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THE EFFECTS OF DEFICIT IRRIGATIONS ON CORN YIELD AND WATER USE EFFICIENCY IN NORTH-EAST NIGERIA

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ABSTRACT

Irrigated Agriculture is the largest water-consuming sector and it faces competing demands from other sectors, this great challenge of the Agricultural sector is to produce more food from less water, which can be achieved by increasing crop water productivity. The study was aimed at evaluating two maize varieties for their variability in growth, yield and yield component using water regimes that achieves the optimum yield of maize in the genuine Savannah using a complete randomized design with 3 replications. higher values of growth and yield of Samaru 14 (WHITE) and Samaru 37 (RED) were obtained when irrigation was scheduled at three-time available soil moisture depletion. Three irrigations regimes could be adopted where ground water quality and quantity is marginal to get high crop production and water use efficiency. Based on the results, it can be suggested that two irrigations approach could be a good strategy to improve water productivity when full irrigation is not possible.

Key words: Water Regimes, Irrigation, Growth variability, Optimum yield

1. INTRODUCTION

Maize is an important multipurpose crop which is used as food, fodder, fuel, as well as in the manufacture of industrial products

Maize is widely adapted to several of climate change. Maize has been reported to be very sensitive to water scarcity or drought and requires sufficient water thorough out its growing period for better yield (Otegui et al., 2005; English, 2010). Further, It was reported that water stress conditions may cause 22.61-26.4% yield reduction which is directly correlated with the decrease in number and weight of kernel (Pandey et al., 2010). Singh et al. (2007) suggested that deficit irrigation also has some influence on emergence time, number of leaves / plant, initiation of tasseling and silking, these things directly influence the plant height and vegetative growth of maize. The heading to milking growth phase is highly sensitive period of deficit irrigation and has ultimate effect on productivity of maize (Hussaini et al., 2008).Maize is grown almost all agro-climatic regions of the world, majority lays in low rainfall and heat stress conditions, where irrigation is the major factor determining yield. For this reason, it is necessary to determine the water regimes that achieving the optimum yield. The production of Maize can be improved positively by sufficient amount of irrigation (Kara & Biber, 2008; Yazar et al., 2009; Farré & Faci, 2013). In field crops, a well-arranged deficit irrigation might maximize water productivity over an area when full irrigation is not possible (Fereres & Soriano, 2007).With increasing concern about declining water resources, there is a great intension to improve water management in farming systems to improve water use efficiency (Buttar et al., 2006). Several possible approaches such as irrigation technologies and efficient irrigation scheduling may be adopted for more effective uses of limited water supplies (Kirda, 2000). The great challenge of the agricultural sector is to produce more food from less water, which can be achieved by increasing crop water productivity. Irrigated agriculture is the largest water-consuming sector and it faces competing demands from other sectors (Bastiaanssen et al., 2001; Kijne et al., 2003; Sander et al., 2011). Therefore, the present research was undertaken to examine the effect of different irrigation levels on the growth performance and grain yield of maize in the guinea savannah. All data were subjected to analysis of variance according to Gomez & Gomez (1984). The statistical analysis was performed using analysis of variance technique by means of "MSTAT-C" software.

MATERIALS and METHODS

The experimental fields were sited at the Teaching and Research farm, College of Agriculture, Jalingo (COAJ), Taraba state, (Longitude 11 50'E, Latitude 80 50'N,; altitude 144 m a.s.l) in the 2019 and 2020 dry seasons to study different irrigation regimes on the growth, development and yield of maize cultivars. Plant materials (Samara 14 ''WHITE'' and Samara 37 ''RED''), the experimental area was characterized by the "dry" season (November to April) and high temperature during the season. The experiment was designed in CRD and treatments were replicated three time. The plot size was 5×4m each and was irrigated as per the experimental treatments: I_0- control/no irrigation, I_1-one irrigation, I_2-two irrigations, I_3-three irrigations. These three irrigation levels; I_1, I_2, I_3 were set to the growth stages and in root initiation stage (20 DAS), panicle initiation stage (50 DAS) and grain filling stage (90 DAS) respectively.

