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Research Article

The influence of Water Stress on the yield of Some Sorghum Cultivars in Shambat, Sudan

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Abstract: A two-year Field Experiment was conducted during the 2013and 2014 seasons at Shambat, Sudan to study the effects of irrigation intervals on grain yield and yield components of 16 genotypes of sorghum. The experiment was laid out in split plot design with four replications. Three watering treatments consist of irrigation every week, 2 weeks and 3 weeks and 16 genotypes of sorghum. The reduction in yield obtained under prolonged watering intervals was associated with significant decrease in yield components i.e. head length, number of grains per head and 100-grain weight measured in this study. The increased of grain yield of wad ahmed, tabat and Bashaeer genotypes, even under water stress condition, was accompanied with substantial increase in yield related characters. This suggest that, the aforementioned tested genotypes showed good plasticity at least in response to irrigation intervals in this study. In conclusion, these sorghum genotypes were adapted and suitable cultivars for drought tolerant selection at the Shmabat conditions.

Keywords: sorghum, water stress, yield, cultivar, drought selection.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is the fifth most important cereal grain in the world. Also it is an important food and feed crop in Africa, Central America, and South Asia. Sorghum is an important food crop in Africa, Central America, and South Asia. Worldwide, it is grown over 42 countries (Belum *et al.,* 2004). During the last three production seasons (2015-2017), the average world sorghum areas were about 42.502 million hectares producing 61.161 million metric tons with average yields estimated at 1.44 tons per hectare. Also, the average Sudan sorghum areas were about 8 million hectares producing 4.599 million metric tons with average yields estimated at 0.53 tons per hectare(FAS- USAD, 2018). Yield differences in sorghum are associated with panicles number per per plant, kernels per panicle and kernel weight (Maman *et al.,* 2004). Al Aref *et al.,* (2009) in their study showed that improved cultivars gave longest panicles compared with the local variety. Also, Izge and Alimata (2008) reported that there was significant difference showed between cultivars on number of grains per panicle, 100-grain weight and grain yield/ha. In Sudan, Mohammed *et al.,* (2008) showed that, Tabat variety gave less yield compared to Wad Ahmed at AlFashir. Mehra *et al.,* (1970) and Elasha (2004) concluded that there was significant differences on HI among cultivars. On the other hand, yield potential of the crop is significantly limited due to drought and heat stresses within the tropics and subtropics necessitating sorghum breeding for drought tolerance and productivity (Belum *et al.,* 2004). Sorghum is an ideal crop for a more concerned crop improvement program in agriculture to utilize marginal lands, to meet food and energy demands which might be increased in the near future (Bibi *et al.,* 2012). Some other scientists focused on morpho-physiological flag leaf related characters especially leaf water relations and their considerable interaction with drought tolerance (Agarwal and Sinha, 1984). Apparently, sorghum can respond to additional irrigation by stem elongation and increased yield (Saeed and El-Nadi, 1998; Singh and Singh, 1995). Further, introducing new cultivars has become an important tool used to increase crop yields and grain quality in intensive agricultural systems Andrews *et al.,* 2004). Thus combination of these two factors can increase crop productivity through application of these agricultural practices. In view of increasing spread of drought belt and the high variation in the pattern of rain distribution, there is an increasing need for selecting cultivars adapted to water stress. Therefore, the objective of this study is to: Study the effects of water stress on yield and yield components in sorghum cultivars.

MATERIALS AND METHODS

Experimental treatments and layout

Sixteen accessions of sorghum (*Sorghum bicolor L. Moench*) of Sudanese origin were used in this study to assess the extent of variation among these genotypes under water stress (Table 1). Three watering treatments consist of irrigation every week, 2 weeks and 3 weeks, and they were designated in this study as W0, W1, and W2, respectively. A spilt-plot design with four replications was used to execute the experiment. The watering treatments were assigned to the main-plots and the genotypes to the sub-plots. Each genotype was grown in a plot of 3x5 meters, consisting of four ridges 70 cm apart. The spacing was 10 cm between holes along the ridge. Four to five seeds were sown per hole on the shoulder of the ridge during the second week of July for the two seasons. Three weeks after sowing, the plants were thinned to raise two plants /hole after three weeks of sowing. Plants were irrigated weekly during the first month and the treatments were commenced thereafter in both seasons.

