



Maize-hybrids Response to Low Nitrogen in the Guinea Savannah of Nigeria

Abubakar, A. W., Dangora, I. I., Mohammad, M., Auyo, M. I., Sunday, E.
Department of Biological Sciences,
Federal University Dutse, Jigawa-Nigeria

ABSTRACT

Many crops are planted as hybrids to increase yield over open-pollinated varieties, especially maize. Maize is the most consumed cereal crop in the Nigerian savannas, with recent development and commercialization of maize-hybrids, limited information is available on their response to low-nitrogen. To unveil this information, 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 effect of low nitrogen on the yield and yield components of recent maize-hybrids. 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 sub-plots laid out in a split-plot design and replicated three times. Yield and yield components of hybrids were significantly affected by low nitrogen at both locations. Interactions among hybrids and nitrogen were significantly affected at both locations. Application of nitrogen significantly increased the grain yield and yield components of maize-hybrids. However recent maize-hybrids were more tolerant to low nitrogen and out-yielded the commercial hybrids.

ARTICLE INFO

Article History
Received: April, 2021
Received in revised form: July, 2021
Accepted: August, 2021
Published online: September, 2021

KEYWORDS

Low nitrogen, maize-hybrids, yield and yield components

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 (Abubakar *et al.*, 2019a). Based on area and production, maize is ranked the third most important cereal crop after wheat and rice (Kling, 1996). 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 (Agbonifo and Olufolaji, 2012).

Nitrogen is the most important element required for plant growth and development. Nitrogen being the most yield limiting nutrient, its stress reduces grain yield by delaying plant growth and development (Abubakar *et al.*, 2017). Sustaining sufficient rates of gain in yields of improved maize varieties in Sub Saharan Africa, where farmers grow the crop on poor soils without possibilities of applying adequate N fertilizer, will require a strong emphasis on improving NUE in the global research agenda. Currently fertilizer application rates are very low but they are increasing in few Sub-Saharan African countries due to targeted fertilizer subsidies.

With the assumption that N rates will increase over the next 10 years, there is need to ensure that new varieties have good N recovery efficiency, which will allow to maintain a relatively high protein level in the grain (Arisede *et al.*, 2020). Similarly nitrogen fertilization and management practices remain significant agronomic practices for maize production to obtain high yield. Usually for optimum crop production nitrogen requirement has generally been determined from field experimentation keeping different rates of nitrogen fertilizer application. Maize starts to take up nitrogen rapidly at the middle vegetative growth period and maximum rate of nitrogen uptake occur near to silking stage (Abubakar *et al.*, 2019b). Hence, application of nitrogen has been one of the best ways of 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 maize grain yield and its components as well as lesser harvest index and leaf area duration 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 (Hammad et al., 2011).

Other researchers have investigated the agronomic responses, reproductive and biochemical responses of the drought tolerant maize-hybrids. A deeper understanding of the physiological determinants of maize endurance to the population 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. This study was conducted to determine the growth and grain yield responses of maize- hybrids under low nitrogen.

MATERIALS AND METHODS

The experiment was conducted in two locations at Samaru Zaria (11° 11' N and 7° 38' E) and Tudun Wada (11° 11' N, 8° 24' 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. The ten 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 the Northern Guinea Savanna. 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.

Each plot size measured 3 m × 5 m (15 m²) consisting of 4 rows of 0.75 m apart and 5 m in length, while the net plot size measured 1.5 m × 5 m (7.5 m²). Alley way of 0.75 m between plots and 2 m between replications giving a total area of 1848.75 m² per replication and 5981.25 m² 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. Four seeds were planted per holes and thinned to 2 plants per stand. 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 pre-emergence 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 WAS, using a hoe. At 6 WAS, 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 physico-chemical 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, and 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 grain yield and yield parameters. Data were collected on the following parameters:

Ear Height (cm)

At maturity, five plants were selected randomly from each plot. Their height was measured from the soil surface to the tip of ear with the help of a meter rule and the average ear height was calculated and recorded.

Grain Weight

The grain weight was determined by weighing grains from each net plot and the average recorded.

Number of Ears

The cobs in each quadrat were counted before threshing and expressed to number of ears m⁻².

