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Phenological Assessment of Maize-Hybrids under low nitrogen levels in parts of Northern Guinea Savanna of Nigeria

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Abstract
A field experiment was conducted during 2014 and 2016 rainy season in Tudun Wada-Kano and Shika-Zaria within the Northern Guinea Savanna of Nigeria in order to study the phenological responses of maize-hybrids under low nitrogen levels. The experiment consisted of two nitrogen levels 0 and 120 N kg ha^{-1} as main plot and 8 recently developed drought–tolerant maize hybrids: M0826-7, M0926-8, M1026-10, M1026-13, M1124-4, M1124-10, M1227-12 and M1227-14 and 2 widely cultivated commercial hybrids as controls (Oba-98 and Oba super-1) as sub-plot laid out in a randomized split-plot design and replicated three times. Interaction between hybrids and nitrogen was significantly affected at both locations. Based on these results, application of nitrogen significantly decreased the phenological growth indices of maize-hybrids. Recent hybrids showed decreased phenology though, they were better adapted to low nitrogen. The magnitude of decrease in phenology was also higher in 2014 in Zaria because rainfall was higher and better distributed. Hence, the recently released maize-hybrids were more adapted to abiotic stress.

Keywords: low nitrogen, growth, abiotic stress, maize-hybrids, phenology

INTRODUCTION
Maize is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America (Kamara *et al.*, 2005). All parts of the crop can be used for food and non-food products. In industrialized countries, maize is largely used as livestock feed and as a raw material for industrial products. Botanically, it is known as Zea mays L. and belongs to family Poaceae (Abubakar *et al.*, 2017). Maize accounts for 30−50% of low-income household expenditures in Eastern and Southern Africa (Agbonifo and Olufolaji, 2012).Based on area and production, maize is ranked the third most important cereal crop after wheat and rice (Kling, 1996).

Maize has been in the diet of Nigerian's for centuries. It started as a subsistence crop and has gradually become more important crop. Maize has now risen to a commercial crop on which many agro-based industries depend on as raw materials (Iken *et al.,* 2004). Maize was

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introduced into Africa in the 1500s and has since become one of Africa's dominant food crops. Like many other regions, it is consumed as a vegetable although it is a grain crop. The grains are rich in vitamins A, C and E, carbohydrates, and essential minerals, and contain 9% protein. They are also rich in dietary fiber and calories, which are a good source of energy (Cathcart and Swanton, 2003).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 (Cathcart and Swanton, 2003).

Nitrogen being the most yield-limiting nutrient, its low level reduces grain yield by delaying plant growth and development. Similarly, nitrogen fertilization and management practices remain significant agronomic practices for maize production to obtain high yield (Imran *et al.,* 2015). Usually for optimum crop production nitrogen requirement has generally been determined from field experimentation keeping different rates of nitrogen fertilizer application hence, application of nitrogen has been one of the best ways of supplying nitrogen to convene this high demand (Kamara *et al*., 2012). Low fertility is reported to be one of the major causes of maize yield loss in the tropics (Sen *et al*., 2013). At low nitrogen supply, crop growth rate slows down causing reproductive structures to decline, as a result lowers 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). The study of phenology is one most important function that determines the crop growth and development of any crop and is essential to acquire knowledge on the physiological response of the crop under different field conditions (Summerfield *et al*.,1991). The phenology of the crop is influenced by parameters like the crop genotype, nutrient, biotic, abiotic and weather parameters. The study of phenological characters would made possible to selection of varieties, time of application of nutrients, irrigation practices and other management practices (Shoban *et al.,* 2014).Maize phenology is a function of genotype, temperature and photoperiod as well as influenced by nitrogen, varieties and moisture (Wallance and Yan, 1998; Hodges, 1991; Kiniry and Bonhemme,1991).

Other researchers have investigated the agronomic responses, reproductive and biochemical responses of the drought-tolerant hybrid. To the best of our knowledge, there are no known public and physiology-focused research publications that have investigated these recently released drought-tolerant hybrids (Abubakar *et al.,* 2017).

In response to these challenges, there is need to conduct further studies that are fundamental to identify the contribution of morphological, physiological, phenological and allometric traits to the putative improvement of modern-hybrids tolerance to high plant population densities. 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 phenological responses of maize-hybrids under low nitrogen levels.

