(Original Article)

Evaluation of Yield and its Associated Traits in Some Grain Sorghum Genotypes under Water Stress Conditions

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Abstract

Response of 20 genotypes of sorghum to both full irrigation (100% ET) and deficit irrigation (60% ET) which were evaluated to identify water stress effects on yield and its attributes. The field experiments were conducted in Assiut Research Station, Assiut Governorate, Egypt, during 2021 and 2022 growing seasons. Two experiments were practiced separately under normal irrigation and water stress conditions. The combined analysis of variance for

20 genotypes across two years under two locations (normal (100% ET) and stress (60% ET) revealed highly significant differences among genotypes for all studied traits. Moreover, the genotypes × irrigation interaction variance was also highly significant or significant for all the studied traits except for panicle length. The highest means value for 1000-kernel weight across two years under two treatments (27.33 g) was given by EXO-27 genotype and for grain yield (24.20 ard. /fed.) by EXO-27. Ten and twelve of genotypes in 2021 and 2022 respectively, gave drought susceptibility indexes less than one, indicating less susceptibility. Under stress a positive and highly significant correlation was found between number of green leaves plant^{-1} and each of panicle width and panicle length (0.612, 0.427, respectively). On the other hand, there are negative and significant correlations (-0.375) between 50% flowering and grain yield under normal irrigation.

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is one of the important food crops in the world. It is cultivated in many parts of Asia and Africa, where its grains are used to make flat breads that form the staple food of many cultures. The species can be used as a source for making ethanol fuel and in some environments may be better than maize or sugarcane, as it can grow under harsh conditions. In Egypt it is the fourth most important cereal after wheat, rice and maize. Although sorghum has an ability to cope with many types of stresses, including heat, drought, salinity and flooding (Ejeta and Knoll, 2007) but in arid and semi-arid regions, this crop is usually affected by water stress at the reproductive stage particularly post flowering stage (Tuinstra *et al* 1997 and

Kebede *et al* 2001). Water stress is major limitation crop productivity worldwide and possible global climate change scenarios suggest a future increase in the risk of drought. Drought is perhaps the most important abiotic stress limiting crop productivity around the world and is certainly great significance in the semi-arid tropics, where rainfall is generally low and its distribution is erratic (Rosenow and Clark, 1995, Boyer 1982 and Bohnet and Jensen, 1996). The estimates of correlations alone may be often misleading due to mutual cancellation of component traits. So, it becomes necessary to study path coefficient analysis, which takes into account the casual relationship in addition to degree of relationship Mahajan *et al* (2011). Path analysis is necessary for better understanding of correlations among traits, which is a pathway for knowledge on specificity of the genetic material being studied. Ikanovic, (2010) concluded that even if correlation values are similar for certain pairs of traits, direct effects for some of them and especially indirect effects *via* other traits, can differ for some traits. Mahajan *et al* (2011), Mallinath *et al* (2004) and Ambekar *et al* (2000) stated that panicle length, panicle width, plant height, number of primary branches/panicle, number of grains/panicle, test weight, harvest index and grain yield/panicle had showed a positive and significant association at both levels with all characters except days to 50%flowering and days to maturity. Therefore, this study aims to analyze and determine the traits having greater interrelationship with grain yield utilizing the correlation and path analysis.

Materials and Methods

Twenty-grain sorghum genotypes were used for this study. Two experiments were practiced separately under normal irrigation 100% ET (2346.79 m^3) and water stress 60% ET (1694.00 m^3) conditions were carried out at Arab El-Awamer Research Station, Assiut during 2021 and 2022 growing seasons in a Randomized Complete Block Design (RCBD) with three replications. Each genotype was planted in one row plot, 4 meter long, 0.6 m wide and hill to hill distance of 0.25 m apart with two plants / hill after thinning. Sowing date in both of the 2021 and 2022 seasons was on 22nd and 24th June, respectively. Nitrogen fertilizer was applied at the rate of 120 kg N/ feddan (one feddan = 4200 m^2) in the form of Urea (46% N), phosphorus was applied at the rate of 30 kg P_2O_5/ feddan in the form of triple superphsphate (46% P_2O_5), while K fertilizer was added at the rate of 50% kg/ feddan in the form of potassium sulfate (50% K_2O). The origin of genotypes is presented in Table (1). Soil of the experimental site were analyzed in seasons according to Chapman and Pratt (1978) and results are shown in (Table 2).

All other cultural practices were carried out as recommended for grain sorghum production in both seasons. The studied traits were plant height (cm), days to 50% flowering, panicle length (cm), panicle width (cm),1000-kernel weight (g), No. of green leaves plant^{-1} and grain yield ard.\ fed. Grain yield was adjusted with grain moisture to 14%. Drought tolerance index and drought susceptibility index were calculated as follows: -

1-Drought tolerance index (DTI):

Drought tolerance index was calculated according to the following equation.

