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RESPONSE OF MAIZE (*Zea mays* L.) GENOTYPES TO WATER STRESS UNDER IRRIGATION IN A SEMI ARID ECOLOGY, NIGERIA

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ABSTRACT

Field trials were conducted at the Irrigation Research Station, Institute for Agricultural Research, Kadawa during 2006/2007, 2007/2008 and 2008/2009 dry seasons to study the response of quality protein maize (QPM) genotypes to water stress. A split plot design was used with combinations of genotypes (TZE-W Pop x 1368, EV DT-W 99 STR, and DMR-ESRW) and irrigation regimes (40, 60 and 80 centibars soil moisture tension) assigned to the main plot and plant population (33,333 44,444, 53,333 and 66,666 plants ha^{-1}) assigned to the sub-plot and treatments were replicated three times. Irrigation scheduling at the less stressful 40 and 60 centibars tension significantly increased leaf area index, crop growth rate and total dry matter plant^{-1} among the growth components and significantly heavier ears per plant, and harvest index among the yield components. Irrigating at 80 centibars tension significantly increased weight of ears per plant. Water stress had no significant effect on grain yield, it can be concluded that irrigating at 80 centibars irrigation scheduling had resulted in good yield performance (2.3 tons/ha) of QPM at Kadawa.

Keywords: Maize; Genotypes; Water stress; Irrigation

INTRODUCTION

Population increase and the improvement of living standards brought about by development have resulted in a sharp increase in food demand. The increased demand for food makes irrigated agriculture inevitable. At the same time, the water input per unit irrigated area will have to be reduced in response to water scarcity and environmental concerns. Water productivity is projected to increase through gains in crop yield and reductions in irrigation water. In Nigeria, where traditional (farmers) irrigation management is widely practiced, sustainable food security has always been a challenge. The challenges are multi-dimensional, but of utmost importance is, poor irrigation water management. In order to meet these projections, irrigation systems will have to be modernized and optimised. Particular attention will have to be paid to the improvement of irrigation water management. Crop and soil water management is an important and integral part of the overall cropping system. Information is therefore needed in order to develop efficient methods of soil water management that reduce the wastage of water in some of these irrigation schemes which tend to accelerate their deterioration and reduced output. It is often assumed that water supply constitutes the primary limiting constraint to crop production (Payne*et al.*, 1991). However in most irrigation schemes in Nigeria, it is the abundance of water that is a problem (Anon., 2001). The challenge in this case is the search for the correct amount of moisture required by crops and better methods of water scheduling that will capture the high water requirement phases of crop growth and satisfy this for increased yield and water use efficiency (WUE). Crop irrigation requirements vary with soils, type of plants, stage of growth and weather conditions (Abdulmumin *et al.*,1986). Irrigation scheduling offers a means of supplying water in a timely manner, alleviating stress to ensure yield goals, and helping minimize water costs by limiting deep percolation. It is impossible to recommend a universally acceptable applicable irrigation schedule. Soil water measurements can be used to schedule irrigation among other methods. Irrigation is an important determinant of crop yield because it is associated with many factors of the plant environment, which influence growth and development. Availability of adequate amount of moisture at critical stages of plant growth not only optimizes the metabolic process in plant cell but also increases the effectiveness of the mineral nutrients applied to the crop. It has been shown that moisture stress occurring at the various vegetative and reproductive stages of growth and development of the maize plant may reduce final grain yield and that the extent of grain yield reduction depends not only on the severity of the stress but also on the stage of plant development when the stress occurred (Claasen and Shaw, 1970). It is reported that maize is relatively tolerant of water stress in the vegetative stage, very sensitive to water stress during the period of tasselling, silking and pollination, and moderately sensitive during the grain filling stage. Soil moisture situation during flowering and early grain formation seems particularly critical in determining yield (Salter and Goode, 1967; Wrigley 1969).Irrigation scheduling with tensiometers is an indirect method and supplies information on allowable depletion of available water or allowable suctions. Several researchers have studied the use of tensiometers to schedule irrigation (Karlen and Robbins, 1983; Camp *et al.*, 1989; Camp *et al.*, 1991; Goyal and Rivera, 1985; Smajstrla and Locascio, 1996; Bussi *et al.*, 1998).

