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ESTIMATION OF GENETIC PARAMETERS FOR YIELD AND YIELD COMPONENTS IN GRAIN SORGHUM UNDER DROUGHT STRESS CONDITIONS

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ABSTRACT

This investigation was conducted at Shandaweel Research Station in the seasons 2019, 2020 and 2021, to estimate some genetic parameters for grain yield and some yield related traits, using the six populations, i.e. P_1, P_2, F_1, F_2, BC1 and BC2 of two grain sorghum crosses viz. RSh-13 × RSh-37 (Cross I) and RSh-18 × RSh-14 (Cross II). Besides P_1, P_2 and F_1 were evaluated for drought tolerance under three levels of water deficit [100, 60 and 40% ET] in three separate experiments. In addition, F_2, BC_1 and BC_2 were also evaluated under drought conditions [60 and 40% ET] in separate experiments. Results of analysis of variance indicated significant differences among the studied generations of each cross for studied traits. The genetic variances within F_2 population were also found to be significant for all the studied traits in the two crosses, therefore genetic parameters for additive, dominance and epistasis were estimated. The scaling test values A, B, C and D were significant for different studied traits, suggesting the presence of non-allelic interaction. The positive and significant estimates for various types of gene action revealed that the dominance × dominance type of epistatic gene action, which accounted for 17 cases out of a total of 24 cases (70.8%), followed by the additive gene effect (45%) contributed by a large portion of the genetic components controlling the inheritance of the studied traits. Estimates of broad-sense heritability were high (>80%) for all the studied traits under 60 and 40% ET. In the same regard, under both conditions, the values of heritability in the narrow sense ranged from low to moderate in all investigated traits. The expected genetic advance as percentage of the F_2 mean (Δg%) values were high enough to select for improving the studied traits in the segregating generations.

Key words: ***Sorghum bicolor, Scaling test, Six populations, Drought tolerance, Gene action, Heritability, Genetic advance.***

INTRODUCTION

Sorghum is the fifth major cereal crop in the world after wheat, rice, maize, and barley. The sorghum is one of the most important crops grown in very diverse environments of deficit water stress, low soil fertility and high temperature conditions (Mindaye *et al* 2016) due to grain sorghum carries natural characteristics, that are adaptable to drought conditions. In Egypt, grain sorghum is the also fourth major cereal crop. The cultivated area is about 359,074 fed producing about 802,128 tons of grains (Economic affairs sector 2020). Sorghum production does not meet the growing demand of the majority of Africa's developing population. Their productions were declined as a result of biotic and abiotic stresses, particularly drought reaction in sorghum, which can be physiological and morphological in nature (Verma *et al* 2018). The isolation of genetically superior genotypes based on the amount of variability present in the material is critical to crop breeding success. In crop improvement, selection progress is more important, and this progress is dependent on the presence of genetic variability for yield and yield components, as well as their heritability percentage. Heritability, in combination with nature of gene action, heterotic effect and expected genetic advance under selection for yield and related traits especially under drought stress are needed for a successful breeding program. However, such information is extensively studied under normal irrigation (Nguyen *et al* 1998, Audilakshmi1 and Reddy 2000 and Mahdy *et al* 2011). Badran (2020) found that the variance components of most studied traits showed that the major contribution in phenotypic performance was due to the genetic variation. With regard to the genetic advance, the results showed a clear discrepancy among the studied traits, as the characters of plant height and grain yield of the plant recorded the highest genetic advance. According to Al-Naggar *et al* (2018) the estimates of phenotypic coefficient of variation (PCV) were higher than genotypic coefficient of variation (GCV). Under the present study, the highest PCV and GCV was shown by plant height (PH) followed by grain yield/plant (GYPP), indicating that selection for high values of these traits of sorghum would be effective. GYPP and PH traits showed high broad sense heritability associated with high genetic advance from selection, indicating that there are good opportunities to get success in improvement of these traits via selection procedures. High heritability coupled with high genetic advance indicates that additive gene effects are operating and selection for superior genotype is possible (Arunkumar *et al* 2004).

The present study aimed to, determine the gene action, potence ratio, heterosis, inbreeding depression, phenotypic and genotypic coefficient of variation, broad and narrow sense heritability and genetic advance for yield and yield related characteristics in the two grain sorghum crosses under drought stress conditions.

