Original Research Article

Microclimatic Effects and Yield Response Factors of Irrigated Maize to Different Irrigation Levels in a Semi-Arid Environment

ABSTRACT

The aim of this research is to determine the appropriate irrigation scheduling under three different maize varieties in Northern Guinea Savanna agro ecological zone of Nigeria. The trial was conducted during the 2015 and 2015 dry seasons at the Institute for Agricultural Research (IAR) field in Samaru (Latitude 11.11^0 N and Longitude 7.38^0E). The experiment was laid out as a split – plot design replicated three times. Planting dates and supplementary Irrigation levels were in the main plots while maize varieties formed the sub-plots with the planting dates at 10days interval starting from March and February respectively. Three levels of irrigation were imposed based on levels of cumulative pan evaporation (E_{pan}) values of 1.0 E_{pan} (EI_1), 0.70 E_{pan} (EI_2) and 0.40 E_{pan} (EI_3). Results from the two trials, revealed more efficient utilization of soil moisture by crops irrigated with 70 CU irrigation regime (6.91 and 6.97kg grain/mm water respectively for the two seasons) while the least efficient water use was recorded by the full CU treatment (6.63 and 6.93 kg grain/mm water respectively) with relatively higher grain yields of 14% and 20% more than the 70 CU and 40 CU regimes respectively in 2015. Similar trends were recorded in the case of cob weight, 100 seed weight, seed/cob, shelling percentage and harvest index. In 2016 season, the similar trend was observed indicating the highest grain weight (3348.0kg/ha) recorded by the full irrigation treatment which was statistically higher than (2724.0 and 2072.0 kg/ha) respectively for the 0.70 and 0.40 CU regimes. The best performing variety in terms of efficient water use and relatively high yield was the medium maturing variety (V3).

Keywords: **Irrigation, maize variety, weather, water use**

1. INTRODUCTION

In Nigeria crop production is essentially rainfed and the most crucial problem in agriculture is the uncertainties of the rainfall establishment due to interannual variability [1]. Irregularities in rainfall reliability and spread have therefore contributed significantly to the poor yields and high variability in production from year to year [2]. The start of the rains, is seldom abrupt, but is usually foreshadowed by a succession of isolated showers of uncertain intensity with intervening dry periods of varying durations.

Maize (*Zea mays* L.) is an important food crops in Nigeria, widely grown in the savanna regions of the country. It is the 5th most important commodity in terms of production volume (2005-2010) and is characterized by an increasing trend over the period 2000 to 2010 [3]. This crop forms the staple food for most of the population especially in areas adaptable for their production. It is also used as basal ingredients of livestock feeds. In spite of the importance of this crop as source of food for human and animal consumption, its production is concentrated in the hands of peasant farmers whose average hectarage is very small, approximately 0.5 – 1.0

hectare per farmer and until recently, most of the production of the crop has been restricted to the rainy season.

The introduction of irrigation facilities through the provision of dams and reservoirs and the development of Fadama projects has greatly encouraged farmers to consider maize production in the dry season alongside vegetables and potatoes. The potential of the crop is yet to be fully exploited due to a number of constraints with low yields obtained on most farmers' fields. The low yield can be boosted and sustainable production achieved when the water requirements of the crop is given due consideration. When crop variety, time of growth and the climate are closely monitored in irrigated agriculture, optimum performance will be the result. Information on soil water management which is an integral part of the overall cropping system is required to efficiently develop methods of reducing water wastage in some of the irrigation schemes which tend to accelerate their deterioration thereby reducing output

2. MATERIAL AND METHODS

2.1 Experimental layout

This trial was conducted to assess the effect of differential irrigation on the growth and yield of some maize varieties at the Institute for Agricultural Research (IAR) field in Samaru, northern Nigeria (Latitude 11^0 11'N and Longitude 7^0 38'E). The area has a mean annual rainfall of about 1011$\pm$ 16. 1mm (CV=16%) from 1960-2003 [4]. The climate is characterized by one well-defined wet season which normally begins in April/May and ends in October [5].