Number of Grains

The grains in each quadrat were counted and expressed to number of grains m⁻².



500 Grain Weight

The ears were shelled and weighed after which grain weight was determined from a sample of 500 seeds.

Total dry Matter per Net Plot

At physiological maturity, a quadrat measuring 1.5m x 1.25m was placed across the two middle rows for the measurement of yield components and dry matter. The plants in the quadrat were separated into stems, leaves, husks and cobs and dried to constant weight in an oven at 60°C for 76 h in a force-draft oven (Kamara et al., 2012). The weight of leaves, stem, husks and cobs were expressed in g m⁻² and summed to obtain total dry matter weight g m⁻².

Harvest Index

Harvest index was determined as the ratio of grain weight m⁻² to total dry matter weight m⁻².

Grain Yield per Net Plot

Cobs from all the plants from the two middle rows excluding the quadrat area were harvested, threshed and weighed for grain yield. Plot yield was determined by adding the yields from the quadrat harvest and remaining net plot harvested and expressed in grain yield kg ha⁻¹.

The data thus obtained were subjected to the analysis of variance technique by using GENSTAT computer software and means were separated by LSD test.

RESULTS AND DISCUSSION

Table 1, shows the ear height of maize as affected by nitrogen, maize-hybrids and their interaction. Ear height was significantly higher in 2016 (79.50) than in 2014 (71.18) at Tudun Wada. Differences between years were not significant at Zaria. Nitrogen applied at 120 kg N ha⁻¹ also showed higher ear height than the control at both locations. Maize-hybrids also significantly differ in their ear heights. Hybrids Oba-98 and M1124-4 had the shortest ear height (71.71, 68.62) and all other hybrids showed similar ear height at Tudun Wada. Non-significant effect of nitrogen on ear height among hybrids was observed at Zaria. The significant increase in ear height of maize-hybrids with application of nitrogen at 120 Kg N ha⁻¹ indicated that the

recent hybrids responded better to added nitrogen in the savannas. This is in conformity with the results of Kaur *et al.* (2012) who showed that grain yield is linked to both higher nitrogen uptake and higher ability to utilize nitrogen accumulated in the plant in yield production. Gyenes *et al.* (2002) reported that main ear height rose when the plant density was increased to 65,000 plants/ha. Mohammed *et al.* (2010) also speculated that nitrogen affected final seed yield and some yield components such as number and weight of cobs m⁻² and weight of seeds per cob.

Table 2 shows significant interaction between nitrogen and hybrids on ear height at Tudun Wada. Hybrid M0926-8 with 120 kg N ha⁻¹ had the highest ear height while the least was with hybrid M1227-14 with 0 kg N ha⁻¹.

Table 1, also shows the ear number of maize as affected by nitrogen, maize-hybrids and their interaction. Number of ears was significantly higher in 2014 than that of 2016 at Zaria. Differences between years were not significant at Tudun Wada. Nitrogen applied at 120 kg N ha⁻¹ showed higher number of ears than the control both at Tudun Wada and Zaria. Maize hybrids also significantly differ in their ear number. Hybrid M1026-13 showed significantly higher ear number than all other hybrids except with hybrids M0826-7, Oba-98 and Oba-super-1 at Zaria. While at Tudun Wada, hybrids M1026-10, M1026-13, M1124-10, M1124-4 and M1227-14 were at par but significantly higher than hybrids Oba-98 and Oba super-1. Maximum ear number was recorded with the recent hybrids and minimum with the older hybrids. Jason *et al.* (2013) reported that older hybrids recorded lower number of ears plant ha⁻¹ than the newer hybrids. The interaction among year, nitrogen and maize hybrids was not significant at both locations.