MATERIALS AND METHODS

The field experiments were conducted at Shandaweel Research Station during the growing seasons 2019, 2020 and 2021. Four parental lines were used in this study. They were promising lines (RSh-13 (tolerant), RSh-37 (sensitive), RSh-18 (tolerant) and RSh-14 (sensitive)). These pure lines were chosen based on their diversity in some agronomic traits and their reactions toward drought stress. In the first season (2019), the four parental lines were intercrossed to produce the F_1 hybrid grains of the two crosses i.e., RSh-13 × RSh-37 (Cross I) and RSh-18 × RSh-14 (Cross II). In the second season 2020, F_1 plants of each cross were selfed and backcrossed to the two parents to obtain F_2, BC_1 and BC_2 generations. And, parents were also selfed to maintain parental purity. In addition, crossing was made between the parents again to produce additional new F_1 grains for each cross. In 2021 season, the grains of P_1, P_2 and F_1 were evaluated for drought tolerance under three levels of watering [100, 60 and 40% ET evapotranspiration] in three separate experiments. Besides, F_2, BC_1 and BC_2 were tested under drought conditions [40 and 60% ET]. Each experiment was conducted in a randomized complete block design with three replications in rows with 4 m long and 60 cm apart with 20 cm between plants. The six populations of each cross were planted in rows, i.e. one row for each of P1, P2 and F1 cross, 4 rows for each of BC1 and BC2, and 6 rows for F2 population. Three grains were planted in each hill and three weeks later seedlings were thinned to only two plants per hill. All other cultural practices were done as recommended. Irrigation was applied each 15 days. The quantity of water applied was calculated according to the modified Penman equation for estimating evapotranspiration (ET) as described by Allen *et al* (1998). Data were recorded on days from sowing to 50% flowering, plant height (cm), 1000 grain weight (g), panicle length (cm), panicle width (cm) and grain yield per plant (g). Grain yield was adjusted at 14% grain moisture. Estimation of tolerance indices was calculated as followe: (SSI) SSI = 1 – (Ys/Yn) / SI where SI = 1 – (Ŷs/Ŷn) (Fischer and Maurer 1978) STI = (Yn×Ys) / (Ŷn)2 (Fernandez 1992), MP = (Yn +Ys) /2) (Rosielle and Hamblin 1981), YI =[(Yn-Ys) / Yn] × 100 (Blum 1983), SM = Ys / Yn (Lin and Binns *et al* 1986) and RP = (Ys/Yn)/R where R = (Ŷs/Ŷn) (Abo-Elwafa and Bakheit 1999).

The genetic analyses were: the scaling test of generation mean analysis as suggested by Mather (1949). The F_2 deviation (E1) and backcross deviation (E2) were calculated according to Marani (1968).

Potence ratio (P) was calculated according to Mather (1949). The six parameters of the genetic model (m, d, h, i, j and l) were computed according to Gamble's procedure (1962). Heterosis was expressed as the percentage deviation of F_1 mean performance from mid-parents and better parent according to Steel *et al* (1997). Inbreeding depression (%), phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were estimated using the formula suggested by Singh and Chaudhary (1977). Broad and narrow sense heritability was estimated using the formula proposed by Mather and Jinks (1982). The expected genetic advance from selection was calculated using the formulae proposed by Allard (1960).

RESULTS AND DISCUSSION

Analysis of variance of the parents and $F_{1's}$ for six studied traits in the two crosses under normal conditions are presented in Table (1).

Table 1. Mean squares of genotypes (P_1, P_2 and F_1) six the studied traits of the two crosses under 100% ET irrigation.

SOV	df	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	1000-grain weight (g)	Grain yield/plant (g)
Cross I (R Sh-13 × R Sh-37)							
Replications	2	2.01	21.35	1.81	0.04	0.05	0.48
Generations	2	21.53**	766.58**	46.33**	3.81*	16.05**	82.26**
Error	4	0.20	6.38	0.87	0.52	0.57	2.46
Cross II (R Sh-18 × R Sh-14)							
Replications	2	0.38	7.75	2.09	0.16	0.04	1.12
Generations	2	13.98**	1154.31**	8.98**	5.94**	8.93**	21.38**
Error	4	0.22	5.16	0.48	0.27	0.46	0.27

*** and **significant at 0.05 and 0.01 probability levels, respectively.**

Results show that mean squares due to genotypes were significant for all studied traits in the two crosses. Analysis of variance of genotypes (P_1, P_2, F_1, F_2, BC_1 and BC_2) for the studied traits in the two crosses under drought stress conditions are presented in Tables (2 and 3).