The experiment was laid out as a Split – plot arrangement with three replications. Planting dates and Irrigation levels formed the main plots while maize varieties were on the sub-plots. The planting date (main treatment) was at 10days interval starting from early March in 2015 and early February in 2016. Three different maize varieties (Extra early, early and late gestation varieties) were used as test crops. The irrigation treatment was based on the restoration of depleted soil moisture via evapotranspiration (ETa) during crop establishment period and at flowering stage as well as full irrigation. Three levels of irrigation based on the restoration of accumulated $E_P$an were imposed at 5 days-interval at $E_P$an coefficient (Kcp) of 0.70 based on the restoration of cumulative pan evaporation ($E_P$an) [6][7][8]. These were 100%, 70% and 40% of $E_P$an which indicates relative water deficit of 0, 0.3 and 0.6 respectively in order to attain maximum and minimum plant water stress conditions.

Soil water content was measured within the top soil layer (0 - 20 cm) by gravimetric method and at fortnight interval during maize growth. Soil samples were taken from four sampling points per treatment and within the 0 – 20 cm depth for the determination of the moisture content using soil auger. It is assumed that soil moisture content would attain field capacity in two days since the soil is sandy clay to silty clay loam [9]. The samples were taken two days after and just before the next irrigation. The difference in moisture content between the two sampling periods was taken to be the moisture used. That is, the evapotranspiration by the crop for that period.

Agronomic parameters monitored were; days to 50% emergence and tasselling, number of leaves per plant, number of cobs per plot at harvest, Cobs weight per plot at harvest, 100 grain weight and date of harvest at two weeks intervals commencing from 4 weeks after emergence.

3. RESULTS AND DISCUSSION

3.1 Weather Condition of the Study Area

Table 1a presents meteorological data at the site during the experimental period. The period of the experiment falls within the late dry season (March to June) low rainfall amount (247.1mm) was received from planting to grain filling (1 – 10 WAS) with the highest rainfall amount of 90.9 received on a single day in March, followed by total dry spell throughout April. Evapotranspiration during the period was 1049.9mm. Mean maximum and minimum air temperatures during the period were 30.9 and 20.9°C respectively while the mean soil temperature was 26.7 with low relative humidity ranging from 20.6 – 72.2%, average sun shine hours of 233.9

The second experiment was conducted during the 2016 early dry season period from the month of February to May. The weather during the study period as shown on table 1b was characterized by high evaporation rate with very little moisture in the soil as a result of rainfall recorded during the anthesis stage of the crop.

Table 1a: Meteorological conditions at the experimental site during late irrigation in 2015

	Jan	Feb	Mar	Apr	May	Jun
Rainfall (mm)	0	0	90.9	0	90.1	66.1
Open water evap. (mm)	245.3	249.5	276.9	333.6	267.7	171.7
Min. Temp. (°C)	14.7	18.4	21.1	16.8	22.6	23.2
Max. Temp. (°C)	29.9	36.6	35.9	30	31.1	26.9
Rel. Humidity (%)	18.6	13.0	28.7	20.6	49.3	72.2
Total Sunshine (Hrs)	232.9	319.4	278.8	221.2	215	220.7
Soil Temp (°C)	22.6	26.2	20.5	28.1	31.2	27.8

Table 1b: Meteorological conditions at the experimental site during the 2016 dry season

	Feb	Mar	Apr	May	Jun
Rainfall (mm)	0	25.3	2.2	81.3	100.8
Open water evap. (mm)	235.3	244.5	299.4	227.9	111.4
Min. Temp. (°C)	18	24.1	25.8	24.2	23.5

Max. Temp. (°C)	34.5	34.7	39.5	35.2	30
Rel. Humidity (%)	13.6	33.5	50.9	66.4	74
Total Sunshine (Hrs)	215.4	201	234.1	242.6	167
Soil Temp (°C)	24.4	28.8	30.9	28.6	27.6