The irrigation scheduling in conventional method was simulated as farmers do in the field. For this system irrigation interval was adjusted for soil (similar to the intervals applied by farmers).The irrigation requirement in all three irrigation methods was estimated using Penman-Montith equation on the base of the long-term mean meteorological data from the nearest climate station (Allen et al.,2000). All the experimental plots were fertilized with the recommended doses of various fertilizers. The rest of twothirds of urea were top dressed in two equal splits, one of the crown root initiation stages (50DAS) and the other at pencil initiation stages (80 DAS).The seeds were sown manually with the spacing of 75 x 25 cm. Two times weeding before first and second irrigation were adopted. During the experimental period there were remarkable infestation of insect-pest and diseases in the plots and hence there were pest/disease control measures taken. The data of 10 randomly selected plants were recorded on growth, yield contributing characteristics and grain yield at the harvesting stage

Data on different growth parameters such as (i) plant height, (ii) plant girth, (iii) total leaves plant-1, (iv) effective leaves plant-1(green leaves), (v) non-effective leaves plant-1(dry leaves), (vi) total roots plant-1, (vii) straw weight plant-1and (viii) straw yield (t ha-1),

data on different yield parameters such as (i) cob length, (ii) cob grain free length, (iii) cob girth, (iv) grain line cob-1, (v) grain number line-1, (vi) total grain cob-1, (vii) grain weight cob-1, (viii) 1000 grain weight cob-1, (ix) grains yield (t ha-1), (x) straw yield (t ha-1) and (xi) biological yield (t ha-1) were obtained.

The analysis of variance with respect to all the tested parameters in our study together with sources of variation and corresponding degrees of freedom were been presented in Table 1-4. All data were subjected to analysis of variance according to Gomez & Gomez (1984). The statistical analysis was performed using analysis of variance technique by means of “MSTAT-C” software.

RESULTS and DISCUSSION

3.1 Effect of irrigation frequency of various growths attributes

3.1.1. Plant height

Irrigation levels showed significant effect on plant height Samara 14 (WHITE) and Samara 37 (RED) (Table 1). The highest plant height (28.33 m) was observed in level-3 irrigation (I3) in BARI hybrid maize-9, which was statistically different from I1 and I2 irrigation levels and the shortest plant height was recorded with I0 (control treatment) for both the varieties. The plant height increased with the increasing irrigation levels. Samaru 37 ‘RED’ always produced tallest plants than samara 14 ‘white’ at all irrigation levels. While the Samaru 14 ‘white’ produced tallest plant only under I_3 level of irrigation, which was statistically similar to Samaru 37 ‘Red; under I_2-level of irrigation and always produce tallest plants than samara 14 ‘white’ at all irrigation levels.

Irrigation plays a vital role in vegetative growth of plant and causing improvement with plant height. Findings of present study are similar to the findings of EL Sabagh et al (2017)) those who observed highest maize plant height in full irrigation (three times). Similarly, Yazar et al.(2012) suggested that, maize crop are highly sensitive to drought stress conditions. The application of less water negatively responded on the plant height (crop sensitivity to drought stress) subsequently reducing the grain yield

(English, 2010). It was reported by various researchers that various plant growth attributes were reduced under different water stress conditions (Al-Ashkar et al., 2016 and Rashwan et al., 2016).

3.1.2. Plant girth

Intensity of irrigation showed significant positive effect on plant girth for both tested cultivars and it increased with increasing irrigation levels (Table 1). There was significant variation reported in plant girth with the application of I_2 and I_3 levels of irrigation on both the varieties and the shortest plant girth was observed under control conditions. Various researchers reported that continuous availability of water improve the plant girth in maize (Dogan & Kirnak, 2010) and established the need of higher irrigation for better plant girth (Hassan et al., 2016).