Table 1, further shows the grain weight of maize as affected by nitrogen, maize hybrids and their interaction. Grain weight was significantly higher in 2014 (437.60) than in 2016(346.00) at Zaria. Differences between years were not significant at Tudun Wada. Nitrogen applied at 120 Kg N ha⁻¹ had significantly higher grain weight than the control at both Tudun Wada and Zaria. Maize hybrids also significantly differ in their grain weight. Hybrids M1127-14 showed higher grain weight than most of the hybrids but was similar



with hybrids M1026-13, M1124-10, M1227-12 at Zaria. While at Tudun Wada non-significant effect was observed. The significant increase in grain weight of maize-hybrids with application of nitrogen at 120 Kg N ha⁻¹ indicated that the recent hybrids responded better to added nitrogen in the savannas. Kamara *et al.* (2004) reported similar results: drought-tolerant genotypes performed well under nitrogen deficient conditions.

Interaction between year and nitrogen on grain weight of maize was observed to be significant at Zariabut not significantly different at Tudun Wada (Table 2). In year 2014 and 2016 nitrogen applied at 120 Kg N ha⁻¹ showed significantly higher grain weight when compared with the control.

Finally, Table 1 shows the grain number of maize as affected by nitrogen, maize hybrids and their interaction. Grain number was significantly higher in 2014 (2025.00) than in 2016 (1600.00) at Zaria. Differences between years were not significant at Tudun Wada. Nitrogen applied at 120 Kg N ha⁻¹ showed higher grain weight than the control at both locations.

Maize hybrids also significantly differ in their grain number. Hybrid M1124-10 significantly showed higher number of grains and was at par with all other hybrids except with hybrids M0826-7, M1124-4, Oba-98 and Oba super-1 at Zaria. While at Tudun Wada, hybrids M0926-8, M1026-10, M1026-13 and M1227-12 had significantly higher grain weight than most of the hybrids but significantly higher than hybrids M1124-4, Oba-98 and Oba-super1. The interaction between nitrogen and maize hybrids was not significant at both Tudun Wada and Zaria. Variation in nitrogen availability can affect plant development and grain production in maize.

Table 2 shows the 500grain weight of maize as affected by nitrogen, maize hybrids and their interaction. 500 Grain weight was significantly higher in 2014 (167.10) than in 2016 (118.60) at Zaria. Differences between years were not significant at Tudun Wada. Nitrogen application was also observed to significantly affect the 500grain weight of the maize hybrids. Nitrogen applied at 120 kg N ha⁻¹ had significantly higher 500grain weight than the control at both locations. Maize hybrids did not significantly differ in their 500grain weight at both locations.

The significant increase in 500 grain weight of maize-hybrids with application of nitrogen at 120 kg N ha⁻¹ may be an indication that recent hybrids have a higher ability to uptake nitrogen from the soil or remobilize it from vegetative tissues to grains after silking, delaying leaf senescence, prolonging the filling period and producing heavier grains. This is in line with the results of Hammad *et al.* (2011) who reported that maximum grain yield was achieved with the application of higher dose of nitrogen fertilizer.

The interaction between nitrogen and maize-hybrids was not significant at both locations. However, there was significant interaction observed between year and nitrogen at Tudun Wada (Table 2). In 2014 and 2016; nitrogen applied at 120 kg N ha⁻¹ revealed significantly higher 500grain weight than the control. Under 0 and 120 Kg N ha⁻¹ there was no significant difference between the years.

Total dry matter was significantly higher in 2014 (1193.00) than in 2016 (949.00) at Zaria (Table 2). Differences between years were not significant at Tudun Wada. Nitrogen applied at 120 Kg N ha⁻¹ showed significantly higher total dry matter than the control at both Tudun Wada and Zaria. Maize hybrids significantly differ in their total dry matter. Hybrid M1026-13 showed significantly higher total dry matter and was similar with most of the hybrids but significantly higher than hybrids M0826-7, M114.4 M1227-14, Oba-98 and Oba Super-1 at Tudun Wada. While at Zaria, hybrid M1227-14 had significantly higher total dry matter and was similar with most of the hybrids but significantly higher than hybrids M0926-8, M1124-4, Oba-98 and Oba Super-1 which showed lowest total dry matter. The significant increase in total dry matter of maize-hybrids with application of nitrogen at 120 kg N ha⁻¹ may be an indication that recent hybrids have a higher ability to uptake nitrogen from the soil Hokmalipour and Darbandi, (2011) speculated that total dry matter increased significantly with nitrogen fertilizer application in maize cultivars at all the growth stages of the crop.