Source: IAR Meteorological Station, A.B.U. Zaria

3.2 Crop Water Use

Trend of the water use of maize crop in this study is shown on Table 2a. In 2015 season, the values indicated that for the irrigation treatments, 100Epan irrigation used more water (513.24 kg/mm) than other the treatments and this was followed by 70Epan irrigation treatment (384.61 kg/mm) and 40Epan irrigation treatment which used the least water (268.53 kg/mm). For the varietal treatments, the values indicated that V3 (medium maturing variety) used more water (473 kg/mm) than the other varieties. V1 was followed by V2 (early maturing variety) with use of 466.31 kg/mm while the least water use was recorded under V1 (extra early variety) as 451.33 kg/mm. In 2016, similar trend was observed with the 100Epan irrigation used more water (526.64 kg/mm) than other the treatments and this was followed by 70Epan irrigation treatment (416.31 kg/mm) and 40Epan irrigation treatment which used the least water (271.13 kg/mm). For the varietal treatments, the values indicated that V3 used more water (468.3 kg/mm) followed by V2 and V1 with 416.3 kg/mm and 266.3kg/mm respectively.

Table 2a: Crop water use in 2015 and 2016 seasons at Samaru

Treatment	**Water use (kg/mm water)**	
	2015	2016
Irrigation		
100Epan	513.24	526.64
70Epan	384.61	416.31
40Epan	268.53	271.13
Variety		
V1	251.33	266.32
V2	466.31	416.43
V3	473.43	468.25

3.3 Water Use Efficiency

The values obtained in Table 2b revealed that at high moisture content, the moisture was adequate for the maize crop physiological processes. The most efficient water usage in 2015 season was recorded under 40 Epan irrigation treatment as 7.34 kg grain/mm water, followed by 70 Epan treatment with (6.91kg grain/mm water) while the 100Epan (full treatment) was the least in efficient water use thus recording 6.63 kg grain/mm water. In terms of varieties, V1 (extra early variety) recorded moderate efficient water use (8.07 kg grain/mm water) which was second to V3 (medium maturing variety) which recorded 8.32 kg grain/mm water while V2 (early maturing variety) recorded was the least in efficient water use, recording 7.20 kg grain/mm water. In 2016, the most efficient water usage was also recorded under 40 Epan irrigation treatment as 7.01 kg grain/mm water, followed by 70 Epan treatment with (6.97kg grain/mm water) while the 100Epan (full treatment) was the least in efficient water use thus recording 6.93 kg grain/mm water. V1 here also recorded moderate efficient water use (7.75 kg grain/mm water) which was second to V3 which recorded 8.15 kg grain/mm water while V2 recorded was the least in efficient water use, recording 7.33 kg grain/mm water.

Table 2b: Water use efficiencies in 2015 and 2016 seasons at Samaru

Treatment	**Water use efficiencies (kg grain/mm water**	
	2015	**2016**
Irrigation		
100Epan	6.63	6.93
70Epan	6.91	6.97
40Epan	7.34	7.01
Variety		
V1	8.07	7.75
V2	7.20	7.33
V3	8.32	8.15

3.4 Growth and Yield of the maize varieties under differential irrigation

3.4.1 Plant height

During the 2015 season, irrigating the crop with full, 0.70 and 0.40 consumptive uses (CU) has shown increasing trend from vegetative to grain filling stage (Fig. 1a). Irrigating with full CU has resulted in taller plants (17.3cm) than plants irrigated with both 0.70 CU (15.4cm) and 0.40 CU (13.5cm) at vegetative stage. At flowering, cob filling and ripening stages, the same trend was maintained with the tallest plants coming from the full CU regime.

The dominance of vigorous plants growth by the full CU irrigation might be due to adequate moisture for their physiological requirements compared to the other treatments which received lesser amounts of water. In 2016 season however, the trends in the plant height showed taller plants with the 0.70 CU throughout the growing season.