Table 2. Mean squares of genotypes (P_1, P_2, F_1, F_2, BC_1 and BC_2) for six the studied traits of the two grain sorghum crosses under 60% ET irrigation.

SOV	df	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	1000-grain weight (g)	Grain yield/plant (g)
Cross 1 (R Sh-13 × R Sh-37)							
Replications	2	2.49	17.13	5.71	0.07	0.57	0.23
Genotypes	5	24.86**	344.84**	21.32**	2.14*	8.14**	46.22**
Error	10	1.09	43.47	2.22	0.38	0.41	7.00
Cross 2 (R Sh-18 × R Sh-14)							
Replications	2	1.15	4.35	1.40	0.38	0.69	0.62
Genotypes	5	8.97**	482.53**	7.98**	0.54*	4.32**	10.16**
Error	10	0.31	29.08	0.46	0.13	0.31	0.85

*** and **significant at 0.05 and 0.01 probability levels, respectively.**

Table 3. Mean squares of genotypes (P_1, P_2, F_1, F_2, BC_1 and BC_2) for six the studied traits of the two grain sorghum crosses under 40% ET irrigation level.

SOV	df	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	1000-grain weight (g)	Grain yield/plant (g)
Cross 1 (R Sh-13 × R Sh-37)							
Replications	2	0.02	52.73	0.01	0.41	0.34	0.45
Genotypes	5	5.72**	84.71**	6.88**	1.18**	7.81**	41.23**
Error	10	0.78	9.13	1.18	0.15	0.91	3.31
Cross 2 (R Sh-18 × R Sh-14)							
Replications	2	0.17	76.95	0.36	0.22	0.42	0.33
Genotypes	5	7.34**	446.38**	4.79**	0.48*	1.90*	4.94**
Error	10	0.69	17.75	0.53	0.13	0.47	0.25

*** and **significant at 0.05 and 0.01 probability levels, respectively.**

Results indicated that mean squares due to genotypes were highly significant for all studied traits in the two crosses, indicating the presence of genetic diversity among the six populations within each cross. Similar trend was observed by Showemimo (2005) and Setimela *et al* (2007) who found that the traits tested have enough genetic variation across generations.

Results in Table (4) shows that the PCV % of the segregating populations (F_2, BC_1 and BC_2) was more than the PCV% of the non-segregating populations (P_1, P_2 and F_1) for all studied traits in the two crosses under the two levels of irrigations (60% and 40% ET), indicating the presence of genetic variation due to genetic segregation occurred in F_2, BC_1 and BC_2 populations. It's worth noting that the two traits, days to flowering and plant height, had the lowest PCV percentage whereas the two traits, panicle width followed by grain yield per plant, had the highest PCV % in the two crosses, which might be regarded sufficient variation. Also, panicle width and grain yield per plant had the greatest percentage for (GCV) in the F2 population, as compared with other traits in two crosses. PCV in the F_2 population was greater than GCV, indicating that environmental effects have a significant impact on the expression of these traits.

Results presented in Table (4) illustrate that there is significant difference in the mean values between the two parents R Sh-13 (P_1) and R Sh-18 (P_2) in the promising cross R Sh-13 x R Sh-18 (cross I) for all studied traits under normal and drought conditions. Same result was obtained for the two parents R Sh-37 (P_1) and R Sh-14 (P_2) in the promising cross R Sh-37 x R Sh-14 (cross II) for all studied traits under normal and drought conditions. In addition, means of back-crosses (BC_1 and BC_2) were less than the results of F_1 and F_2 generations in most studied traits under (60 and 40 % ET) conditions, respectively. Also, the means showed that means of all six generations were increased in number of days to 50% flowering with increasing water stress, and decreased for plant height and panicle length, panicle width, 1000-grain weight and grain yield per plant by increasing water stress. These findings are consistent with those of Wani *et al* (2003), Amir (2004), Blum (2008), Vinodhana and Ganesamurthy (2010), Ahmad *et al* (2013), El-Sherbeny *et al* (2019), EL- Sagheer (2019) and Badran (2020).

Table 4. Means ($\bar{x}$) and variances (S^2) of the genotypes, *i.e.* P_1, P_2, F_1 under (100, 60 and 40% ET) conditions and F_2, BC_1, BC_2 under (60 and 40% ET) conditions for the studied traits of the two grain sorghum crosses.