MATERIALS AND METHODS

The experiment was conducted in two locations at Shika-Zaria (11^0 11′ N and 7^0 38′ E) and Tudun Wada-Kano (11^0 11′ N, 8^0 24′ E) in the northern Guinea Savanna in 2014 and 2016 rainy season (Abubakar *et al.,* 2017). Eight recently developed maize-hybrids were evaluated at two nitrogen levels 0 and 120 kg N ha^{-1}. The eight were (M0826-7, M0926-8, M1026-10, M1026-13, M1124-4, M1124-10, M1227-12 and M1227-14) and two widely cultivated maize-hybrids in the Northern Guinea Savanna (Oba-98 and Oba super-1). 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.

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 treated as main plots, whereas the ten hybrids were the subplots within each main plot. 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 × 5 m (7.5 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. Four seeds were planted per holes and thinned to 2 plants 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 pre-emergence herbicide Gramoxone {(1:1-dimethyl-4, 4-bipyrisdinum dichloride) 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.

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 were collected for phenological parameters.

Data were collected based on the following parameters:

Number of days to 50% tasseling: Days to tasseling (anthesis date) was calculated as the number of days from planting to when 50% of the plants shed pollen.

Number of Days to 50% Silking: Days to silking (silking date) was calculated as the number of days from planting to when 50% of the plants extrude silks.

Anthesis-silking interval (ASI): Anthesis-silking interval was calculated as the difference between days to anthesis and days to silking.

Number of Days to 95% Maturity: Number of days from planting to when 95% of the plants in the net plot reached physiological maturity (turn brown) was taken and recorded.

RESULTS:

Days to Flowering: As shown intable 1; the days to flowering of maize as affected by nitrogen, maize hybrids and their interaction. Days to flowering were significantly longer in 2014 (85.00) than in 2016 (61.00) at Tudun Wada,while days to flowering was significantly longer in 2016 (63.00) than that of 2014 (60.00) at Zaria. Nitrogen applied at 0 Kg N ha^{-1} showed delayed flowering (74.00, 63.00) than nitrogen applied at120 Kg N ha^{-1} at both locations. Days to flowering significantly differ among maize hybrids. Hybrid M1026-13 showed delayed flowering and significantly differ from all other hybrids, but was similar to hybrid M0826-7 at Tudun Wada. Hybrid M1026-13 also had delayed flowering but was similar to hybrids M0826-7, M1026-10 and M1227-14.

Interaction between year and hybrids on days to flowering was significantly affected at both locations. At Tudun Wada the highest number of days to flowering was with Obasuper-1 in 2014 while the least was with Oba-98 in 2016 (Table 2). However at Zaria the highest number of days to flowering was with hybrid M1026-13 in 2016 while the least was with hybrid M1124-4 (Table 3).

Days to Silking: Data on table 1 shows the days to silking of maize as affected by nitrogen, maize hybrids and their interaction. Days to silking was significantly longer in 2014 than in 2016 at Tudun Wada. While at Zaria, days to silking was significantly longer in 2016 than in 2014. Nitrogen applied at 0 Kg N ha^{-1} showed delayed silking (78.00, 75.00) than nitrogen applied at 120 Kg N ha^{-1} at both locations. Maize hybrids significantly differ in their days to silking. Hybrid Oba-super-1 took longer days to silking but was at par with hybrid M1026-13 at Tudun Wada. Looking at Zaria, hybrid Oba-super-1 also spent longer days to silking but was similar with hybrids M1026-13, M0826-7 and M1227-14. Excessive silk delay is a predictor of barrenness and the production of fewer kernels per ear. Table 2 and 3 shows the interaction between year and hybrids on days to silking of maize hybrids at Tudun Wada and Zaria. Oba super-1 took longer time to silk but was at par with hybrid M1026-13, which were all significantly higher than the remaining hybrids at Tudun Wada. At Zaria, hybrid Oba-super-1 also took longer time to silk and was statistically similar to hybrids M1026-10, M1026-13, M1124-10, M1124-4, M1227-12 and M1227-14 in 2016 (Table 3).

Anthesis Silking Interval (ASI): Table 1 shows the anthesis-silking interval of maize as affected by nitrogen, maize hybrids and their interaction. ASI was significantly higher in 2016 (4.00) than that of 2014 (3.00) at Tudun Wada. While at Zaria, ASI was significantly higher in 2014 (4.00) than in 2016 (2.00). Nitrogen applied at 120 Kg N ha^{-1} recorded ASI (1.00) that is lower than that of the control at Zaria but was not significantly different at Tudun Wada. Differences among maize-hybrids for ASI was not significant at both locations. Interaction between year and hybrids was significant for ASI at Tudun Wada (Table 2). Hybrids M1026-13 and Oba-98 showed higher ASI in 2014.