DTI= Trait mean under stress condition (40% Et)/ Trait mean under optimum condition (100%Et).

2-Drought susceptibility index (DSI)

Drought susceptibility index was calculated according to Fischer and Mourer (1978) equation as follows: DSI =(1-YD/YW)/(1-YMD/YMT).

where: YD yield under the drought stress. YW = yield under the non-drought stress.

YMD = mean yield for all genotypes under optimum irrigation. YMT = mean yield for all genotypes under stress irrigation

Table 1. Origin of genotypes used

No.	Genotype	Origin	No.	Genotype	Origin	No.	genotype	Origin	No.	genotype	Origin
1	EXO-1	Indian	6	EXO-19	Indian	11	EXO-33	Indian	16	EXO-41	Texas
2	EXO-2	Indian	7	EXO-20	Indian	12	EXO-36	Indian	17	EXO-48	Texas
3	EXO-4	Indian	8	EXO-24	Indian	13	EXO-38	Texas	18	EXO-49	South of Africa
4	EXO-10	Indian	9	EXO-25	Indian	14	EXO-39	Texas	19	EXO-50	South of Africa
5	EXO-12	Indian	10	EXO-27	Indian	15	EXO-40	Texas	20	Dorado	USA

Table 2. Some physical and chemical properties of normal soil

Chemical properties									
pH (1:1)	EC ds/m (1:1)	Soluble cations (meg / L)				Soluble anions (meg / L)		Available phosphorus (ppm)	Total nitrogen (%)
		Ca++	Mg++	Na+	K+	CO$_3$	+HCO$_3$		
8.37	0.33	1.43	1.16	0.19	0.75	1.68	1.47	8.31	0.009

Physical properties								
Particle size distribution (%)			Texture class	Moisture content (Volumetric %)			O.M (%)	CaCO$_3$ (%)	Bulk density
Sand	Silt	Clay	Sandy	S.P	F.C	W.P	0.19	30.9	1.63
89.9	7.1	3.0		23.3	10.9	4.5			

Statistical Analysis

Data for all these attributes were subjected to analysis of variance according to Steel and Torrie (1980) to evaluate the significant differences among genotypes. Differences between means were compared using revised least significant differences (R.L.S.D.) at 5% level of significant. Estimation of variation components and phenotypic correlations were calculated as suggested by Wright (1960) and Narasimharao and Rachie (1964). The correlation coefficient was partitioned into direct and indirect causes according to Dewey and Lu (1959). Test of significance was carried out with (n-2) degrees of freedom for phenotypic correlation by referring to the table given by Snedecor and Cochran (1989).

Results and Discussion

Data presented in Table (3) are mean squares in the combined analysis of variance of analyzed traits of 20 grain sorghum genotypes. The analysis of variance for yield and its attributes revealed that the differences among studied genotypes were highly significant (P<0.01) for all the studied traits. Interaction between genotype*Years *Irrigation had a significant or highly significant in all studied traits except for panicle length and no. of green leaves plant^{-1}. The data regarding means of grain yield and other characters of 20 genotypes of grain sorghum across two years under normal irrigation and water stress environments are presented in Table 4-13. Plant height (Table 4) across two years under normal irrigation ranged from1 12.2 (EXO-40) to 154.8 cm (EXO-24) with an average 134.9 cm. Under water stress across two years the plant height ranged from 105.0 (EXO-36 and Dorado) to 135.9 cm (EXO-39) with an average of 120.0 cm. The combined average across the two years under normal irrigation and water stress indicated that plant height ranged from109.2 (Dorado) to140.8 cm (EXO-39) with an average 127.5 cm. Days to 50% flowering across two years under normal irrigation (Table 5) ranged from 82.83(EXO-12) to 92.33 day (EXO-36) with an average 88.15 day. However, under stress water across two years the days to 50% flowering ranged from 77.84 (EXO-41) to 89.34 day (EXO-10) with an average 85.05 day. The combined average across the two years under normal irrigation and water stress indicated that days to 50% flowering ranged from 82.34 (EXO-41) to 89.59 day (EXO-49) with an average 86.60 day. Panicle length across two years under normal irrigation (Table 6) ranged from 17.00 (EXO-49) to 22.0cm (EXO-24) with an average 20.08 cm. However, under stress water across two years the panicle length ranged from 16.67 (EXO-49) to 19.83 cm (EXO-19) with an average 18.82 cm. The combined average across the two years under normal irrigation and water stress indicated that panicle length ranged from 16.84 (EXO-49) to 21.17cm (EXO-39) with an average 19.45 cm. Average panicle width across two years under normal irrigation (Table 7) ranged from 6.14 (Dorado) to 7.67 cm (EXO-20) with an average 6.87 cm. While, under stress water across two years the panicle width ranged from 5.17 (Dorado) to 6.83 cm (EXO-25) with an average 5.97 cm. The combined average across the two years under normal irrigation and water stress indicated that panicle width ranged from 5.65 (Dorado) to 7.13 cm (EXO-25) with an average 6.42 cm. Regarding no. of green leaves across two years under normal irrigation (Table 8) ranged from 6.09(EXO-49) to 9.67 leaves (EXO-12) with an average 8.38 leaves. At water stress across two years no. of green leaves ranged from 5.17(EXO-49) to 8.59 leaves (EXO-24) with an average 7.13 leaves. The combined average across the two years under normal irrigation and water stress indicated that no. of green leaves ranged from 5.63 (EXO-49) to 9.09 leaves (EXO-24) with an average 7.75 leaves. Moreover, 1000-kernels weight per plant across two years under normal irrigation (Table 9) ranged from 19.57 (EXO-24) to 30.04 g (EXO-27) with an average 24.45 g. At stress water across two years 1000- kernel weight per plant ranged from 17.95 (EXO-48) to 24.62