The same kind of trends goes for the plant height under different varieties (Fig. 1b). Variety V2, which is an early yielding variety, recorded taller plant heights ranging from 18.14cm to 241.31cm from vegetative to ripening stages while the other two varieties recorded comparatively shorter plant heights. This same trend was maintained for the two seasons with little variations.

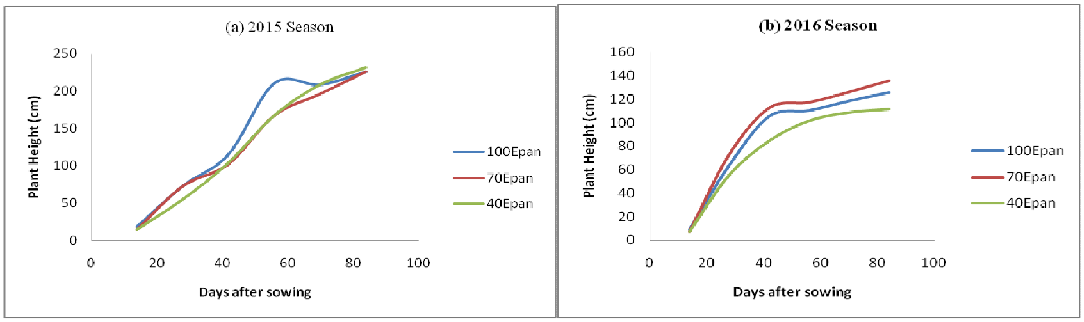

Fig. 1a: Trend of maize plant height over time as affected by irrigation in 2015 and 2016 seasons at Samaru

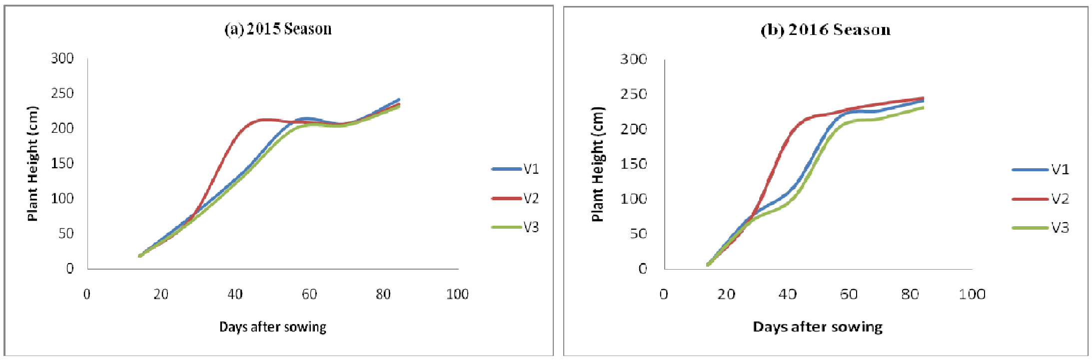

Fig. 1b: Trend of maize plant height over time as affected by Variety in 2015 and 2016 seasons at

3.4.2 Leaf Area Index (LAI)

The LAI which is another important growth parameter, showed increasing trend from vegetative to flowering stages (Fig. 2a) where the highest LAIs were recorded for all the regimes after which they began to decline. The highest LAI was recorded under the full CU irrigation regime (2.51) followed by 2.30 and 2.16 under the 0.70 and 0.40 CU respectively in the 2015 season. Similar trend was observed in the 2016 season with the full irrigation treatment out yielding the other two treatments. The LAI under different varieties (Fig.2b), showed highest LAI of 2.28, 2.25 and 2.16 at 56 DAS (flowering stage) for varieties V2, V1 and V3 respectively in 2015 season. Thereafter, the LAIs gradually dropped before harvest. This same pattern was observed during the 2016 season.