Days to Maturity: As can be seen intable 1, the days to maturity of maize as effected by nitrogen, maize hybrids and their interaction. Days to maturity were not significantly different in 2014 and 2016 at both locations. Days to maturity were not significant due to nitrogen application at both Tudun Wada and Zaria. Days to maturity did not significantly differ among maize hybrids at both locations. Non-significant interaction was also observed among nitrogen, maize-hybrids and the year on days to maturity at both Tudun Wada and Zaria.

Table 1: Effect of nitrogen on days to flowering, days to silking, anthesis-silking interval and days to maturity of maize-hybrids in 2014 and 2016 rainy season at Tudun Wada and Zaria Combined

Treatments		**TudunWada**				**Zaria**		
Year	**Days to flowering**	**Days to silking**	**Anthesis Silking interval**	**Days to maturity**	**Days to flowering**	**Days to silking**	**Anthesis Silking interval**	**Days to maturity**
2014	85.00^{a}	89.30^{a}	3.00^{b}	102.00	60.00^{b}	63.00^{b}	3.00^{a}	101.00
2016	61.00^{b}	64.00^{b}	4.00^{a}	104.00	63.00^{a}	65.00^{a}	2.00^{b}	97.00
SED	0.298	0.231	0.173	0.340	0.480	0.270	0.176	1.712
Nitrogen								
(kg N ha^{-1})	74.00^{a}	78.00^{a}	3.00	129.00	63.00^{a}	67.00^{a}	3.00^{a}	102.00
0	72.00^{b}	75.00^{b}	3.00	119.00	60.00^{b}	62.00^{b}	1.00^{b}	98.00
120	0.319	0.534	0.514	4.638	0.298	0.315	0.117	1.579
SED								
Hybrids								
M0826-7	74.00^{ab}	77.00^{bc}	3.00	112.00	65.00^{bc}	65.00^{abc}	0.00	99.00
M0926-8	73.00^{bc}	76.00^{cde}	3.00	119.00	61.00^{cd}	63.00^{de}	2.00	92.00
M1026-10	73.00^{bc}	77.00^{cd}	3.00	114.00	62.00^{bc}	64.00^{bcd}	2.00	101.00
M1026-13	75.00^{a}	78.00^{ab}	3.00	119.00	63.00^{ab}	65.00^{ab}	2.00	101.00
M1124-10	73.00^{bc}	77.00^{cde}	3.00	114.00	61.00^{cd}	64.00^{cde}	2.00	101.00
M1124-4	72.00^{c}	76.00^{de}	3.00	114.00	60.00^{e}	63.00^{e}	3.00	100.00
M1227-12	72.00^{c}	76.00^{e}	3.00	119.00	61.00^{cd}	64.00^{de}	2.00	101.00
M1227-14	73.00^{bc}	76.00^{de}	3.00	119.00	62.00^{bc}	65.00^{a-d}	2.00	101.00
Oba – 98	72.00^{c}	76.00^{cde}	4.00	130.00	60.00^{de}	64.00^{de}	3.00	110.00
Oba – Super	75.00^{a}	79.00^{a}	3.00	103.00	63.00^{cd}	66.00^{a}	3.00	112.00
-1	0.632	0.684	0.514	11.856	0.543	0.667	0.469	3.569
SED								
Interaction	NS	NS	NS	NS	NS	NS	NS	NS
Y * N	*	*	*	NS	*	*	NS	NS
Y * H	NS	NS	NS	NS	NS	NS	NS	NS
N * H	NS	NS	NS	NS	NS	NS	NS	NS
Y *N* H								

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: Comparison between year and interval of maize-hybrids on days to flowering, silking and anthesis-silking during two rainy seasons in Tudun Wada-Kano

	Tudun Wada					
Treatments	**Days to flowering**		**Days to silking**		**Anthesis-silking interval**	
Year Hybrid	**2014**	**2016**	**2014**	**2016**	**2014**	**2016**
M0826-7	87.00[a]	61.00[hi]	89.00[bc]	64.00[hi]	2.00[cd]	3.00[a-d]
M0926-8	84.00[de]	61.00[ghi]	87.00[def]	64.00[hi]	3.00[a-d]	2.00[cd]
M1026-10	85.00[de]	62.00[gh]	89.00[cd]	64.00[hi]	4.00[abc]	2.00[cd]
M1026-13	87.00[bc]	63.00[g]	92.00[ab]	65.00[h]	5.00[a]	2.00[cd]
M1124-10	85.00[cd]	62.00[gh]	89.00[cde]	65.00[h]	3.00[abc]	3.00[cd]
M1124-4	83.00[f]	61.00[ghi]	87.00[fg]	65.00[hi]	3.00[abc]	3.00[a-d]
M1227-12	82.00[f]	62.00[gh]	86.00[g]	65.00[h]	3.00[a-d]	3.00[cd]
M1227-14	84.00[de]	61.00[ghi]	86.00[fg]	65.00[h]	3.00[a-d]	2.00[d]
Oba 98	84.00[de]	60.00[i]	89.00[cd]	63.00[i]	5.00[a]	3.00[cd]
Oba super-1	89.00[a]	61.00[ghi]	93.00[a]	64.00[hi]	3.00[abc]	3.00[bcd]
SED	0.298		0.231		0.173	