Table 2 shows the harvest index of maize as affected by nitrogen, maize hybrids and their interaction. Harvest index was not significantly different in 2014 and in 2016 at both locations. Nitrogen applied at 120 Kg N ha⁻¹ showed significantly higher harvest index



than the control at Tudun Wada but not significantly different at Zaria. Maize hybrids did not significantly differ in their harvest index at both locations.

Interaction between nitrogen and maize hybrids on harvest index was not significant at both locations. However, interaction between year and nitrogen on harvest index of maize was significantly different at Tudun Wada (Table 2). In 2014, nitrogen application was not significantly different. In 2016, however, nitrogen applied at 120 Kg N ha⁻¹ had significantly higher harvest index than the control.

Grain yield was significantly higher in 2014 than in 2016 at both Tudun Wada and Zaria (Table 2). Nitrogen applied at 120 kg N ha⁻¹ showed significantly higher harvest index than the control at both locations. Maize hybrids significantly differ in their grain yield at both locations. Hybrid M1124-10 produced the highest grain yield and was similar with most of the hybrids except with hybrids Oba-98 and Oba super-1 at Tudun Wada. While at Zaria, hybrid M1227-12 and M1227-14 produced the highest grain yield and was similar with most of the hybrids but significantly higher than hybrids M0826-7, M1124-4, Oba-98 and Oba Super-1, which showed lowest grain, yield. The significant increase in grain yield of maize-hybrids with application of nitrogen at 120 kg N ha⁻¹ shows that nitrogen is an important element for plant growth, addition of nitrogenous fertilizers can substantially increase plant yield. Similarly results by Kaur *et al.* (2012) showed that grain yield is a function of cumulative behavior of various yield components such as number of kernel rows per cob, number of kernels per cob and 1000-kernel-weight. Therefore, grain yield increased with increase in yield components. Interaction between year, nitrogen and maize hybrids on grain yield of maize was not significantly different at both locations.

Total rainfall and relative humidity were higher in 2014 than in 2016 at both locations; which affected crop performance. Crop performance was also better at Zaria than at Tudun Wada, probably because of the higher rainfall in Zaria. Hernandez *et al.*, (2014) speculated that stand density varies with the environment. Valero *et al.*, 2005 reported that favourable environmental conditions and adequate availability of

essential elements have a positive influence on growth of crops. This is in conformity with the work of Mkhabela and Pali-Shikulu, (2001) who reported that nitrogen requirement and utilization in maize depends on environments and factors like rainfall, varieties and expected yield.



Table 1: Effect of nitrogen on ear height, ear number, grain number and grain weight of hybrid-maize in 2014/2016 rainy season at Tudun Wada and Zaria Combined.

Treatments	Tudun Wada				Zaria				
	Year	Ear height (cm)	Ear Number	Grain Weight (m ²)	Grain Number (m ²)	Ear height (cm)	Ear Number	Grain Weight (m ²)	Grain Number (m ²)
2014	71.18b	6.00	400.00	1583.00	93.17	6.00a	437.60a	2025.00a	
2016	79.50a	4.00	348.00	1586.00	91.73	5.00b	346.00b	1600.00b	
SED	2.872	0.299	39.597	110.874	2.276	0.124	31.833	129.96	
Nitrogen (kg N ha⁻¹)									
0	67.64b	4.00b	240.00b	1279.00b	89.60b	5.00b	296.80b	1418.00b	
120	83.04a	5.00a	508.00a	1890.00a	95.29a	6.00a	487.00a	2207.00a	
SED	2.406	0.129	59.396	96.732	0.941	0.205	161.68	116.672	
Hybrid									
M0826-7	72.00bc	4.00ab	330.00	1532.00abc	89.41	5.00d	354.20cd	1671.00bcd	
M0926-8	81.97a	5.00ab	385.00	1859.00a	93.85	6.00abc	410.70bc	1987.00abc	
M1026-10	80.55ab	5.00a	395.00	1792.00a	93.37	5.00a-d	385.20bcd	1783.00a-d	
M1026-13	81.72a	5.00a	368.00	1800.00a	91.67	6.00a	417.70abc	1741.00a-d	
M1124-10	74.65abc	5.00a	436.00	1622.00abc	97.52	6.00abc	442.70ab	2087.00a	
M1124-4	68.62c	5.0a	566.00	1368.00bcd	89.31	5.00a-d	336.40cd	1632.00cd	
M1227-12	73.30abc	5.00ab	380.00	1800.00a	94.38	6.00ab	420.20abc	2089.00a	
M1227-14	72.62bc	5.00a	368.00	1747.00ab	92.34	6.00ab	498.50a	2038.00ab	
Oba – 98	71.61c	3.00c	257.00	1053.00d	92.07	5.00bcd	345.00cd	1526.00d	
Oba – Super	76.32abc	4.00bc	258.00	1271.00cd	89.56	5.00cd	309.00d	1573.00d	
-1	4.454	0.412	128.693	203.081	3.097	0.353	49.653	195.585	
SED									
Interaction									
Y * N	NS	NS	*	NS	NS	NS	NS	NS	
Y * H	NS	NS	NS	NS	NS	NS	NS	NS	
Y * N * 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 DMRT; NS=Not significant at 5% level of confidence