3.1.3. Total leaves plant-1

Total leaves plant-^{1}was positively influenced by the irrigation frequency in Samara 14 and samara 37 (Table 1). The highest total number of leaves plant-^{1}(12.67) was obtained in BARI hybrid maize-9 with I_3 treatment, which were statistically identical with I_1or I_2 levels of irrigation and the lowest, was observed under control conditions in both the varieties. Lamm et al. (2005) stated that deficit irrigation reduced total number of leaves so also Al-Ashkar et al. (2016) who reported reduction in Leaf area index and dry matter yield by the deficiency of irrigation in maize.

3.1.4. Effective leaves plant-1:

Proper irrigation frequency significantly increased the number of effective leaves plant-1in Samaru 7 and Samara 9. The highest effective leaves plant-1(24) produced with I_3irrigation while the lowest effective leaves plant-1(7) was produced under control treatment (rain fed condition) at BARI hybrid maize-7 (Table 1). Effective leaves gradually increased with increasing irrigation frequency, this might be probably due to a availability of soil moisture that enhances the uptake of nutrients resulting in the production of more leaves. The results are in agreement with the finding of Bozkurt et al. (2011) in Mediterranean climatic conditions.

3.1.5. Non-effective leaves plant-1

The number of non-effective leaves plant-^{1}was significantly influenced by the irrigation treatments in both maize varieties. The non-effective leaves plant- ^{1} gradually decreased with increasing irrigation levels. The effect of irrigation frequency on the non - effective leaves was opposite to that of effective leaves (Table 2). I_2 or higher irrigations significantly reduced non- effective leaves plant-^{1}. Similar result was observed by Igbadun et al. (2008) in Marmara region of Turkey

3.1.6. Total roots plant-1

Irrigation treatments showed significant effect on the total roots plant-1in Samaru 14 and samara 37. The maximum number of roots (54.67) was produced by I_3treatment while minimum root plant-^{1} (43.33) was produced by without irrigation treatment (Table 2). This result might probably be due to availability of irrigation water which enhances the production of more roots. However, water availability is usually the most important natural factor limiting expansion and development of roots (Yazar et al.,2009; Farre & Faci, 2009).

3.1.7. Straw weight plant-1

Straw weight plant-^{1}is also an important factor in determination of the crop performance, Irrigation treatments significantly affected the straw weight plant samara 14 ‘White’ and Samara 37 ‘Red’ (Table 1). The highest straw weight plant-^{1}(142.23 kg) was recorded in the I_3 irrigation treatment while the lowest straw weight plant-^{1}(91.26 g) with no irrigation. Increased irrigation frequency gradually increased the straw weight plant-^{1}. This might be because of the availability of water supply. Maize straw yield per plant increased significantly by amount of irrigation water and irrigation frequency (Kara & Biber, 2008). Pandey et al. (2010) reported 22.6-26.4% reduction in straw yield with deficit water condition .The maximum mean maize straw yield was achieved from full irrigation (Yazar et al.,2012). However, Yildirim & Kodal (2008) reported that straw yields did not improve thought adding excessive irrigation.

Table 1: Effect of irrigation on the growth performance of SAMARU 14 'White' and SAMARU 37 'RED'