Characters studied (Yield attributes): At harvest, the two inner rows in each subplot used for the determination of the following yield components. Head length (cm), Number of grains head^{-1}, 100-grain weight(g), Grain yield (kg/ha^{-1}) and Grains weight (g plant^{-1}). Also, harvest index (HI) was calculated as the ratio of grain yield to the total above ground shoot biomass as follows: HI =Grain yield / Biological yield x 100. Data was statistically analyzed according to the combined analysis of variance (ANOVA) for split plot design using MSTAT-C computer software package (Nielsen, 1992). Mean comparisons were worked out by Duncan's Multiple Range Test (DMRT) at 5% level of probability.

Table (1): Sorghum accessions used in the study

No.	Accession	Origin	Note
1	Wad Ahmed	Medani, Sudan	
2	Tabat	Medani, Sudan	
3	Bashaeer	Medani, Sudan	
4	Botana	Medani, Sudan	
5	Arfa Gadamak	Medani, Sudan	
6	kulom	Obeid, Sudan	
7	arwasha	Obeid, Sudan	
8	Arooselrimal	Obeid, Sudan	
9	Geshesh	Obeid, Sudan	
10	E94	Obeid, Sudan	local
11	E315	Obeid, Sudan	local
12	Abu 7	Damazine area	
13	Abu 8	Damazine area	
14	Kloklo	Damazine area	local
15	Rosaries 1	Damazine area	local
16	Rosaries 2	Damazine area	local

RESULTS AND DISCUSSION

Analysis of variance showed significant effects on all studied characters due to watering and genotypes treatments and their interaction. Frequent watering (W_0) significantly increased number of heads plant^{-1}, head length, number of grains head^{-1} , 100-grain weight, grain yield /ha and harvest index (Tables: 2 to7). Among all genotypes studied in this experiment, Botana(V_4), Kloklo(V_{14}) and Abu7 (V_{12}) were significantly gave the highest number of heads plant^{-1} while frequent irrigation of wadahmed(V_1), V_4 , Arooselremal(V_8), Geshesh(V_9) and Abu7 (V_{13}) gave the higher number of heads plant^{-1} as compared to their relative treatments(Table 2). This might be due to special factor of variety. The longest heads were observed in V_1 at first season while in the second season, Rosaries1(V_{15}) gave longest heads as compared to other genotypes. Moreover, sowing of V_1, V_2,V_6, V_{11} under frequent irrigation resulted in longer heads(Table 3).This result in accord with, Al Aref *et al.,* (2005) who showed that, the improved cultivars gave the longest pencils compare to local variety. The highest number of seeds head^{-1} were recorded in E94(V_{10}) even under water stress condition as compared to other genotypes. Also, under frequent irrigation of V_7, V_8, V_9, and V_{10} significantly increased number of seeds head^{-1}(Table 4). While water stress significantly decreased number of seeds head^{-1} for all genotypes under studying**.** The heavier 100-grain weights were recorded in V_1, V_2 ,V_3, V_{11} , V_{12} and V_{13} under normal watering treatment across the two seasons(Table 5). Also, under water stress condition V_1, V_2 ,V_8, V_9 and V_{10} gave higher 100-grain weights relative to their treatments. These results are in agreement with those reported by many researchers (Singh and Singh, 1995; Saeed and El-Nadi 1998 ; Belum *et al.,* 2004). They concluded that the reduction in number of number of grains head^{-1} and 100-grain weight under water stress condition could be attributed to the fact that water deficit severely affected pollination process and caused floret abortion ,while lack of assimilate needed for grain filling may reduce grain weight head^{-1}. In this study, although number of grains head^{-1} in Wadahmed(V1) was lower than those of E94 (V10) but Wadahmed gave higher 100-grain weights in both seasons indicated that there w as negative correlation between grain size and number of grains head^{-1} occur frequently in grain sorghum as reported by (Heinrich *et al.,* 1983). Although, water stress resulted in significant reduction of grain yield per unit area but V_1, $V_{2,}$ $_{V3}$, V_6 and V_7 significantly out-yielded other genotype under such condition while V_3 under frequent irrigation out-yield other genotypes in both seasons (Table 6). The increased of yield in could be due to 100-grain weight. Further, this is agree with those stated by Pal *et al.*, (1984) they reported that improve cultivars gave high grain yield compare to local cultivars .Also, the reduction in yield obtained under prolonged watering intervals was associated with significant decrease in all yield components measured in this study. This could be attributed to reduction in number of head length, number of grains $head^{-1}$ and 100-grain weight under water stress condition. On the other hand, the out-yielded of V1, V2 and V3 in grain yield even under water stress condition could be due to genotypic traits and the ability of sorghum to produce good yields under condition of low soil-moisture as reported by (Arnon, 1972). Harvest index (HI) is frequently quoted as a measure of efficiency of crop production and associated with seed yield.. Yet in the present study the reduction in HI was reduced under water stress. This because due to that, one of the main mechanisms reduce crop yield by soil water deficit was reduced harvest index (Earl and Davis, 2003).