Table 2: Effect of nitrogen on 500 grain weight, total dry matter harvest index and grain yield of hybrid-maize in 2014/2016 rainy season at Tudun Wada and Zaria combined.

Treatments	Tudun Wada				Zaria				
	Year	500 Grain Weight (m ²)	Total dry matter (m ²)	Harvest index	Grain Yield (kg ha ⁻¹)	500 Grain Weight (m ²)	Total dry matter (m ²)	Harvest index	Grain Yield (kg ha ⁻¹)
2014	108.40	948.00	0.36	3200.00a	167.10a	1193.00a	0.44	3953.00a	
2016	102.60	877.00	0.34	2892.00b	118.60b	949.00b	0.38	3123.00b	
SED	3.252	109.742	0.022	321.026	5.077	31.254	0.056	142.835	
Nitrogen (kg N ha⁻¹)									
0	100.70b	870.00b	0.33b	1827.00b	73.40b	690.00b	0.36	2678.00b	
120	111.30a	1271.00a	0.38a	4266.00a	102.20a	1135.00a	0.46	4398.00a	
SED	3.012	56.568	0.016	140.572	9.715	41.719	0.086	93.479	
Hybrid									
M0826-7	94.00	849.00bcd	0.36	3010.00ab	104.00	937.00cd	0.38	2916.00d	
M0926-8	93.40	959.00a-d	0.36	3047.00a	103.40	1080.00a-d	0.40	3522.00a-d	
M1026-10	97.60	1031.00ab	0.35	3319.00a	107.60	1101.00abc	0.42	3911.00ab	
M1026-13	102.90	1181.00a	0.36	3239.00a	112.90	1149.00ab	0.36	3798.00ab	



Treatments	Tudun Wada			Zaria				
	500 Grain Weight (m ⁻²)	Total dry matter (m ⁻²)	Harvest index	Grain Yield (kg ha ⁻¹)	500 Grain Weight (m ⁻²)	Total dry matter (m ⁻²)	Harvest index	Grain Yield (kg ha ⁻¹)
M1124-10	128.10	1005.00abc	0.38	3666.00a	105.10	1158.00ab	0.44	3757.00abc
M1124-4	102.50	754.00bcd	0.33	3199.00a	103.50	1006.00bcd	0.69	3259.00bcd
M1227-12	100.60	1005.00abc	0.34	3260.00a	100.60	1155.00ab	0.36	4174.00a
M1227-14	110.70	900.00bcd	0.39	3273.00a	115.70	1214.00a	0.37	4146.00a
Oba – 98	88.70	707.00d	0.36	3210.00c	109.70	908.00d	0.33	3057.00cd
Oba – Super	84.50	733.00cd	0.29	2242.00bc	97.50	998.00bcd	0.34	2846.00d
-1	7.127	139.158	0.028	362.038	7.127	139.158	0.131	362.038
SED		NS						
		NS						
Interaction	*	NS	*	NS	NS	NS	NS	NS
Y * N	NS	NS	NS	NS	NS	NS	NS	NS
Y * H	NS		NS	NS	NS	NS	NS	NS
N * H	NS		NS	NS	NS	NS	NS	NS
Y * N * H								