MATERIALS AND METHODS

Study Area

The study was conducted under irrigation during 2006/2007, 2007/2008 and 2008/2009 dry seasons at the Kadawa Irrigation Research Sub-Station of the Institute for Agricultural Research, Ahmadu Bello University, Zaria. The site is located in the Sudan Savanna ecological zone of Nigeria (11^0 39'N, 08^0 20'E and 500m above sea level). The area has a cool dry season that has the north-eastern winds, which are cool and contain dust blown from the Sahara desert. The dust reduces visibility and intercepts a great deal of solar radiation (IAR, 1994). The minimum temperature ranges between 11and 18^{o}C in the cool months (November to March) with maximum temperatures of 25^{o}C - 40^{o}C in the warmer months (April to October) which is ideal for cultivation of wide variety of crops in the wet season. The soils are, in general, moderately deep and well drained with sandy loam textured surface and sandy clay loam textured subsoil.

Treatments and Experimental Design

The treatments consisted of three QPM genotypes (TZE-W Pop x 1368, EV DT-W 99 STR, and DMR-ESRW) three irrigation scheduling regimes (40, 60 and 80 centibars soil moisture tension) and four plant populations (inter row spacing was 75cm and intra row spacing used was 40cm to give 33,333; inter row spacing was 75cm and intra row spacing used was 30 cm to give 44,444; inter row spacing was 75cm and intra row spacing used was 25 cm to give 53,333 and inter row spacing was 75cm and intra row spacing used was 20cm to give 66,666 plants ha^{-1},). The experiment was laid out in a split plot design in which a factorial combination of genotype and irrigation scheduling were assigned to the main plot and plant population density was assigned to the sub-plots and replicated three times. The gross and net plot sizes used were of $22.5m^2$ and $15m^2$, respectively. The gross plot consisted of six ridges spaced at 0.75 m apart and 5m long (4.5 x 5 m) while the net plot consisted of the inner six ridges of 5 m length. Tensiometers were installed in each main plot to schedule irrigation. Growth (plant height, Leaf area index, crop growth rate and total dry matter) and yield (weight of ears paer plant, number os rows per cobs, grain yield and harvest index) data were collected from the net pot.

Data Analysis

The data collected were statistically analyzed and where the F-value was found to be significant, the treatment means were separated using Duncan's Muliple Range Test, DMRT, (Duncan, 1955).

RESULTS AND DISCUSSION

Weather

The agro-climatic conditions during the growth period of the maize genotypes as manifested by temperature and relative humidity and also by the differences in soil fertility and hydrological status as shown in Tables 1 and 2. The soil of the study area was sandy loam, which implies moderately coarse texture, the pH of the soil was slightly alkaline and adequate for crop growth. The organic carbon, available phosphorus and total nitrogen values were low, while exchangeable bases were medium. The cation exchange capacity (CEC) of the soil was also low. Optimum temperature and humidity are required for good maize growth and yield. The results in Table 2 show that the temperature range recorded within the study period fall within the optimum range required for optimum maize growth. Kumar *et al.*, 1982, reported that environments with cool night temperatures (14 – 18^{o}C) are more favourable for maize grain production, every degree rise in minimum temperature (night temperature) beyond 14^{o}C decreased grain yield by 153kg/ha, while each degree rise in mean temperature beyond 30^{o}C (maximum temperature) decreased grain yield by more than 211 kg/ha. This indicates that maize growth is a function of optimum temperature. During the course of this study, the minimum temperature was above 14^{o}C, while maximum temperature was also above 30^{o}C in all the years. Similarly, relative humidity values ranged from low to high during the period of the study. This might have negatively affected the attainment of full yield potential since the values were higher than that required for optimal growth. In addition, since plant growth was more vigorous in 2009, the superior yield components might be as a result of balanced development between vegetative and reproductive growth.

Table 1: Physico- chemical properties of soil from 0 – 30cm at the experimental site, Kadawa during 2007 – 2009 dry seasons.