Table (2): Effect of watering interval on mean number of heads/plant of different sorghum genotypes during 2012/13 and 2013/14 seasons

	2012/013				**2013/014**			
Treatment	**W_0**	**W_1**	**W_2**	**Mean**	**W_0**	**W_1**	**W_2**	**Mean**
V_1	6.0	3.0	1.0	3.3	3.3	2.0	2.0	2.4
V_2	5.0	3.0	1.0	3.0	2.3	1.0	2.7	2.0
V_3	4.0	3.0	1.0	2.6	3.3	3.0	4.7	3.6
V_4	6.0	3.0	1.0	3.3	2.3	2.7	5.0	3.3
V_5	5.0	3.0	1.0	3.0	3.7	1.0	6.0	3.5
V_6	3.0	2.0	1.0	2.0	3.0	5.0	3.0	3.6
V_7	2.0	3.0	1.0	2.0	3.3	4.7	4.3	4.1
V_8	3.0	3.0	1.0	2.3	2.0	6.0	2.0	3.3
V_9	2.0	2.0	2.0	2.0	6.0	3.0	1.5	3.5
V_{10}	1.0	2.0	1.0	1.3	5.0	3.3	2.2	3.5
V_{11}	3.0	4.0	2.0	3.0	3.3	2.0	2.1	2.4
V_{12}	2.0	5.0	1.0	2.6	4.0	3.0	1.0	2.6
V_{13}	1.0	6.0	2.0	3.0	6.0	2.7	1.0	3.2
V_{14}	5.0	3.0	2.0	3.3	5.0	3.0	2.2	3.4
V_{15}	4.0	4.0	2.0	3.3	1.7	3.3	1.7	2.2
V_{16}	6.0	2.0	1.0	3.0	3.0	3.0	1.0	2.3
Mean	3.6	3.1	1.3		3.5	3.0	2.6	
LSD $_{0.05}$ for V			0.9		0.7			
LSD $_{0.05}$ for W			0.9		NS			
LSD $_{0.05}$ for V*W			0.15		1.6			

Table (3): Effect of watering interval on mean head length (cm) of different sorghum genotypes during 2012/13 and 2013/14 seasons

	2012/013				**2013/014**			
Treatment	**W_0**	**W_1**	**W_2**	**Mean**	**W_0**	**W_1**	**W_2**	**Mean**
V_1	33.0	31.0	25.3	29.8	41.0	28.3	21.3	30.2
V_2	31.3	30.0	24.3	28.5	39.0	29.0	20.0	29.3
V_3	30.3	34.0	22.3	28.9	34.7	23.3	15.3	24.4
V_4	32.0	31.7	22.3	28.7	35.0	27.3	20.3	27.5
V_5	25.7	29.7	23.0	26.1	31.3	25.3	17.3	24.6
V_6	26.0	24.7	18.0	22.9	32.0	22.7	16.0	23.5
V_7	26.0	22.7	16.0	21.6	40.0	23.3	14.0	25.7
V_8	23.7	24.0	20.7	22.8	38.0	25.7	18.7	27.4
V_9	29.3	26.7	17.7	24.6	36.3	28.7	22.7	29.2
V_{10}	24.0	24.7	19.3	22.7	37.3	20.7	18.3	25.4
V_{11}	28.3	28.7	19.0	25.3	42.0	26.0	16.3	28.1
V_{12}	26.3	33.0	20.3	26.5	38.7	28.7	18.0	28.4
V_{13}	24.3	29.0	20.0	24.4	37.7	26.7	18.3	27.5
V_{14}	28.0	30.3	21.0	26.4	38.3	30.3	24.3	30.9
V_{15}	23.7	32.0	21.0	25.6	37.7	33.3	27.3	32.7
V_{16}	25.0	30.3	22.0	25.8	34.0	24.0	31.3	29.7
Mean	27.3	28.9	20.8		37.0	26.4	19.9	
LSD $_{0.05}$ for V			5.6		5.1			
LSD $_{0.05}$ for W			NS		2.3			
LSD $_{0.05}$ for V*W			NS		NS			