Means followed by the same letter(s) within columns are not significantly different using DMRT; NS=Not significant at 5% level of confidence

CONCLUSIONS

Results showed nitrogen fertilizer levels, hybrids and their interaction significantly affected the grain yield of maize-hybrids. Maize-hybrids performed better with optimum nitrogen rate of 120 N kg ha⁻¹. Grain yield is a function of integrated genetic makeup of hybrids and the growing conditions. There was consistent grain yield increase with increasing application of nitrogen, most of the recent hybrids selected for combined tolerance performed better under low nitrogen levels conditions than the commercial hybrids. Regardless of the amount of nitrogen applied, the recently released maize-hybrids were more productive since they adapted more to abiotic stress and out-yielded the commercial hybrids. This may be due to genetic characteristics of the new maize-hybrids and high yield potential of the experimental area, which allowed yield increases at high nitrogen application. Improved maize-hybrids might also have some inherent genetic variability that facilitated the resistance to low nitrogen. The results also revealed that the recent maize-hybrids are fertilizer consumers.

Acknowledgments

The authors would like to express their gratitude to the International Institute of Tropical Agriculture Kano-Station (IITA). They also appreciate the guidance of Dr Maharaz Mohammed Nasir, Department of Physics, Federal University Dutse Jigawa and Dr Kabir

Mustapha Umar, Center for Dry Land Agriculture, Bayero University Kano in preparation of the manuscript.

REFERENCES

- Abubakar, A. W. and Manga, A. A. (2017). Effect of Plant Population on the Growth of Hybrid-Maize (*Zea Mays L.*) in The Northern Guinea Savanna of Nigeria, *International Journal of Advances in Chemical Engineering & Biological Sciences*, (IJACEBS) 4(1): 134-141.
- Abubakar, A. A. Manga, A. Y. Kamara, and A. I. Tofa (2019)a. Physiological Evaluations of Maize Hybrids under Low Nitrogen. Hindawi. *Advances in Agriculture*. Volume 2019.
- Abubakar, A. W. Dangora, I. I. Sadiq, S. B. Sunday, E. , Tofa, A. I. (2019)b Phenological Assessment of Maize-Hybrids under low nitrogen levels in parts of Northern Guinea Savanna of Nigeria. *Dutse Journal of Pure and Applied Sciences*. DUJOPAS 5(1a): 68-77.
- Agbonifo, O. C. and Olufolaji, D. B. (2012). A fuzzy expert system for diagnosis and treatment of maize plant diseases. *International Journal of Advanced Research in Computer Science and Software Engineering* Vol 2:1 t. Cienc. Rur. 31:1075-1084.



- Chikasa, Arisede. Mainassara, Zaman-Allah (2020). Low-N stress tolerant maize hybrids have higher fertilizer N recovery efficiency and reduced N-dilution in the grain compared to susceptible hybrids under low N conditions. *Agronomy & Crop Ecology*. 417-426.
- Azam, S. M. Ali, M. Amin, S. Bibi and Arif, M. (2007). Effect of plant population on maize hybrids. *Journal of Agricultural and Biological science* 2(1):13-20.
- Betran, F. J. Beck, D. Banziger, M. Ed meads, G. O. (2003). Secondary Traits in Parental Inbreds and Hybrids under Stress and Non-Stressed Environments in Tropical Maize. *Field Crops Research* 83: 51-65.
- Cathcart R. J., Swanton, C. J., (2003). Nitrogen management will influence threshold values of green fox- tail (*Setaria viridis*) in corn. *Weed Sci* 51: 975-86.
- Gyenes-Hegy, Z. Pok, I. Kizmus, L. (2002). Plant height and height of the main ear in maize (*Zea mays* L.) at different locations and different plant densities. *Acta Agronomica Hungarica* 50(1):75-84.
- Hammad, H. M. Ahmad, A. Wajid, A. Akhter, J. (2011). Maize Response to Time and Rate of Nitrogen Application. *Pakistan Journal of Botany* 43(4): 1935-1942
- Hokmalipour, S. and Darbandi, M. H. (2011). Effects of Nitrogen Fertilizer on chlorophyll content and other leaf indicate in three cultivars of maize (*Zea Mays* L.). *World Applied Sciences Journal* 15(12):1780-1785.
- Kamara, A.Y., Sylvester, V. E. and Menkir, A. (2013). Assessment of Nitrogen and Utilization in Drought Tolerant and Striga Resistant Tropical Maize Varieties *Archives of Agronomy and Soil Science*
- Kaur, A. Bedi, S. Gill, K. G. Kumar, H. (2012). Effect of Nitrogen Fertilizers on Radiation Use Efficiency, Crop Growth and Yield in some Maize Genotypes.
- Kling, J. G. Berner, D. K. Ibikunle. O. A. (1996). Developing Tropical Maize Cultivars with Reduced Striga Emergence and Host Plant Damage Symptoms under Artificial Infestation with Striga Hermonthica. Paper Presented at the Fourth General Workshop on the pan African Control Network, Bamako, Mali, October 28th to November 1st, 1996.
- Mohammed A. Mohammed, J. Khan, N. U. Iqbal, A. (2010). Impact of plant populations and Nitrogen Levels on Maize. *Pakistan Journal of Botany* 42(6):3907-3913.