Treatment	Plant height (m)		Plant girth		Total leaves plant^{-1}		Effective leafs plant^{-1}		Non-effective leafs plant^{-1}		Total roots plant-^{1}		Straw weight plant-^{1}	
	Samaru -14 White	Samaru -37 Red	Samaru -14 White	Samaru -37 Red	Samaru -14 White	Samaru -37 Red	Samaru -14 White	Samaru -37 Red	Samaru -14 White	Samaru -37 Red	Samaru -14 White	Samaru -37 Red	Samaru -14 White	Samaru -37 Red
L_0	21.63^{e}	23.23^{e}	6.06^{e}	7.00^{e}	8.99^{b}	9.67^{b}	8^{d}	9^{d}	7.17^{b}	7.17^{b}	43.33cd	37.33^{d}	91.26^{e}	97.01^{d}
L_1	25.33^{c}	26.26^{e}	7.00^{e}	10.15^{c}	11.46^{a}	12.45^{a}	10^{d}	14^{c}	7.83^{a}	7.67^{ab}	47.00c	41.67^{cd}	107.67^{d}	133.43^{c}
L_2	26.34^{c}	27.35^{e}	8.17^{cd}	11.15^{b}	12.33^{a}	12.81^{a}	13^{c}	19^{b}	8.17^{a}	7.80^{a}	50.33b	47.33^{ab}	116.67^{c}	139.23^{c}
L_3	27.67^{b}	28.33^{e}	9.33^{c}	12.97^{a}	12.14^{a}	12.90^{a}	18^{b}	26^{a}	8.17^{a}	8.17^{a}	54.33^{a}	51.67^{a}	124.33^{b}	142.13^{a}
CV(%)	1.01		7.32						0.59		6.17		2.15	
LS	4.56*		1.15*						4.4*		7.68*		45.24**	

In a column figures having common letters(s) do not differ significant as per DMRT

TABLE 2: Effect of Irrigation on the Yield and Yield Performance of BARI hybrid maize-7 and BARI hybrid maize-9

Treatment	Cob length (m)		Cob grain free length (m)		Cob girth (m)		Grain line cob^{-1}		Grains number line^{-1}		Total grain cob-^{1}	
	Samaru -14 white	Samaru -37 Red	Samaru -14 white	Samaru -37 Red	Samaru -14 white	Samaru -37 Red	Samaru -14 white	Samaru -37 Red	Samaru -14 white	Samaru -37 Red	Samaru -14 white	Samaru -37 Red
Lo	1.8^{g}	2.3^{e}	1.79^{a}	1.37^{b}	1.33^{e}	1.73^{d}	13.43^{c}	13.43^{c}	38.33^{c}	41.67^{b}	489.54^{c}	520.52^{bc}
L_1	1.9^{f}	2.4^{c}	2.10^{b}	0.09^{c}	1.78^{d}	2.03^{c}	13.98^{bc}	14.00^{a}	44.50^{a}	41.54^{b}	567.45^{b}	601.40^{ab}
L_2	2.2^{b}	2.7^{b}	1.10^{c}	0.08^{c}	1.97^{c}	2.32^{b}	14.43^{abc}	14.70^{ab}	49.43^{a}	41.33^{b}	635.81^{a}	610.71^{b}
L_3	2.8^{d}	2.9^{a}	0.09^{c}	0.68^{d}	2.54^{b}	3.01^{a}	15.40^{ab}	15.40^{a}	46.65^{a}	45.76^{a}	700.50^{a}	670.00^{a}
CV (%)	1.78		6.93		5.49		1.49		12.09		74.04	
LS	0.76**		0.14*		1.89*		6.41**		7.23**		7.4*	

In a column figures having common letters(s) do not differ significant as per DMRT

TABLE 3: Effect of Irrigation on the Yield and Yield Attributing Traits of Samara 14 -White and Samara 37-Red

Treatment	Grains weight cob-^{1} (kg)		1000 grains weight (kg)		Grain yield (kgha-1)		Straw yield kgha-1)		Biol. yield (kgha-1)	
	Samaru -14 white	Samaru -37 Red	Samaru -14 white	Samaru -37 Red	Samaru -14 white	Samaru -37 Red	Samaru -14 white	Samaru -37 Red	Samaru -14 white	Samaru -37 Red
L_0	1020^{f}	1034^{f}	2550^{f}	2690^{e}	660.1^{f}	670.9^{f}	486.8	490.6	553.9	563.1
L_1	1420^{e}	1560^{d}	2670^{ef}	2800^{c}	735.4^{e}	827.1^{d}	581.0	595.7	648.8	674.9
L_2	1940^{c}	2100^{b}	2710^{e}	2980^{b}	892.7^{c}	944.8^{b}	620.7	658.4	700.92	750.5
L_3	2200^{b}	2300^{a}	2900^{d}	3100^{a}	1000.7^{a}	1100.1^{a}	710.9	750.7	810.1	860.7
CV (%)	1.41		0.82		2.11		3.79		3.59	
LS	3.85**		3.73**		0.433**		NS		NS	