Table (4): Effect of watering interval on mean number of grains/head of different sorghum genotypes during 2012/13 and 2013/14 seasons

	2012/013				2013/014			
Treatment	**W_0**	**W_1**	**W_2**	**Mean**	**W_0**	**W_1**	**W_2**	**Mean**
V_1	126.3	120.7	96.1	114.3	142	120.8	116.3	126.3
V_2	132.2	120.5	100.6	117.7	138.6	128.8	114	127.1
V_3	110.4	131.06	92	111.1	119.6	144.6	109	124.4
V_4	115.2	126	86.4	109.2	116.9	135	107	119.6
V_5	114.8	117.2	70.8	100.9	84.3	136.3	87.8	102.8
V_6	118.8	124.6	95.1	112.8	72.6	91	89	84.2
V_7	140	105.7	90.7	112.1	106.6	85.6	80.39	90.8
V_8	138.2	117.4	102.7	119.4	141.2	127.8	108	125.6
V_9	149	120.8	100.7	123.5	152.3	127.6	107.6	129.1
V_{10}	161	127.4	117.5	135.3	165.9	132.3	117.2	138.4
V_{11}	131.2	129.7	73.06	111.3	139.3	144.5	103	128.9
V_{12}	138.06	110	88.6	112.2	157	131	84	124.0
V_{13}	129	131.2	105.2	121.8	137.3	143.3	106.6	129.0
V_{14}	122.3	116.3	88.9	109.1	130.6	124	101.3	118.6
V_{15}	134.7	123.1	98.06	118.6	145.1	139.2	106.6	130.3
V_{16}	133.7	122.4	89.1	115.0	140.6	121	99.8	120.4
Mean	130.9	121.5	93.4		130.6	127.0	116.3	
$LSD_{0.05}$ for V			NS		0.5			
$LSD_{0.05}$ for W			0.25		0.24			
$LSD_{0.05}$ for V*W			NS		1.1			

Table (5): Effect of watering interval on mean 100-grain weight(g) of different sorghum genotypes during 2012/13 and 2013/14 seasons

	2012/013				2013/014			
Treatment	**W_0**	**W_1**	**W_2**	**Mean**	**W_0**	**W_1**	**W_2**	**Mean**
V_1	4.5	3.0	2.9	3.4	2.9	4.3	3.2	3.4
V_2	4.1	2.9	2.7	3.2	2.8	5.5	3.8	4.0
V_3	4.2	3.3	2.1	3.2	3.1	5.1	3.1	3.7
V_4	4.4	3.5	1.9	3.2	3.0	4.1	2.9	3.3
V_5	4.6	3.1	1.5	3.0	2.8	4.8	3.2	3.6
V_6	3.2	3.6	1.9	2.9	2.4	3.9	3.3	3.2
V_7	3.4	3.5	1.8	2.9	2.2	4.1	3.2	3.1
V_8	3.5	3.4	1.7	2.8	1.7	3.6	3.7	3.0
V_9	3.7	3.3	1.2	2.7	1.9	3.7	3.4	3.0
V_{10}	3.9	3.2	1.7	2.9	1.4	4.9	3.5	3.2
V_{11}	3.8	3.0	1.9	2.9	1.6	4.0	3.1	2.9
V_{12}	4.5	3.0	2.1	3.2	1.7	4.1	3.1	2.9
V_{13}	4.6	3.5	2.3	3.4	1.7	5.1	3.3	3.3
V_{14}	4.2	3.2	2.2	3.2	2.2	4.2	3.1	3.1
V_{15}	4.7	3.1	1.9	3.2	4.2	3.8	2.2	3.4
V_{16}	4.1	3.0	2.3	3.1	4.4	3.6	2.9	3.6
Mean	4.0	3.2	2.0		2.5	4.3	3.1	
$LSD_{0.05}$ for V			0.16		NS			
$LSD_{0.05}$ for W			0.3		0.4			
$LSD_{0.05}$ for V*W			0.27		1.0			