leaves (EXO-27) with an average 20.73 g. The combined average across the two years under normal irrigation and water stress indicated that 1000- kernel weight per plant ranged from 19.77 (EXO-40) to 27.33 g (EXO-27) with an average 22.59 g. Grain yield per plant across two years under normal irrigation (Table 10) ranged from 40.17 (EXO-40) to 64.67 g (EXO-27) with an average 52.36 g. At stress water across two years the grain yield per plant ranged from 28.87 (EXO-20) to 48.04 g (EXO-27) with an average 37.85 g. The combined average across the two years under normal irrigation and water stress indicated that grain yield per plant ranged from 36.32 (EXO-50) to 56.38 g (EXO-27). Grain yield (ard\fed) across two years under normal irrigation (Table 11) ranged from 15.68 (Dorado) to 24.09 g (EXO-27). At stress water across two years the grain yield ard\fed ranged from 10.74 (EXO-20) to 19.07 g (EXO-41). The combined average across the two years under normal irrigation and water stress indicated that grain yield ard\fed ranged from 13.82 Dorado) to 20.99 g (EXO-27) with an average of 45.11 g. Similar results were obtained by, Abd-Elrahman (1985), Ali (2002), and Hassaballa *et al*. (2018). These variation between genotypes in all studied traits may be due to the genetic behavior combination with environment factors, which were suitable for one genotype than other.

Table 3. Combined analysis of variance for 20 genotypes of grain sorghum under normal irrigation and water stress environments and two years.

S.O.V	d.f	Days to 50% flowering	Panicle length(cm)	Panicle width (cm)	Grain yield per plant (g)	1000 grain weight	No. of green leaves	Grain yield / plant	Plant height
					Mean squares				
Years (Y)	1	176.8**	67.52**	1.365	0.007	2.243	1.751*	0.387	847.5**
Irrigation (I)	1	22.36**	2.246	0.154	11464.1**	828.4**	94.88**	1710.9**	10706.7**
Rep. / Y	4	16.02*	88.70**	12.29**	10.68*	6.822**	0.391	1.608	249.1**
Y x I	1	576.6**	0.360	22.51**	5.084	2.340	0.009	0.0001	182.0**
Genotypes (G)	19	42.39**	10.86**	1.586**	346.9**	49.02**	8.462**	52.14**	1374.5**
G x Y	19	30.84**	3.373**	1.401**	25.23**	5.975**	0.781*	3.718**	163.7**
G x Y	19	24.89**	1.521	0.812*	142.5**	11.14**	0.817*	21.88**	829.3**
G x Y x I	19	68.24**	1.450	1.452**	24.60**	5.044**	0.296	3.430**	139.9*
Error	156	2.833	1.513	0.502	7.359	1.759	0.444	0.829	77.42

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 4. Means of plant height (cm) of 20 genotypes of grain sorghum across two years under normal irrigation and   water stress conditions