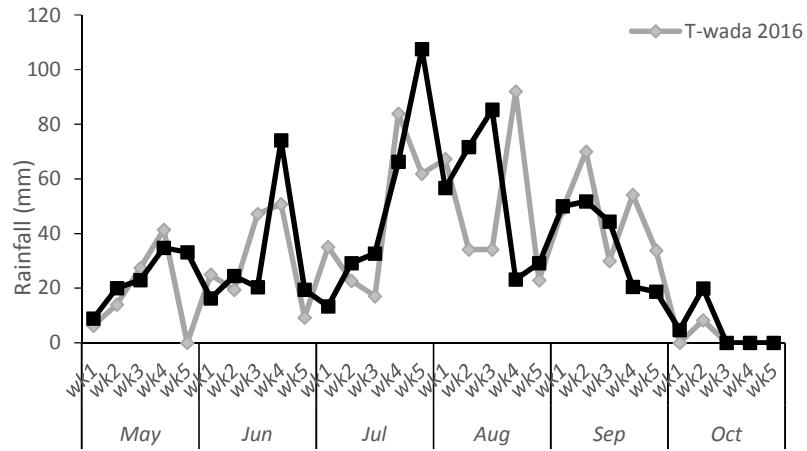


Fig. 1. Weekly rainfall at Tudun Wada during the experimental periods

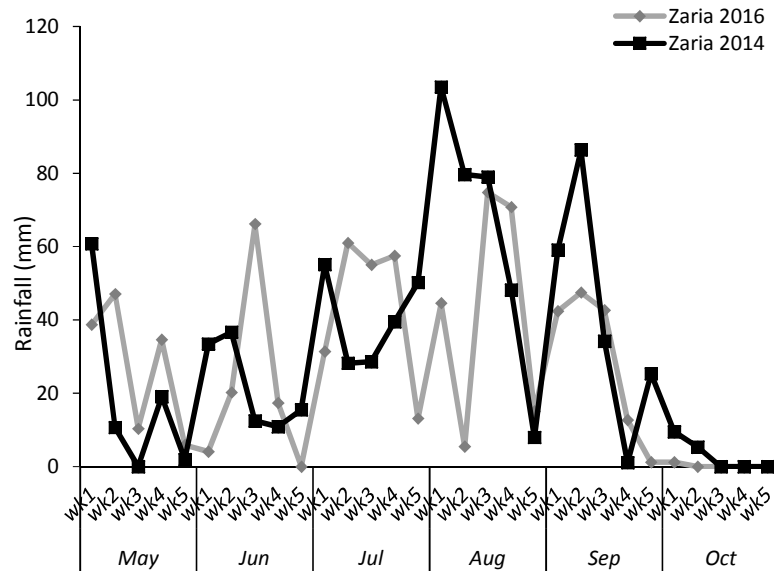


Fig. 2. Weekly rainfall at Samaru Zaria during the experimental