Means followed by the same letter(s) within columns are not significantly different using Fisher's protected LSD
SED=standard error of a difference

Table 3: Comparison between year and interval of maize-hybrids on days to floweringand days to silking during two rainy seasons in Shika-Zaria.

	Zaria			
Treatments	**Days to flowering**		**Days to silking**	
Year Hybrid	**2014**	**2016**	**2014**	**2016**
M0826-7	61.00[c-f]	63.00[b-e]	65.00[b-f]	65.00[a-d]
M0926-8	59.00[h]	63.00[ab]	62.00[hij]	65.00[a-f]
M1026-10	60.00[fgh]	64.00[ab]	63.00[d-h]	65.00[abc]
M1026-13	61.00[ef]	65.00[a]	65.00[b-f]	66.00[ab]
M1124-10	59.00[gh]	64.00[ab]	62.00[ghi]	66.00[abc]
M1124-4	57.00[i]	63.00[bc]	60.00[j]	66.00[abc]
M1227-12	59.00[h]	64.00[ab]	61.00[ij]	66.00[abc]
M1227-14	60.00[fg]	63.00[ab]	63.00[e-i]	66.00[ab]
Oba 98	59.00[gh]	61.00[def]	64.00[b-f]	63.00[f-i]
Oba super-1	63.00[ab]	63.00[bcd]	67.00[a]	65.00[a-e]
SED	0.332		0.270	

Means followed by the same letter(s) within columns are not significantly different using Fisher's protected LSD
SED=standard error of a difference

DISCUSSION

The results clearly indicated that, successive increase in fertilizer from 0 to 120 kg N ha^{-1} had marked influences on the phenological parameters of maize. The phenological parameters of the crop were extremely sensitive to the availability of nitrogen during growth period. Maize-hybrids took longer days to flower with nitrogen applied at 0 Kg N ha^{-1}flowering than hybrids with nitrogen applied at120 Kg N ha^{-1} at both locations{Table 1(74.00, 63.00)}. Days to flowering significantly differ among maize-hybrids. The significant reduction in days to flowering of hybrids with application of optimum dose of nitrogen fertilizer (120 kg N ha^{-1}) at both locations indicates the importance of nitrogen uptake prior to flowering. The reason for early phenology with application of higher nitrogen level was also be due to better root development and thus facilitated the plants uptake of more nitrogen and other nutrient. Kaur *et al.* (2012) reported that application of higher dose of nitrogen fertilizer led to a significant reduction in days to anthesis.

Silk delay allowed the recent hybrids to set more kernels per plant, contributing to its grain yield superiority over the older genotypes (Table 1).This is in line with the work of Hammad et al. (2011)who stated that rates of N application significantly influenced the days to silking of maize. Phenological development enhanced (early) with the application of higher nitrogen level (120 kg N ha^{-1}).Kaur *et al.* (2012) and Zaidi *et al.* (2003) concluded similar results; comparison of delay to anthesis and silking days at low nitrogen supply revealed the days to silking were delayed more at reduced nitrogen supply as compared to days to anthesis which leads to an average prolongation of anthesis-silking interval. This is in line with the work of Kamara *et al*. (2012) who reported that severed nitrogen stress increases ASI in maize. Previous studies by Amanullah and Parmar, (2016) also revealed similar results. Responses of agronomic traits such as delay in silk growth (ASI) are typically reactions of maize under drought stress (Bolanos and Edmeads, 1996). The shorter ASI reflects the adaptation to low-nitrogen. Several reports have shown that the shorter ASI under stressful conditions is an indirect index for greater tolerance and biomass partitioning to the developing ear (Table 1).Omoloran *et al.*(2014) also reported decrease in days to anthesis, silking and anthesis-silking interval in recent hybrids. Soltani *et al.* (2013) also concluded that N deficiency delays both vegetative and reproductive and phenological development. Shoban *et al.*, also reported that application of higher nitrogen influenced the vital phenological parameters of the crop in spite of difference in the genotypes and seasons. The higher nitrogen level delayed the vegetative growth period and resulted in late production of tasseling and physiological maturity.