In a column figures having common letters(s) do not differ significant as per DMRT

3.1.8. Cob length

No-significant difference was found among the irrigation treatments on the production of cob length in Samaru -37 Red and samara 14- white (Table 02). However, maximum cob length (2.9 m) was achieved with I_3irrigation and the minimum (1.8 m) was produced under control treatment. Pandey et al.(2010) reported that water use efficiency influenced the potential cob length.

3.1.9. Cob grain free length

Cob grain free length gradually decreased with increasing irrigation treatments in the maize hybrids (Table 2). The highest grain free length (1.7 m) was found under control treatment while the lowest (0.68 cm) was obtained with I_3 irrigation level. The resulting cob grain free length might be probably due to irrigation levels increased not increasing properly. Often the aim of producers is not to improve cob grain free but to maximize profits (Pajo et al.,2019).

3.1.10. Cob Girth

The cob girth values increased with increasing irrigation frequency in both varieties. The maximum cob girth (2.53 m) achieved with I_3 irrigation while the smallest cob girth (1.30 m) obtained in control (Table 2). Increased cob girth might probably be due to optimum cell expansion under sufficient water supply. Mansouri Far et al.(2010) reported that limited water reduced cob girth length. The results was also supported by Yildirim & Kodal (2008) and Yazar et al.(2012).

3.2 Effect of irrigation frequency of various yields attributes

3.2.1 Grain lines cob-1

It was found grain line cob-^{1}was affected by the treatments of irrigation regimes in Samaru -14 white

and Samaru -37 Red (Table 2) The maximum grain line cob-^{1} (2300kgha^{1}) was reported from the treatment having I_3 irrigation treatment while lowest grain line cob-1 (1020 kgha^{1}) was obtained from the controlled treatments. Similar results were reported by Farre & Faci (2009) and Bozkurt et al.(2011). However, Al-ashkar et al. (2016) found a positive association between grain line /cob and the amount of irrigation seasonally. The adding of excessive water was not significant to improve the production of grain yield.

3.2.2 Grains number line-^{1}

Grain number line-^{1} showed significant effect among the irrigation treatments in Samaru -14 white and Samaru -37 Red (Table 2). The maximum grain line-[1](49.30) counted at I_2 irrigation treatment and the lowest (38.33) at control. The value of grain number line-1 irrespective of increasing irrigation significantly increased the production. The reduction of yield (22.6-26.4%) caused by water stress was correlated with a reduction in number and weight of kernel in maize (Pandey et al.,2010). There was no significant variation between $I_1$and I_2 irrigation levels on producing grain number line-1

3.2.3 Total grains cob-[1]

The grain total cob[1] were affected by irrigation regimes in Samaru -14 white and Samaru -37 Red Table 2

The maximum total grain cob-[1] (700.0) was produced with I_3 irrigation treatment and it was statistically similar with I_2 irrigation level. The minimum total grain cob-[1] (489.54) found in treatment without irrigation, which statistically differs from all other treatments. Yazar et al. (2012) recorded that the maximum total grain / cob was achieved from full irrigation using drip irrigation method. Ertek & Kara (2013) also reported that deficit irrigation decreased the number of grain per ear, which was in agreement with findings of this study.

3.2.4 Grain weight cob-[1]:

The treatments of irrigation remarkably influenced the grain weight cob-[1] in Samaru -14 white and Samaru -37 Red (Table 3). The maximum grain weight cob-[1] (1020 kgha[1]) was recorded with I_3 treatment while the minimum value (2300 kgha[1]) was counted with I_0. The grain weight cob-1increased with the increasing of irrigation levels, However, Yazar et al. (2012) reported that irrigation frequencies increased grain weight cob-[1] and the drip irrigation method was more advantageous over other methods due to reducing the incidence of diseases and weeds in dry row middles and nutrient loss through deep percolation. Maximum mean, maize grain weight cob-[1] produced by complete irrigation (Yazar et al.,2012).