TR	Cr	Par.	P_1			BC_1		F_1			F_2		BC_2		P_2		
			100%	60%	40%	60%	40%	100%	60%	40%	60%	40%	60%	40%	100%	60%	40%
Days to 50% heading	Cross I	$\bar{X}$	67.44	71.89	74.56	74.6	76.22	63.97	69.7	72.37	71.80	73.47	73.78	75.44	70.44	72.44	75.33
		S2	1.14	1.65	2.02	10.2	10.67	183.00	2.17	2.09	17.23	19.18	11.28	12.89	1.35	1.80	2.00
		PCV	1.59	1.79	1.91	4.28	4.28	2.13	2.11	2.02	5.78	5.96	4.55	4.76	165.0	1.85	1.88
		GCV									5.46	5.63					
		LSD 0.05	100% = 1.01						60% = 1.53					40% = 1.61			
	Cross II	$\bar{X}$	68.44	74.00	78.33	74.7	76.56	64.88	73.0	74.00	73.60	75.33	74.00	75.56	71.33	76.00	77.44
		S2	1.83	1.86	2.17	11.8	10.58	2.43	2.94	3.22	18.07	16.46	12.44	12.69	1.75	1.98	2.06
		PCV	1.98	1.69	1.88	3.98	4.25	2.40	1.91	2.43	5.78	5.38	4.37	4.72	1.86	1.85	1.85
		GCV									5.40	4.96					
		L.S.D 0.05	100% = 1.05						60% = 0.82					40% = 1.51			
Plant height (cm)	Cross I	$\bar{X}$	187.56	179.67	161.2	177.	164.2	207.78	181.	168.1	177.4	170.3	166.2	159.4	176.2	168.6	156.33
		S2	30.47	38.00	41.28	234.	238.1	39.51	51.2	57.88	295.1	301.1	237.9	243.1	25.95	56.44	57.11
		PCV	2.94	3.43	3.99	8.63	9.40	3.03	3.94	4.53	9.68	10.19	9.28	9.78	2.89	4.45	4.83
		GCV									8.85	9.27					
		LSD 0.05	100% = 5.73						60% = 5.61					40% = 5.49			
	Cross II	$\bar{X}$	160.11	149.67	139.6	160.	156.8	191.44	181.	161.0	164.2	159.4	158.1	147.8	155.3	139.8	130.56
		S2	29.21	25.33	30.00	194.	212.1	35.80	26.1	48.44	241.2	260.7	260.7	204.7	26.33	25.43	37.14
		PCV	3.38	3.36	3.92	8.71	9.28	3.13	2.92	4.32	9.46	10.13	10.13	9.68	3.30	3.61	4.67
		GCV									8.94	9.15					
		LSD 0.05	100% = 5.14						60% = 13.91					40% = 7.66			
Panicle length (cm)	Cross I	$\bar{X}$	30.00	26.89	24.55	28.0	25.89	35.33	30.2	27.89	29.27	26.33	27.44	24.67	27.67	25.89	24.00
		S2	2.78	2.10	2.14	13.7	13.33	3.44	2.62	3.59	17.93	17.66	14.47	14.44	1.56	2.77	2.17
		PCV	5.56	5.39	5.95	13.2	14.61	10.47	5.35	6.80	14.47	15.96	13.86	15.41	4.51	6.42	6.13
		GCV									13.42	15.00					
		LSD 0.05	100% = 2.11						60% = 1.75					40% = 1.97			
	Cross II	$\bar{X}$	29.67	24.67	22.67	25.4	22.89	31.11	26.0	24.07	26.73	23.02	24.67	21.44	27.67	22.89	20.50
		S2	2.44	2.50	2.67	11.5	12.68	2.10	2.22	2.44	14.33	14.55	12.06	12.47	2.67	2.79	2.78
		PCV	5.27	6.41	7.20	13.3	14.27	4.66	5.73	8.76	14.16	16.57	14.08	15.57	5.90	7.27	8.15
		GCV									12.87	15.00					
		LSD 0.05	100% = 1.56						60% = 1.24					40% = 1.32			

Table 4. Cont.