Genotypes	Normal irrigation			Stress water			Comb.
	2021	2022	Mean	2021	2022	Mean	
EXO-1	142.8	138.3	140.6	118.3	120.0	119.2	129.9
EXO-2	139.2	155.0	147.1	125.0	115.0	120.0	133.6
EXO-4	131.5	130.0	130.8	128.3	125.0	126.7	128.7
EXO-10	140.7	140.0	140.4	126.7	135.0	130.9	135.6
EXO-12	154.5	152.3	153.4	98.3	105.0	101.7	127.6
EXO-19	142.0	160.0	151.0	125.0	115.0	120.0	135.5
EXO-20	140.3	125.0	132.7	135.0	135.0	135.0	133.9
EXO-24	154.5	155.0	154.8	115.0	120.0	117.5	136.2
EXO-25	142.7	146.7	144.7	116.7	108.3	112.5	128.6
EXO-27	140.8	140.0	140.4	126.7	125.0	125.9	133.2
EXO-33	140.3	118.3	129.3	120.0	116.7	118.4	123.9
EXO-36	132.7	128.3	130.5	105.0	105.0	105.0	117.8
EXO-38	148.5	111.3	129.9	140.0	120.0	130.0	130.0
EXO-39	143.2	148.3	145.8	135.0	136.7	135.9	140.8
EXO-40	107.7	116.7	112.2	118.3	125.0	121.7	117.0
EXO-41	125.5	105.0	115.3	116.7	123.3	120.0	117.7
EXO-48	141.2	151.7	146.5	120.0	105.0	112.5	129.5
EXO-49	121.0	125.0	123.0	121.7	125.0	123.4	123.2
EXO-50	112.5	120.0	116.3	120.0	118.3	119.2	117.8
Dorado	110.0	116.7	113.4	106.7	103.3	105.0	109.2
Mean	135.6	134.2	134.9	120.9	119.1	120.0	127.5
F-test		L.S.D. 0.05		F-test		L.S.D. 0.05	
Years(Y)	**	--		G x Y	**	10.03	
Irrigation(I)	**	--		G x I	**	10.03	
Y x I	**	3.173		G x y x I	*	14.19	
Genotype	**	7.095					

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 5. Means of days to 50% flowering of 20 genotypes of grain sorghum across two years under normal irrigation and water stress conditions

Genotypes	Normal irrigation			Stress water			Comb.
	2021	2022	Mean	2021	2022	Mean	
EXO-1	87.67	88.00	87.84	89.67	88.67	89.17	88.50
EXO-2	89.33	84.33	86.83	86.33	87.67	87.00	86.92
EXO-4	84.33	82.67	83.50	88.67	88.00	88.34	85.92
EXO-10	89.33	87.67	88.50	91.00	87.67	89.34	88.92
EXO-12	84.33	81.33	82.83	87.00	89.33	88.17	85.50
EXO-19	91.00	89.00	90.00	89.00	85.00	87.00	88.50
EXO-20	89.00	88.00	88.50	88.00	88.33	88.17	88.33
EXO-24	89.33	88.00	88.67	88.67	83.00	85.84	87.25
EXO-25	89.33	86.67	88.00	83.33	87.33	85.33	86.67
EXO-27	88.00	87.00	87.50	86.67	83.00	84.84	86.17
EXO-33	94.00	87.33	90.67	82.67	83.67	83.17	86.92
EXO-36	94.33	90.33	92.33	83.67	81.67	82.67	87.50
EXO-38	94.67	89.67	92.17	81.67	83.33	82.50	87.34
EXO-39	87.33	91.00	89.17	85.33	80.67	83.00	86.08
EXO-41	84.67	89.00	86.84	73.00	82.67	77.84	82.34
EXO-48	89.33	87.67	88.50	83.33	72.67	78.00	83.25
EXO-49	94.67	87.67	91.17	93.33	82.67	88.00	89.59
EXO-50	85.67	81.67	83.67	79.00	88.33	83.67	83.67
Dorado	87.00	84.67	85.84	89.33	82.67	86.00	85.92
Mean	89.27	87.03	88.15	85.65	84.45	85.05	86.60
F-test		L.S.D. 0.05		F-test		L.S.D. 0.05	
Years(Y)	**	--		G x Y	**	1.920	
Irrigation(I)	**	--		G x I	**	1.920	
Y x I	**	0.607		G x y x I	**	2.715	
Genotype	**	1.357					

** Significant at 0.01 levels of probability.

Table 6. Means of panicle length of 20 genotypes of grain sorghum across two years under normal irrigation and water stress conditions

Genotypes	Normal irrigation			Stress water			Comb.
	2021	2022	Mean	2021	2022	Mean	
EXO-1	20.33	18.33	19.33	18.83	17.83	18.33	18.83
EXO-2	19.20	19.87	19.54	18.67	18.67	18.67	19.10
EXO-4	20.33	19.00	19.67	20.00	17.60	18.80	19.23
EXO-10	19.67	20.67	20.17	19.67	18.33	19.00	19.59
EXO-12	22.00	19.33	20.67	20.33	18.67	19.50	20.08
EXO-19	22.67	20.00	21.34	20.33	19.33	19.83	20.58
EXO-20	21.33	19.67	20.50	19.00	18.67	18.84	19.67
EXO-24	23.00	21.00	22.00	20.33	19.00	19.67	20.83
EXO-25	19.67	20.33	20.00	19.00	17.53	18.27	19.13
EXO-27	20.67	18.17	19.42	19.17	17.90	18.54	18.98
EXO-33	22.00	20.33	21.17	18.33	18.00	18.17	19.67
EXO-36	22.00	19.67	20.84	19.00	18.50	18.75	19.79
EXO-38	18.00	19.00	18.50	17.70	17.33	17.52	18.01
EXO-39	23.00	20.00	21.50	22.67	19.00	20.84	21.17
EXO-40	20.00	19.00	19.50	19.57	18.50	19.04	19.27
EXO-41	21.33	20.67	21.00	18.67	20.00	19.34	20.17
EXO-48	20.33	18.67	19.50	20.33	17.33	18.83	19.17
EXO-49	16.67	17.33	17.00	16.57	16.77	16.67	16.84
EXO-50	20.00	19.67	19.84	19.33	19.53	19.43	19.63
Dorado	20.50	19.57	20.04	19.00	17.67	18.34	19.19
Mean	20.64	19.51	20.08	19.33	18.31	18.82	19.45
F-test		L.S.D. 0.05		F-test		L.S.D. 0.05	
Years(Y)	**	--		G x Y	*	1.403	
Irrigation(I)	n.s	--		G x I	n.s	--	
Y x I	n.s	--		G x y x I	n.s	--	
Genotype	**	0.992					

