Wada				Zaria			
Treatments Year	Plant height (cm)	Chlorophyll content (SPAD)	LAI	IPAR (μmol $m^{-2}s^{-2}$)	Plant height (cm)	Chlorophyll content (SPAD)	LAI	IPAR (μmol $m^{-2}s^{-2}$)
2014	182.90	35.88	1.35	0.25^{b}	189.00^{b}	35.59^{b}	2.48^{a}	0.48^{b}
2016	176.70	36.28	1.32	2.32^{a}	175.00^{a}	40.45^{a}	2.32^{b}	2.24^{a}
SED	6.081	0.796	0.899	0.083	4.765	0.318	0.182	0.055
Nitrogen (kg N ha^{-1})								
0	177.50	33.54^{b}	1.29^{b}	0.94^{b}	126.00^{b}	29.15^{b}	1.89^{b}	1.16^{b}
120	182.20	38.62^{a}	2.31^{a}	1.64^{a}	178.00^{a}	46.89^{a}	2.91^{a}	1.56^{a}
SED	4.313	0.593	0.062	0.091	1.541	16.034	0.121	0.082
Hybrid								
M0826-7	172.90^{d}	33.97	0.42	1.24^{abc}	184.00^{cd}	41.23	2.44	1.40
M0926-8	180.70^{a-d}	35.28	0.49	1.32^{ab}	174.00^{ab}	37.94	2.46	1.55
M1026-10	174.40^{d}	38.61	0.47	1.30^{ab}	190.00^{abc}	37.78	2.53	1.42
M1026-13	189.30^{a}	38.65	0.47	1.21^{bc}	187.00^{a}	39.48	2.40	1.63
M1124-10	184.40^{abc}	38.68	0.47	1.43^{a}	186.00^{abc}	39.97	2.35	1.15
M1124-4	176.10^{cd}	37.78	0.47	1.35^{ab}	185.00^{d}	37.11	2.31	1.44
M1227-12	186.50^{ab}	34.77	0.49	1.08^{c}	183.00^{bcd}	37.06	2.51	1.21
M1227-14	176.20^{cd}	36.75	0.52	1.38^{a}	181.00^{bcd}	39.16	2.55	1.34
Oba – 98	180.10^{a-d}	33.74	0.48	1.22^{bc}	160.00^{a-d}	34.97	2.47	1.26
Oba – Super -1	177.40^{bcd}	32.58	0.52	1.34^{ab}	161.00^{abc}	35.49	2.25	1.24
SED	6.659	3.283	0.083	0.097	7.392	2.194	0.152	0.216
Interaction								
Y * N	NS	NS	*	*	*	NS	NS	*
Y * H	*	NS	NS	NS	NS	NS	NS	NS
N * H	NS	NS	NS	NS	NS	NS	NS	NS
Y *N* H	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within columns are not significantly different using Fisher's protected LSD.
NS = not significant at 5% level of confidence. SED = standard error of a difference. Y = year. P = population. H = hybrids.

Table 2: Interaction between year and nitrogen on photosynthetic active radiation (par) and leaf area index at Tudun Wada and photosynthetic active radiation (par) and plant height at Zaria of maize-hybrids in 2014 and 2016.

Treatments	*Tudun Wada*				*Zaria*			
Year	*Nitrogen (Kg N ha^{-1})*							
	0	120	0	120	0	120	0	120
	IPAR		*Leaf area index*		*IPAR*		*Plant height*	
2014	0.23^{c}	0.28^{c}	2.19^{b}	2.77^{a}	0.38^{c}	0.59^{c}	82.80^{c}	176.30^{ab}
2016	1.59^{b}	3.05^{a}	1.59^{b}	3.05^{a}	1.74^{b}	2.75^{a}	169.3^{b}	180.80^{a}
SED	0.083		0.271		0.055		4.765	

Means followed by the same letter(s) within rows and columns are not significantly different using DMRT.
SED = standard error of a difference.