Physical composition	2007	2008	2009
Sand (g/kg)	570	560	580
Silt (g/kg)	240	280	260
Clay (g/kg)	190	160	160
Textural class	Sandy-loam	Sandy-loam	Sandy-loam
Chemical composition			
pH (0.01m $CaCl_2$)	7.13	7.40	7.30
Organic carbon (g/kg^{-1})	0.47	0.63	0.59
Available phosphorus (meq/kg^{-1})	0.27	7.16	5.82
Total nitrogen (g/kg^{-1})	0.14	0.18	0.32
Exchangeable bases (mg/100g)			
Ca	5.30	4.88	5.69
Mg	0.42	0.59	0.82
K	0.09	0.16	0.17
Na	2.26	2.32	2.34
Exchangeable acidity (H + AI)			
CEC	7.10	8.60	9.10
Water table depth (cm)			
Pre-rainy season	NA	NA	65-80
Post rainy season	NA	NA	100-110

Soil samples as analyzed at the Agronomy Department, IAR/ABU, Zaria

Growth Components

The effect of maize genotypes (TZE-W Pop X 1368 QPM, EV-DT W99 STR QPM and DMR-ESRW QPM) on growth components (plant height, Leaf area index, crop growth rate and total dry matter) is shown in Table 3. The results indicate that genotype EV-DT W99 STR QPM significantly recorded taller plants than the other genotypes in 2007 and 2009.

The results indicates that irrigating at 40 and 60 centibars resulted in significantly higher crop growth rate and leaf area index in 2007, and total dry matter per plant in 2009 than irrigating at 80 centibars respectively. Plant height was not significantly affected by soil moisture tension level. The significance of this result is that since efficient irrigation aims to conserve scarce water resources for sustainable production, delayed irrigation, signified by irrigating at 80 centibars, would be better. Plant height, leaf area index and crop growth rate can all do well with delayed irrigation by withholding irrigation till the tension is 80 centibars without significantly affecting the crop. However, higher values of total dry matter per plant were produced when irrigating at 40 and 60 centibars, respectively.

Yield components

The effect of maize genotypes (TZE-W Pop X 1368 QPM, EV-DT W99 STR QPM and DMR-ESRW QPM) on yield components is shown in Table 4. The results indicate that genotype EV-DT W99 STR QPM significantly outperformed the other genotypes in all parameters in all years except in 2007 where it recorded statistically similar weight of ears per plant and harvest index with genotype TZE-W Pop X 1368 QPM.

The effect of soil moisture tension on maize yield components is shown in Table 4 and indicates that irrigating at 40 and 60 centibars resulted in significantly higher values for weight of ears per plant in 2009, number of rows per cob in 2007 and harvest index in all the years. Irrigating at 80 centibars resulted in significantly higher values for weight of ears per plant in 2009 though at par with irrigating at 60 centibars. Grain yield per hectare was not significantly affected by soil moisture tension levels. The aim of any production effort is to attain maximum yield with the highest efficiency, the results points that irrigating at 80 centibars produced the similar yield as irrigating at 40 centibars. For sustainable production, irrigating at 80 centibars is the best option since at that tension, there will be fewer irrigations that when irrigation is supplied at 40 or 60 centibars.