n.s, * and ** means non-significant, significant at 0.05 and 0.01 levels of probability, respectively.

Table 7. Means of panicle width of 20 genotypes of grain sorghum across two years under normal irrigation and water stress conditions

Genotypes	Normal irrigation			Stress water			Comb.
	2021	2022	Mean	2021	2022	Mean	
EXO-1	6.67	6.67	6.67	6.63	5.50	6.07	6.37
EXO-2	6.67	7.17	6.92	6.27	4.67	5.47	6.20
EXO-4	7.17	7.17	7.17	6.87	6.33	6.60	6.89
EXO-10	6.83	6.67	6.75	6.67	6.17	6.42	6.59
EXO-12	7.73	6.83	7.28	5.67	5.50	5.59	6.43
EXO-19	7.67	7.17	7.42	6.97	6.17	6.57	7.00
EXO-20	7.50	7.83	7.67	4.17	6.33	5.25	6.46
EXO-24	7.63	6.67	7.15	7.33	5.33	6.33	6.74
EXO-25	7.67	7.17	7.42	7.33	6.33	6.83	7.13
EXO-27	7.17	7.00	7.09	6.50	6.17	6.34	6.71
EXO-33	6.83	6.53	6.68	5.83	5.33	5.58	6.13
EXO-36	6.33	6.50	6.42	6.17	5.83	6.00	6.21
EXO-38	7.07	6.83	6.95	5.00	6.50	5.75	6.35
EXO-39	6.83	7.00	6.92	6.50	6.17	6.34	6.63
EXO-40	6.50	7.00	6.75	6.00	5.67	5.84	6.29
EXO-41	6.80	6.50	6.65	6.50	5.00	5.75	6.21
EXO-48	6.00	6.83	6.42	5.83	5.50	5.67	6.04
EXO-49	5.67	6.50	6.09	5.00	6.50	5.75	5.92
EXO-50	6.50	7.00	6.75	6.00	6.00	6.00	6.38
Dorado	5.67	6.60	6.14	5.17	5.17	5.17	5.65
Mean	6.85	6.88	6.87	6.12	5.81	5.97	6.42
F-test		L.S.D. 0.05		F-test		L.S.D. 0.05	
Years(Y)	**	--		G x Y	**	0.808	
Irrigation(I)	n.s	--		G x I	*	0.808	
Y x I	**	0.256		G x y x I	**	1.143	
Genotype	**	0.571					

n.s, * and ** means non-significant, significant at 0.05 and 0.01 levels of probability, respectively.

Table 8. Means of green leaves number plant-1 of 20 genotypes of grain sorghum across two years under normal irrigation and water stress conditions

Genotypes	Normal irrigation			Stress water			Comb.
	2021	2022	Mean	2021	2022	Mean	
EXO-1	9.00	8.67	8.84	7.00	6.83	6.92	7.88
EXO-2	9.33	8.67	9.00	7.50	7.27	7.39	8.20
EXO-4	8.33	7.83	8.08	7.83	7.50	7.67	7.88
EXO-10	9.67	8.83	9.25	8.33	8.17	8.25	8.75
EXO-12	10.0	9.33	9.67	8.50	7.17	7.84	8.75
EXO-19	8.67	8.17	8.42	7.50	7.33	7.42	7.92
EXO-20	9.33	9.17	9.25	8.67	8.00	8.34	8.80
EXO-24	10.17	9.00	9.59	9.17	8.00	8.59	9.09
EXO-25	9.67	8.33	9.00	7.17	6.83	7.00	8.00
EXO-27	9.00	8.67	8.84	7.50	7.33	7.42	8.13
EXO-33	9.67	8.83	9.25	7.33	7.67	7.50	8.38
EXO-36	8.00	8.50	8.25	6.67	6.83	6.75	7.51
EXO-38	8.33	8.97	8.65	7.27	7.33	7.30	7.98
EXO-39	7.67	8.17	7.92	5.83	6.17	6.00	6.96
EXO-40	7.17	7.50	7.34	5.83	5.83	5.83	6.59
EXO-41	7.83	7.83	7.83	7.17	7.33	7.25	7.54
EXO-48	6.67	7.53	7.10	6.33	7.17	6.75	6.93
EXO-49	5.67	6.50	6.09	5.50	4.83	5.17	5.63
EXO-50	7.00	7.83	7.42	6.33	6.67	6.50	6.96
Dorado	8.17	7.33	7.75	6.50	6.83	6.67	7.21
Mean	8.47	8.28	8.38	7.20	7.05	7.13	7.75