produced taller plants (178.0 cm) than the control (126.0) but not significantly different at Tudun Wada. Maize hybrids also significantly differ in their plant height. Hybrid M1026-13 produced significantly taller plants (189.30) than most of the hybrids but was similar with hybrids M0926-8, M1124-10, M1227-12, and Oba-98 at Tudun Wada. Looking at Zaria, hybrid M1026-10 produced significantly taller plants (190.0) while shortest plants were produced with hybrids Oba-98 and Oba super-1 (160.0, 161.0), respectively. The significant increase in plant height with application of nitrogen at 120 kg N ha^{-1} might be due to increase level of nitrogen as it increases cell division, cell elongation, and nuclear formation. Similar to [7, 8], [9] reported that the application of higher dose of nitrogen produced maximum emergence in maize and also increased plant elongation and yield. The interaction between nitrogen and maize hybrids was not significant at Tudun Wada. Significant interaction between year and nitrogen was observed at Zaria.

Table 2 presents the interaction between year and nitrogen on plant height of maize. Nitrogen applied at 120 kg N ha^{-1} produced significantly taller plants than the control in all the years. Data on Table 2 also shows the interaction between year and hybrids on plant height of maize at Tudun Wada. Hybrid M1026-13 produced significantly taller plants than other hybrids but at par with hybrids M1124-10 and M1227-12 in 2014, and in 2016 it was at par with M1124-10, M1124-4, M1124-10, and M1227-12.

Chlorophyll Content (SPAD). As can be seen from Table 1, the effect of nitrogen on chlorophyll content of maize and their interaction, SPAD meter reading of chlorophyll content was higher for hybrids grown in 2016 than that of 2014 (35.59) at Zaria. Differences between years were not significant at Tudun Wada. At both locations, application of N at 120 kg ha^{-1} showed significantly higher chlorophyll content than the control. Chlorophyll content did not significantly differ among maize hybrids at both locations. The significant increase in chlorophyll content with application of nitrogen at 120 kg N ha^{-1} is attributed to enhanced availability of nitrogen fertilizer which led to the increased interception of solar radiation by the canopy and also revealed that nitrogen is a major component of chlorophyll essential for plant life. Chlorophyll content was higher for the high nitrogen treatments [10]. Reference [11] also reported that, with an adequate supply of nitrogen, plants maintain their chlorophyll content for a long time. Hybrids x nitrogen interaction was not significant for chlorophyll content at both locations.

Leaf Area Index. Leaf area index of maize as affected by nitrogen, maize hybrids, and their interactions is presented in Table 1. Leaf area index was significantly higher in 2014 than in 2016 at Zaria. Differences between years were not significant at Tudun Wada. Application of nitrogen at 120 kg N ha^{-1} produced significantly higher leaf area index than the control at both locations. Leaf area index did not significantly differ among maize hybrids at both locations. The increase in LAI with increasing nitrogen application indicates the positive effect of nitrogen on the growth of the meristem and the appearance and development of leaves. Higher LAI allows hybrids to intercept more light and efficient photosynthetic system, which played vital role in the development of lengthy cobs. Increase in LAI with increasing nitrogen fertilizer was reported by [12]. Reference [13] reported that increasing nitrogen fertilizer significantly increases plant height. The increase in plant height in response to application of nitrogen fertilizer is probably due to availability of nitrogen, which enhanced more leaf area resulting in higher photo assimilates and hence more dry matter accumulation. Year x nitrogen interaction was significant for LAI at Tudun Wada but not significantly different at Zaria (Table 2). The highest LAI was with 120 kg N ha^{-1} in 2016 and was at par with 120 kg N ha^{-1} in 2014. The least was with the control in 2016, which was also statistically the same with the control in 2014.