CONCLUSION AND RECOMMENDATION

The findings of this study showed that nitrogen is an integral component of many compounds essential for plant growth processes and many enzymes. Higher phenological responses were observed with low nitrogen. The magnitude of decrease in phenology was also higher in Zaria because rainfall was higher and better distributed at this location. Interaction studies also showed that maize-hybrids responded differently to the optimum nitrogen level (120 kg N ha^{-1}). Therefore, recent hybrids showed better adaptation to abiotic stress. Further research should be conducted to broaden the scope of investigation of the recent drought-tolerant and widely cultivated maize-hybrids using intermediate nitrogen rates of 30 kg N ha^{-1} and 60 kg N ha^{-1}.

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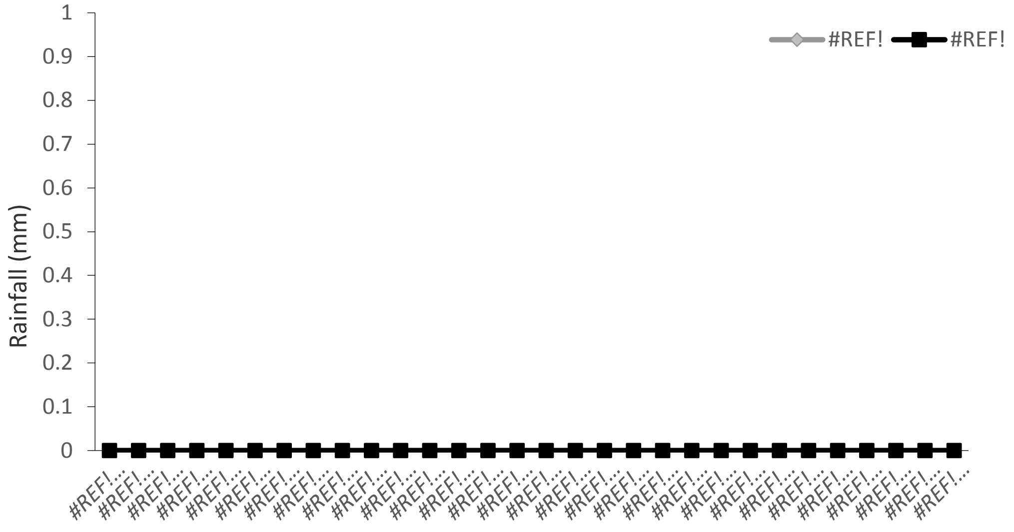

Fig. 1. Weekly rainfall at Tudun Wada during the experimental periods

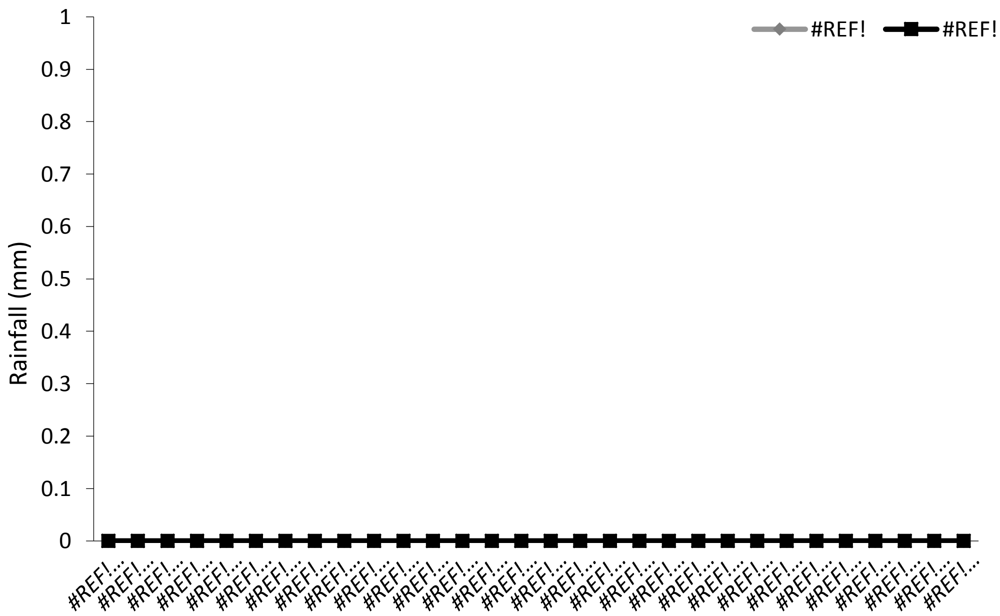

Fig. 2. Weekly rainfall at Samaru Zaria during the experimental periods