F-test		L.S.D. 0.05		F-test		L.S.D. 0.05	
Years(Y)	*	--		G x Y	*	0.760	
Irrigation(I)	n.s	--		G x I	*	0.760	
Y x I	n.s	--		GxYxI	n.s	--	
Genotype	**	0.537					

n.s, * and ** means non-significant, significant at 0.05 and 0.01 levels of probability, respectively.

Table 9. Means of 1000 kernel weight \ plant of 20 genotypes of grain sorghum across two years under normal irrigation and water stress conditions

Genotypes	Normal irrigation			Stress water			Comb.
	2021	2022	Mean	2021	2022	Mean	
EXO-1	24.85	23.37	24.11	20.57	21.77	21.17	22.64
EXO-2	27.42	25.97	26.70	21.28	21.33	21.31	24.00
EXO-4	25.87	25.23	25.55	21.93	20.77	21.35	23.45
EXO-10	25.53	21.77	23.65	20.80	20.50	20.65	22.16
EXO-12	20.25	20.43	20.34	19.40	19.80	19.60	19.98
EXO-19	24.23	23.33	23.78	20.90	20.37	20.64	22.21
EXO-20	26.60	22.30	24.45	22.77	21.37	22.07	23.27
EXO-24	18.17	20.97	19.57	18.63	20.90	19.77	19.67
EXO-25	28.03	27.10	27.57	22.32	22.00	22.16	24.87
EXO-27	29.70	30.37	30.04	24.83	24.40	24.62	27.33
EXO-33	29.22	29.00	29.11	23.43	21.37	22.40	25.76
EXO-36	28.33	27.00	27.67	22.20	21.13	21.67	24.67
EXO-38	20.62	26.47	23.55	18.68	18.57	18.63	21.09
EXO-39	25.53	24.07	24.80	22.37	20.77	21.57	23.19
EXO-40	21.10	21.10	21.10	17.47	19.37	18.42	19.77
EXO-41	22.33	23.33	22.83	19.50	21.37	20.44	21.64
EXO-48	23.00	25.60	24.30	18.57	17.33	17.95	21.13
EXO-49	23.53	20.17	21.85	19.40	22.37	20.89	21.37
EXO-50	24.37	23.17	23.77	19.23	18.67	18.95	21.36
Dorado	24.17	24.30	24.24	20.30	20.53	20.42	22.33
Mean	24.64	24.25	24.45	20.73	20.73	20.73	22.59

F-test		L.S.D. 0.05		F-test		L.S.D. 0.05	
Years(Y)	n.s	--		G x Y	**	1.513	
Irrigation(I)	**	--		G x I	**	1.513	
Y x I	n.s	--		G x y x I	**	2.139	
Genotype	**	1.07					

n.s and ** means non-significant and significant at 0.01 levels of probability, respectively.

Table 10. Means of grain yield per plant of 20 genotypes of grain sorghum across two years under normal irrigation and water stress conditions

Genotypes	Normal irrigation			Stress water			Comb.
	2021	2022	Mean	2021	2022	Mean	
EXO-1	52.00	55.33	53.67	33.24	32.90	33.07	43.37
EXO-2	59.20	58.33	58.77	41.72	40.53	41.13	49.95
EXO-4	44.03	45.20	44.62	33.53	34.67	34.10	39.36
EXO-10	58.53	60.00	59.27	39.30	38.20	38.75	49.01
EXO-12	55.70	55.67	55.69	35.44	35.10	35.27	45.48
EXO-19	49.67	51.83	50.75	37.93	38.80	38.37	44.56
EXO-20	60.33	58.57	59.45	27.00	30.73	28.87	44.16
EXO-24	40.77	45.27	43.02	33.80	35.83	34.82	38.92
EXO-25	62.00	64.67	63.34	44.10	43.57	43.84	53.59
EXO-27	64.33	65.00	64.67	50.37	45.70	48.04	56.35
EXO-33	49.87	50.33	50.10	30.87	39.00	34.94	42.52
EXO-36	62.00	53.00	57.50	42.33	39.37	40.85	49.18
EXO-38	48.00	47.33	47.67	42.00	40.53	41.27	44.47
EXO-39	62.13	60.27	61.20	29.93	43.20	36.57	48.89
EXO-40	39.67	40.67	40.17	42.33	31.50	36.92	38.55
EXO-41	53.33	53.67	53.50	50.00	45.00	47.50	50.51
EXO-48	54.00	52.83	53.42	39.67	40.53	40.10	46.76
EXO-49	50.63	45.50	48.07	40.40	36.03	38.22	43.15
EXO-50	38.33	42.33	40.33	33.77	30.83	32.30	36.32
Dorado	40.67	43.20	41.94	30.53	33.77	32.15	37.05
Mean	52.26	52.45	52.36	37.91	37.79	37.85	45.11
F-test		L.S.D. 0.05		F-test		L.S.D. 0.05	
Years(Y)	n.s	--		G x Y	**	3.094	
Irrigation(I)	**	--		G x I	**	3.094	
Y x I	n.s	--		G x y x I	**	4.375	
Genotype	**	2.188					