3.2.5 1000-grain weight

The irrigation levels also influenced the weight of 1000-grain Samaru -14 white and Samaru -37 Red (Table 3). The highest 1000-grain weight (3100.kg) was produced with I_3 irrigation treatment where as the minimum weight of 1000-grain (2550.17 kg) was produced by the control treatment. Above results are in agreement with the findings of Gencoglan & Yazar (2009) and Farre & Faci (2009).

3.2.6 Grain yield

The levels of irrigation Remarkably influenced the grain yield in Samaru -14 white and Samaru -37 Red (Table 3).Maximum grain yield (660.1kgha-1) was achieved with the treatment I_3 due to satisfactory soil moisture throughout the growing period, which was statistically similar with I_3 treatments produced by BARI maize-7 (1100.09 kg ha-1). Minimum grain yield (660.1kgha-1) counted from treatment I_0 and it differed statistically from other treatments applications. It was followed by the grain yield of I_1 treatment for both the varieties. In this research, irrigation is the main factor determining the yield. This result is consistent with the findings of Farré & Faci (2009) , Yazar et al.(2009) and Abd ewahed et al.(2015) reported reduction in grain and dry matter yield, and leaf area index by deficit irrigation conditions. The water stress (deficit water) remarkably influenced productivity and quality in maize (EL Sabagh et al., 2015; Barutcular et al., 2016 a; Barutcular et al., 2016 b; EL Sabagh et al., 2017). Similarly, effect of abiotic stress (deficit water) on the growth and grain quality of wheat was reported by Barutcular et al. (2016c) and Barutcular et al. (2016d).

However, water availability is usually the most important crop production factor limiting yield and yield traits of maize.

3.2.7 Straw Yield

It was observed that straw yield indicated non-significant effects at irrigation regimes in Samaru -14 white and Samaru -37 Red (Table 3). The highest straw yield (750.4 kgha-1) was observed in BARI hybrid maize-9 in the I_3treatment while the lowest 486.3kgha^1 It might be due to sufficient water which enhanced more vegetative growth, resulting in more straw yield. BARI hybrid maize-9 achieved better straw yield than BARI hybrid maize-9 in treatments. The maximum mean maize for the production of straw yield produced from full irrigation Yazar et al.(2012). All studied traits of flax crop significantly influenced by Irrigation intervals (Rashwan et al., 2016).

3.2.8. Biological Yield

Biological yield increased non-significantly with the increasing irrigation levels in both varieties (Table 3). Full irrigation (I_3) produced the maximum biological yield for both varieties. Among various irrigation treatments, highest biological yield (860.7 kg ha-1) was obtained in BARI hybrid maize-9 at I_3treatment, which was statistically differed with BARI hybrid maize-7at the same treatment. This result may be attributed with vigorous plant growth with sufficient irrigation water. In control treatment, (water stress) both varieties produced the minimum but statistically identical biological yields in this study. Results of present study are similar to the findings of Hanson et al.(2007) and Karasu et al.(2015) who observed deficit water in maize yield traits and biological yield. Dry matter yield of maize reduced severely with water deficit condition as reportedby Karam et al.(2003).

Conclusion

Increasing soil moisture within the root zone during crop growing period would be a great concern to enhance water use efficiency while saving water. In this study, higher values of growth and yield of Samaru -14 white and Samaru -37 Red were obtained when irrigation was scheduled at three-time available soil moisture depletion. It is recommended that three irrigations could be adopted where ground water quality and quantity is marginal to get high crop production and water use efficiency. Based on the results, it can be suggested that two irrigations approach could be a good strategy to improve water productivity when full irrigation is not possible. The performance of samara 37- Red was better than Samaru 14- white in all measured traits under different irrigation regimes.

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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