Table 2: Kadawa Meteorological observation for 2007-2009 dry seasons

		Temperature ^{0}C						Relative humidity					
		Maximum			Minimum			Maximum			Minimum		
Months	Days	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
February	1-10	38.3	36.3	31.6	17.3	16.2	19.7	34.3	32.0	35.2	18.8	18.0	16.8
	11-20	34.7	35.9	31.6	15.6	19.7	18.2	30.8	34.1	36.4	16.8	19.8	17.6
	21-28	35.9	37.1	40.0	14.8	19.5	18.7	32.0	35.8	37.4	16.9	21.6	20.3
March	1-10	34.5	35.8	42.2	15.7	19.2	22.8	29.9	37.1	37.6	16.4	19.8	21.2
	11-20	32.3	38.3	37.6	18.9	19.4	21.4	32.3	36.1	34.9	18.2	21.7	18.1
	21-31	39.4	41.4	42.1	23.3	20.4	20.5	36.2	36.7	36.4	20.3	18.6	18.7
April	1-10	42.8	40.7	41.5	25.7	19.6	19.6	38.3	36.9	36.5	24.4	18.2	18.1
	11-20	41.1	39.1	43.9	23.9	18.6	23.8	36.9	37.5	38.3	21.6	18.7	22.1
	21-30	41.2	40.9	41.1	25.7	22.3	26.6	37.6	37.6	36.1	25.6	20.8	25.1
May	1-10	39.6	46.1	37.4	26.0	26.8	25.1	37.2	38.8	32.9	24.6	23.4	24.2
	11-20	38.4	39.4	41.7	26.6	25.2	25.3	34.8	39.3	37.2	23.7	23.8	24.7
	21-31	40.11	37.7	43.0	26.0	24.1	25.9	35.9	37.9	36.0	25.1	22.6	22.5

Source: IAR Meteorological Unit, IAR/ABU, Zaria

Table 3: Mean effects of soil moisture tension on growth performance of Maize genotypes at harvest at Kadawa (2007-2009)

	Plant Height			Crop Growth Rate (CGR)			Leaf Area Index (LAI)			Total Dry Matter (TDM)		
	Irrigation Schedule (centibars)											
Treatments	40	60	80	40	60	80	40	60	80	40	60	80
Genotype												
TZE-W Pop X 1368 QPM	155.29^{c}	175.33	159.55^{b}	12.68^{b}	13.71	14.89^{b}	2.80^{b}	2.74	3.47^{b}	395.33	410.05	354.37^{b}
EV-DT W99 STR QPM	171.33^{a}	168.83	172.92^{a}	13.96^{a}	13.74	16.56^{a}	3.88^{a}	2.86	5.26^{a}	432.83	386.83	472.92^{a}
DMR-ESRW QPM	164.15^{b}	165.38	160.87^{b}	11.70^{c}	14.07	15.50^{b}	2.93^{b}	3.00	3.51^{b}	423.55	358.38	376.87^{b}
SE (±)	2.30	3.99	3.43	0.17	0.20	0.36	0.16	0.12	0.02	21.66	20.12	19.67

Means followed by the same letter(s) within a column and treatment group are statistically similar using DMRT

Table 4: Mean effects of soil moisture tension on yield performance of Maize genotypes at harvest at Kadawa (2007-2009)

	Weight of ears/plant (g)			No. rows/cob			Grain Yield (kg/Ha)			Harvest Index (HI)		
	Irrigation Schedule (centibars)											
Treatment	40	60	80	40	60	80	40	60	80	40	60	80
Genotype												
TZE-W Pop X 1368 QPM	133.39^{a}	92.28^{b}	139.19^{b}	19.76^{a}	18.44	20.27^{b}	1592^{b}	1905^{b}	2487^{b}	0.36^{a}	0.54^{a}	0.45^{b}
EV-DT W99 STR QPM	143.45^{a}	105.38^{a}	197.60^{a}	24.30^{a}	18.13	27.20^{a}	2746^{a}	2506^{a}	4393^{a}	0.35^{a}	0.56^{a}	0.63^{a}
DMR-ESRW QPM	115.15^{b}	106.90^{a}	122.21^{b}	17.65^{b}	20.44	18.43^{b}	1592^{b}	1984^{b}	2518^{b}	0.30^{b}	0.46^{b}	0.56^{b}
SE (±)	6.83	5.14	8.82	2.33	2.05	2.56	115.18	99.53	154.27	0.02	0.02	0.02

Means followed by the same letter(s) within a column and treatment group are statistically similar using DMRT

CONCLUSION

From the results of this trial, it can be concluded that irrigating at 80 centibars, which takes the longest interval performed statistically similar to irrigating at 40 centibars, which requires more frequent irrigation. Grain yield per hectare was also not affected by varying the soil moisture tension. As a result of the outcome of this trial, it can be concluded that scheduling irrigation at 80 centibars on a sandy clay loam resulted in good growth and yield of maize at the said location.

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