n.s and ** means non-significant and significant at 0.01 levels of probability, respectively.

Table 11. Means of grain yield Ard/Fed of 20 genotypes of grain sorghum across two years under normal irrigation and water stress conditions

Genotypes	Normal irrigation			Stress water			Comb.
	2021	2022	Mean	2021	2022	Mean	
EXO-1	19.24	20.60	19.92	12.38	12.23	12.31	16.12
EXO-2	21.93	21.73	21.83	15.54	15.00	15.27	18.56
EXO-4	16.33	16.85	16.59	12.51	12.93	12.72	14.66
EXO-10	21.80	22.37	22.09	14.65	14.23	14.44	18.27
EXO-12	20.73	20.73	20.73	13.22	13.10	13.16	16.95
EXO-19	18.51	19.30	18.91	14.13	14.47	14.30	16.61
EXO-20	22.51	21.83	22.17	10.05	11.43	10.74	16.46
EXO-24	15.19	16.87	16.03	12.56	13.33	12.95	14.49
EXO-25	23.11	24.10	23.61	16.42	16.27	16.35	19.98
EXO-27	23.98	24.20	24.09	18.78	17.00	17.89	20.99
EXO-33	18.57	18.73	18.65	11.50	14.50	13.00	15.83
EXO-36	23.11	19.73	21.42	15.77	14.63	15.20	18.31
EXO-38	17.89	17.65	17.77	15.66	15.07	15.37	16.57
EXO-39	23.17	22.45	22.81	11.13	16.10	13.62	18.22
EXO-40	14.79	15.15	14.97	15.77	11.73	13.75	14.36
EXO-41	19.87	19.99	19.93	18.63	19.50	19.07	19.50
EXO-48	20.11	19.75	19.93	14.77	15.13	14.95	17.44
EXO-49	18.87	16.96	17.92	15.07	13.38	14.23	16.07
EXO-50	14.27	15.77	15.02	12.57	11.47	12.02	13.52
Dorado	15.28	16.07	15.68	11.33	12.57	11.95	13.82
Mean	19.46	19.54	19.50	14.12	14.20	14.16	16.84
F-test		L.S.D. 0.05		F-test		L.S.D. 0.05	
Years(Y)	n.s	--		G x Y	**	1.038	
Irrigation(I)	**	--		G x I	**	1.038	
Y x I	n.s	--		G x y x I	**	1.468	
Genotype	**	0.734					

n.s and ** means non-significant and significant at 0.01 levels of probability, respectively.

Drought susceptibility indexes (DSI)

The results of drought tolerance index and stress susceptibility index for grain yield/plant (Table 12) cleared that the different genotypes differed greatly in their response to water stress, some genotypes scored stress susceptibility index >1.0 indicate relatively stress susceptible and some genotypes scored stress susceptibility index <1.0 indicate relatively water stress tolerance. For example, ten of genotypes across two years under normal and water stress gave drought susceptibility indexes less than one, indicating less susceptibility. The tolerate genotypes scored the lowest susceptibility index and selection should be for high yielding genotypes at sever a drought which should DSI lower than the unity. These finding are in agreement with those obtained by House (1985), Mahdy *et al* (2011), Tag El-Din *et al* (2012, 2022), Abd El-Raheem *et al* (2020), EL-Abd (2003) and Al-Naggar *et al* (2007).