Table(6): Effect of watering interval on mean grain yield (kg/ha) of different sorghum genotypes during 2012/13 and 2013/14 seasons

	2012/013				2013/014			
Treatment	**W_0**	**W_1**	**W_2**	**Mean**	**W_0**	**W_1**	**W_2**	**Mean**
V_1	2067.3	1437.7	869.3	1458.1	1529.3	1255.7	706.3	1163.7
V_2	1481.7	1435.7	572.3	1163.2	1464.3	1294.8	530.7	1096.6
V_3	2384.3	1033.0	647.7	1355.0	2243.0	851.0	610.0	1234.6
V_4	2049.3	808.7	400.7	1086.2	1956.0	780.0	371.3	1035.7
V_5	1995.3	950.0	384.3	1109.9	1951.0	872.0	384.3	1069.1
V_6	1961.3	817.0	467.0	1081.7	1816.0	777.0	468.3	1020.4
V_7	2039.7	699.3	423.7	1054.2	1814.3	668.3	423.7	968.7
V_8	2014.3	674.0	353.0	1013.7	1899.0	670.3	349.0	972.7
V_9	1886.0	778.3	342.0	1002.1	1749.0	730.3	338.7	939.3
V_{10}	1929.0	850.3	240.3	1006.5	1884.0	758.0	241.0	961.0
V_{11}	1629.7	872.3	330.7	944.2	1817.3	717.0	330.7	955.0
V_{12}	1853.3	784.3	214.3	950.6	1880.3	652.3	214.3	915.6
V_{13}	1994.0	749.0	367.7	1036.9	1960.0	655.0	347.0	987.3
V_{14}	2023.0	724.0	250.3	999.1	1695.3	727.7	246.0	889.6
V_{15}	1776.7	813.3	254.3	948.1	1622.7	819.3	254.3	898.7
V_{16}	1602.7	822.7	200.3	875.2	1381.7	689.3	188.0	753.0
Mean	1917.9	890.6	394.8		1791.4	807.3	375.2	
LSD $_{0.05}$ for V			275.3		NS			
LSD $_{0.05}$ for W			128.1		131.4			
LSD $_{0.05}$ for V*W			NS		NS			

Table(7): Effect of watering interval on mean Harvest index of different sorghum genotypes during 2012/13 and 2013/14 seasons

	2012/013				2013/014			
Treatment	**W_0**	**W_1**	**W_2**	**Mean**	**W_0**	**W_1**	**W_2**	**Mean**
V_1	34.3	27.6	13.6	25.1	34.3	26.3	13	24.5
V_2	34.3	25.3	13.6	24.4	35.3	24.3	12.3	23.9
V_3	34.6	28.3	13.3	25.4	34	26	12.6	24.2
V_4	31.3	25.3	12.3	22.9	33.6	24	12.6	23.4
V_5	33	23	11.6	22.5	34.3	21.6	12.6	22.8
V_6	34	25.6	12	23.8	33.3	26	11.6	23.6
V_7	36.3	25	12	24.4	35	24.3	11	23.4
V_8	36	22	13	23.6	33.6	22.3	11	22.3
V_9	35.3	24.6	13	24.3	34.6	24.3	10	22.9
V_{10}	33	22.3	13.3	22.8	33.6	25	11	23.2
V_{11}	33	21.3	13	22.4	33	22	12	22.3
V_{12}	31.3	21.3	12.3	21.6	32	21.3	11.3	21.5
V_{13}	33.6	20	12	21.8	32.3	20.3	13	21.8
V_{14}	32.3	23	12	22.4	33	23	12.3	22.7
V_{15}	34.3	24	12	23.4	33	20.3	12	21.7
V_{16}	35.6	24	12.6	24.0	32.6	20.3	12.3	21.7
Mean	33.8	23.9	12.6		33.9	23.2	11.91	
LSD $_{0.05}$ for V			275.3		NS			
LSD $_{0.05}$ for W			128.1		131.4			
LSD $_{0.05}$ for V*W			NS		NS			

CONCLUSION

The increased of grain yield of wad ahmed, tabat and Bashaeer genotypes, even under water stress condition, was accompanied with substantial increase in yield related characters. This suggest that, the aforementioned tested genotypes showed good plasticity at least in response to irrigation intervals in this study. In conclusion, these sorghum genotypes were adapted and suitable cultivars for drought tolerant selection at the Shmabat conditions.

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