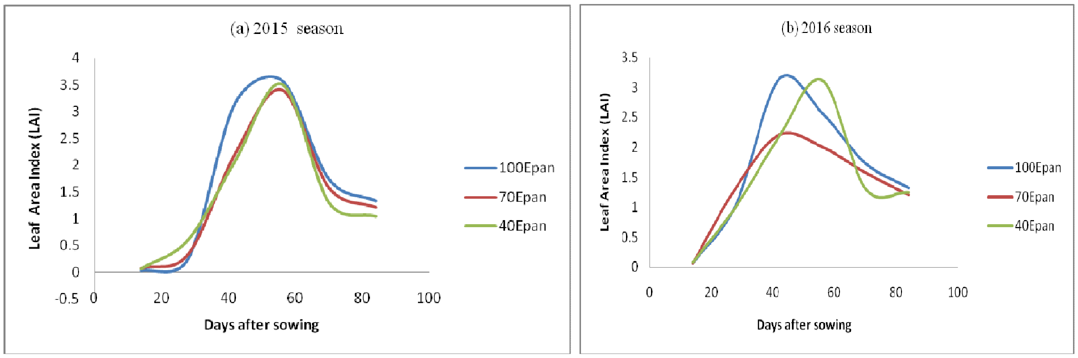

Fig. 2a: Trend of maize Leaf Area Index over time as affected by irrigation in 2015 and 2016 dry seasons at Samaru

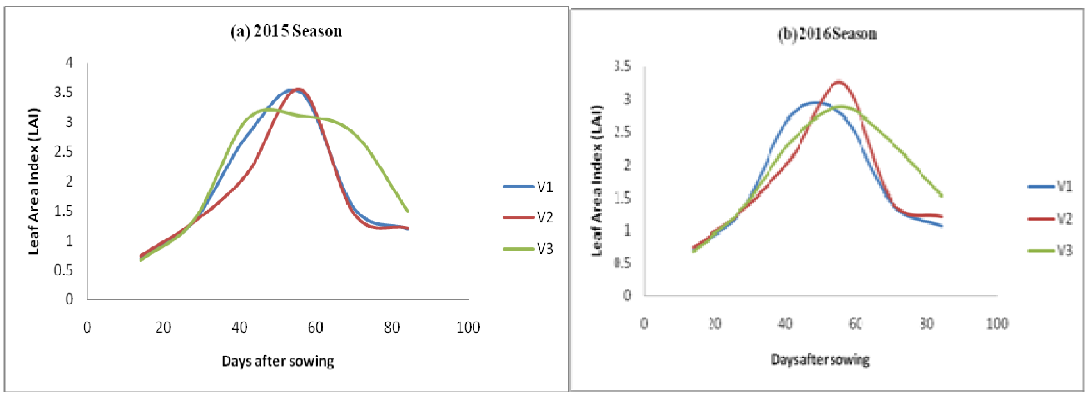

Fig. 2b: Trend of maize Leaf Area Index over time as affected by variety in 2015 and 2016 dry seasons at Samaru.

3.4.3 Grain Yield

Table 3 showed the result for grain yield of the different maize varieties under deficit irrigation. Although statistically there were no significant difference in the yield parameters, in 2015 the result indicated that the highest grain weight (3865.6kg/ha) which was recorded by the full irrigation treatment was significantly greater than that recorded by the 0.70 and 0.40 CU regimes which were about 14% and 20% less grain (3314.3kg/ha and 3093.9kg/ha) respectively. Similar trends were recorded in the case of cob weight, 100 seed weight, seed/cob, shelling percentage and harvest index. In 2016 season, the similar trend was observed indicating the highest grain weight (3348.0kg/ha) recorded by the full irrigation treatment which was statistically higher than (2724.0 and 2072.0 kg/ha) respectively for the 0.70 and 0.40 CU regimes.