Table 12. The drought susceptibility index (DSI) and grain yield (GY) of 20 genotypes of grain sorghum across two years under normal and water stress

| Genotypes | 2021 | | | Genotype | 2022 | | |
	Normal irrigation	Stress water	DSI		Normal irrigation	Stress water	DSI
EXO-1	52.00	33.24	1.336	**EXO-1**	55.33	32.90	1.448
EXO-2	59.20	41.72	1.094	**EXO-2**	58.33	40.53	1.090
EXO-4	44.03	33.53	0.883	**EXO-4**	45.20	34.67	0.832
EXO-10	58.53	39.30	1.217	**EXO-10**	60.00	38.20	1.298
EXO-12	55.70	35.44	1.347	**EXO-12**	55.67	35.10	1.320
EXO-19	49.67	37.93	0.875	**EXO-19**	51.83	38.80	0.898
EXO-20	60.33	27.00	2.046	**EXO-20**	58.57	30.73	1.698
EXO-24	40.77	33.80	0.633	**EXO-24**	45.27	35.83	0.745
EXO-25	62.00	44.10	1.069	**EXO-25**	64.67	43.57	1.165
EXO-27	64.33	50.37	0.804	**EXO-27**	65.00	45.70	1.060
EXO-33	49.87	30.87	1.411	**EXO-33**	50.33	39.00	0.804
EXO-36	62.00	42.33	1.175	**EXO-36**	53.00	39.37	0.918
EXO-38	48.00	42.00	0.463	**EXO-38**	47.33	40.53	0.513
EXO-39	62.13	29.93	1.920	**EXO-39**	60.27	43.20	1.012
EXO-40	39.67	42.33	-0.25	**EXO-40**	40.67	31.50	0.805
EXO-41	53.33	50.00	0.231	**EXO-41**	53.67	45.00	0.577
EXO-48	54.00	39.67	0.983	**EXO-48**	52.83	40.53	0.832
EXO-49	50.63	40.40	0.748	**EXO-49**	45.50	36.03	0.743
EXO-50	38.33	33.77	0.441	**EXO-50**	42.33	30.83	0.970
Dorado	40.67	30.53	0.923	**Dorado**	43.20	33.77	0.780
Mean	52.26	37.91	-0.27	Mean	52.45	37.79	-0.28

At normal irrigation, Phenotypic correlations are presented in Table (13). They showed highly significant (p<0.01) and negative association between days to 50% flowering and grain yield (-0.375). While at stress condition, Panicle length and panicle width showed highly significant correlation (P<0.01) with No. of green leaves (0.427, 0.612), respectively.

Table 13. Phenotypic correlation among the studied traits for yield and its contributing characters in grain sorghum

	Days to 50% flowering	Panicle length (cm)	Panicle width (cm)	Grain yield per plant (g)	1000 grain weight	No. of green leaves	Grain yield (ard.\ fed)	Plant height
Days to 50% flowering	--	0.135	0.039	-0.375*	0.202	0.213	-0.370*	0.122
Panicle length (cm)	0.015	--	0.273	-0.183	0.010	0.193	-0.139	0.110
Panicle width (cm)	-0.208	0.310	--	0.180	0.099	0.071	0.127	0.099
Grain yield per plant (g)	0.093	0.097	0.238	--	0.079	-0.059	0.981**	-0.051
1000 grain weight	0.119	0.023	-0.032		--	0.104	0.085	0.235
No. of green yield green leaves	0.079	0.427**	0.612**			---	-0.047	0.024
Grain yield	0.094	0.098	0.236	0.989**	0.484	0.330*	---	-0.037
Plant height	-0.014	0.229	0.462**	0.469**	0.037	0.473**	0.468**	--

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

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تقييم المحصول ومكوناته لبعض التراكيب الوراثية لمحصول الذرة الرفيعة تحت ظروف الاجهاد المائي

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الملخص

تهدف هذه الدراسة الى تقييم استجابة عشرون تركيبا وراثيا من محصول الذرة الرفيعة وكذلك مدى ارتباط المحصول ومكوناته تحت ظروف الري العادي 100% والإجهاد المائي 60%. حيث أجريت تجربتين منفصلتين في محطة عرب العوامر بأسيوط خلال موسمي 2020 و 2021. أظهرت النتائج محل الدراسة اختلافات عالية المعنوية لكل الصفات محل الدراسة لكل من معاملتي الري خلال الموسمين. بينما التفاعل بين التراكيب الوراثية ومعاملات الري كان عالي المعنوية أو معنويا لكل الصفات محل الدراسة فيما عدا صفة طول القنديل وعدد الاوراق الخضراء للنبات. تم الحصول على أعلى قيمة لوزن ألاف حبة لكل من معاملتي الري خلال موسم الزراعة (27.33جم) و ولصفة المحصول (24.20 اردب/فدان) للتركيب الوراث- EXO 27.

كما اوضحت النتائج ان هناك عشرة من التراكيب الوراثية للموسومين متحملة للجفاف تحت ظروف الاجهاد المائي. كانت هناك علاقة موجبة وعالية المعنوية بين عدد الاوراق الخضراء وكل من طول وعرض القنديل (0.612 و0.427 على التوالي) ، على الجانب الآخر كانت هناك علاقة سالبة ومعنوية (0.375-) بين 50% تزهير وصفة المحصول تحت ظروف الري العادي.

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