Intercepted Photosynthetically Active Radiation. Data on IPAR of maize as affected by nitrogen, maize hybrids, and their interaction is presented in Table 1. Photosynthetically active radiation was significantly higher in 2016 than in 2014 at both locations. Nitrogen applied at 120 kg N ha^{-1} also had significantly higher PAR (0.94, 1.16) than the control at both locations. Photosynthetically active radiation did not significantly differ among maize hybrids at both locations. The significant increase in PAR with application of nitrogen at 120 kg N ha^{-1} is attributed to enhanced availability of nitrogen fertilizer which led to the functional leaf area and photosynthetic efficiency that increased interception of more solar radiation by the canopy during the growth period. References [14, 15] reported that higher rate of nitrogen helps

Table 3: Physical and chemical properties of soil at Tudun Wada and Zaria during 2014 and 2016 rainy season.

	Tudun Wada		*Zaria*	
Year	2014	2016	2014	2016
Physical properties (g kg^{-1})				
Sand	490	90	450	560
Silt	420	570	190	190
Clay	90	340	360	250
Textural class	Clay loam	Silty clay	Sandy clay loam	Sandy clay loam
Chemical properties				
PH in H_20 1;1	6.60	6.18	5.80	5.54
Organic carbon (mg kg^{-1})	2.40	8.10	7.70	10.19
Total N (mg kg^{-1})	0.36	0.070	0.59	0.109
Available P (mg kg^{-1})	3.70	6.15	10.45	16.11
Exchangeable bases (cmol kg^{-1})				
Ca^{++}	2.86	0.15	4.78	0.57
K^{+}	0.03	0.03	0.03	0.06
Na^{++}	0.11	0.56	0.13	0.53
Mg^{++}	0.84	0.88	1.00	1.90
ECEC	3.88	1.62	3.29	3.07

Key. ECEC: effective cation exchange capacity.

maintain functional leaf area and photosynthetic efficiency during the growth period, because of better utilization of solar radiation which favored photosynthetic capacity [16]. This result is also supported by [17, 18] who concluded that main effect of nitrogen fertilizer was to increase the rate of leaf expansion. Low nitrogen reduces crop photosynthesis by reducing leaf area development and leaf photosynthesis rate [10]. Significant interaction was observed between year and nitrogen on PAR (Table 2). At Tudun Wada, when 120 kg N ha^{-1} was applied in 2016 PAR was found to be higher than all other treatment combinations at both locations.

5. Soil Analysis of the Experimental Sites

Table 3 shows the result of soil analysis at the experimental sites of nitrogen trials. The soil at Tudun Wada in 2014 and 2016 was clay loam and silty clay in texture slightly acidic with pH range of 6.60 and 6.18. The soil nutrient status was 2.40 and 8.10 mg kg^{-1} organic carbon, 0.36 and 0.070 mg kg^{-1} total nitrogen, and 3.70 and 6.15 mg kg^{-1} available phosphorus. Exchangeable bases were 2.86 and 0.15 cmol kg^{-1} Ca, 0.03 and 0.03 cmol kg^{-1} potassium, 0.11 and 0.56 cmol kg^{-1} Na, 0.84 and 0.88 cmol kg^{-1} Mg, and 3.88 and 1.62 cmol kg^{-1} ECEC. At Zaria, in 2014 and 2016 the soil was sandy clay loam in texture slightly acidic with pH range of 5.80 and 5.54. The soil nutrient status was 7.70 and 10.19 mg kg^{-1} organic carbon, 0.59 and 0.109 mg kg^{-1} total nitrogen, and 10.45 and 6.11 mg kg^{-1} available phosphorus. Exchangeable bases were 4.78 and 0.57 cmol kg^{-1} Ca, 0.03 and 0.06 cmol kg^{-1} potassium, 0.13 and 0.53 cmol kg^{-1} Na, 1.00 and 1.90 cmol kg^{-1} Mg, and 3.29 and 3.07 cmol kg^{-1} ECEC.

6. Conclusions

The recent hybrids performed better to optimum nitrogen of 120 N kg ha^{-1} than the commercial single cross (Oba super-1) and top cross (Oba-98) hybrids. Physiological parameters of the hybrids were generally higher in Zaria than in Tudun Wada. The extent of increment in physiological reactions was additionally higher in Zaria in view of higher soil natural carbon and nitrogen and higher precipitation was better dispersed at this area.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

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