Under the varietal treatment, variety V1 (3210.6 kg/ha) out yielded the other two varieties in 2015 season while in 2016, V3 (3598.0 kg/ha) performed better than the other two varieties followed by V2 and V1 with 2925.0 and 2654.0 kg/ha respectively.

Table 3: Effect of irrigation and variety on the cob weight, grain weight, 100 grain weight and grain weight per cob in 2015 and 2016 seasons at Samaru.

Treatment	Cob wt (g)		100 grain wt (g)		Grain wt per cob (g)		Grain wt/ha (kg/ha)	
	2015	2016	2015	2016	2015	2016	2015	2016
Irrigation								
Full	161.6	141.1	24.2	21.2	112.3	111.0	3865.6	3348.0a
0.70	116.9	153.1	24.9	22.2	120.1	117.9	3314.3	2724.0ab
0.40	87.3	150.5	25.2	20.8	108.7	116.9	3093.9	2072.0b
SE±	37.33	5.76	1.2	0.82	4.67	4.66	694.71	358.40
Variety								
V1	184.0	154.9	25.1	21.7	118.8	116.6	3549.0	2654.0b
V2	104.6	149.5	24.7	21.3	116.3	114.6	3434.8	2925.0ab
V3	100.5	146.3	24.6	21.2	114.8	114.7	3210.6	3598.0a
SE±	37.33	5.21	1.1	0.82	4.58	4.44	694.71	298.60
Interaction	NS	NS	NS	NS		NS	NS	NS

3.5 Discussion

3.5.1 Maize performance under differential irrigation and varieties

Several studies have shown that seed yield and components of maize, was markedly affected by irrigation treatment [10][11][12]. In similar experiments, the effects of drought stress conditions on maize varieties were significantly affected by the growth and yield parameters. Cultivars differed significantly for all parameters and a gradual increasing trend was observed in every variety with the increase in irrigation level [13]. A lot of other studies have also confirmed that stress of early stages of crop development to be devastating on yield according to [14][15][16].

In the 2015 irrigation trial, the growth parameters considered (plant height and leaf area index) showed increasing trend from vegetative to ripening stages with the full consumptive water treatment out yielding the other two treatments thus suggesting that there was increasing trend with increasing irrigation amount. The lowest plant height and LAI were recorded on plots with 0.40 regimes which is a stress treatment. This result agrees with those of [17].

Result of the yield and yield parameters on table 3 in experiment one above, indicated better performance with the full irrigation for almost all the parameters. This is in agreement with the results obtained by [18], [19] and [20], who reported increase in yield with increasing water supplied by irrigation. Maize variety effects on yield revealed a similar trend as above with the extra early variety out yielding the other varieties in 2015 irrigation trial while under the 2016 trial the medium maturing variety was significantly the higher of the two varieties thus suggesting the influence of other environmental factors such as solar radiation due to longer duration in the field. This agrees with the work of Agele [21] and [22] that recognized that longer maturing varieties produced greater yield to enable for a long duration in metabolic transformation into grain yield and stover.

The calculated values for water use obtained in both seasons indicated that the crops irrigated with full consumptive water use irrigation used more water. The high water use for this treatment may be due to the abundance of soil moisture in the soil and the plants tend to grow luxuriantly and hence use more water as observed in the work of [23].

Application of 70% moisture at all the growth stages resulted in moderate water use efficiency value. This agrees with the work of [24]. In the varietal treatments in 2015, the extra early variety used less water and yielded higher than the other treatments while in 2016, the medium maturing variety used more water than the other treatments followed by extra early maturing variety while the early variety was the least in efficient water usage. This might be due to its relatively short gestation period.

4. CONCLUSION

The water use efficiency values obtained for the two seasons, revealed more efficient utilization of soil moisture by crops irrigated with 70Epan irrigation regime while the least efficient water use was recorded by the full irrigation treatment despite the fact that the highest yield was recorded under this treatment. For the varieties, the most efficient water use was recorded under V3 (medium maturing variety) followed by the extra early variety.

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