TR	Cr	Par.	P1			BC1		F1			F2		BC2		P2		
			100%	60%	40%	60%	40%	100%	60%	40%	60%	40%	60%	40%	100%	60%	40%
Panicle width (cm)	Cross I	$\bar{X}$	7.00	6.39	5.56	6.11	5.56	8.44	7.28	6.44	6.07	5.07	5.11	4.67	6.22	6.11	5.00
		S2	0.44	0.60	0.91	1.65	1.80	0.47	0.62	0.69	2.20	2.46	1.42	1.56	0.40	0.54	0.67
		PCV	9.52	12.11	17.20	21.05	24.17	8.11	10.80	12.90	24.42	30.97	23.29	26.73	10.10	12.06	16.3
		GCV									20.91	25.77					
		LSD 0.05	100% = 1.63 60% = 1.17 40% = 0.71														
	Cross II	$\bar{X}$	7.67	5.39	4.89	5.11	4.33	8.11	6.44	5.16	5.59	4.43	5.56	4.22	6.00	4.78	3.17
		S2	0.22	0.43	0.54	1.65	1.89	0.54	0.69	0.74	2.09	2.03	1.80	1.84	0.17	0.56	0.89
		PCV	6.15	12.20	15.08	25.11	31.72	9.09	12.90	16.71	25.83	32.13	24.17	32.12	6.80	15.69	29.7
		GCV									22.08	25.77					
		LSD 0.05	100% = 1.81 60% = 0.62 40% = 0.67														
1000-grain weight (g)	Cross I	$\bar{X}$	27.11	24.22	22.56	26.11	23.61	30.44	26.72	24.33	26.53	24.01	24.11	22.78	26.00	23.78	19.8
		S2	1.65	1.73	1.80	9.88	10.32	1.36	1.62	1.72	11.93	12.14	9.21	9.73	1.56	1.73	1.88
		PCV	4.74	5.43	5.95	12.04	13.61	3.83	4.76	5.39	13.02	14.51	12.59	13.69	4.80	5.53	6.89
		GCV									12.06	13.39					
		LSD 0.05	100% = 1.70 60% = 1.64 40% = 1.73														
	Cross II	$\bar{X}$	25.67	24.00	23.00	24.78	22.89	29.56	26.11	24.17	25.53	24.87	25.11	22.78	24.11	23.06	21.8
		S2	1.33	1.56	1.78	10.62	10.77	1.14	1.28	1.78	12.15	13.23	10.33	10.40	1.21	1.33	1.43
		PCV	4.50	5.20	5.80	13.15	14.33	3.61	4.33	5.52	13.65	14.63	12.80	14.15	4.56	5.00	5.47
		GCV									12.85	13.68					
		LSD 0.05	100% = 1.54 60% = 1.11 40% = 1.25														
Grain yield/plant (g)	Cross I	$\bar{X}$	73.33	66.83	63.84	62.67	61.89	77.17	72.00	67.78	70.40	63.53	62.33	60.33	68.00	63.17	52.5
		S2	29.56	26.10	28.02	159.99	160.54	32.28	30.84	36.06	210.2	217.5	147.7	157.33	27.38	25.95	28.6
		PCV	7.41	7.64	8.29	20.18	20.47	7.36	7.71	8.86	20.60	23.22	19.50	20.79	7.69	8.06	10.1
		GCV									19.20	21.60					
		LSD 0.05	100% = 3.56 60% = 5.61 40% = 3.31														
	Cross II	$\bar{X}$	64.11	60.56	54.56	59.33	56.78	73.56	63.56	63.11	62.33	58.60	58.15	55.67	62.22	58.22	48.7
		S2	26.10	27.13	30.19	116.44	127.95	33.52	26.92	37.54	160.3	175.5	143.8	148.67	29.51	30.17	32.1
		PCV	7.97	8.60	10.07	18.19	19.92	7.87	8.16	9.64	20.32	22.61	20.63	21.90	8.73	9.43	11.6
		GCV									18.45	20.93					
		LSD 0.05	100% = 1.81 60% = 2.22 40% = 0.91														

TR = Traits Cr = Crosses, Par. = Parameters, Cross 1 (ICSB-88005 × MR-812) and Cross 2 (ICSB-37 × ICSR-93002)

The data in Table 5, represent stress tolerance indices for performance evaluation of genotypes (P_1, P_2, F_1, F_2, BC_1 and BC_2) for grain yield/plant under normal and drought conditions. The mean performances of genotypes (P_1, P_2, F_1, F_2, BC_1 and BC_2) under normal conditions was higher than under stress condition in the two crosses. Also, the highest value was obtained for F_1 in the two crosses under normal stress conditions.

Table 5. Estimation of drought tolerance indices for genotypes (P_1, P_2, F_1, F_2, BC_1 and BC_2) for in the two grain sorghum hybrids for grain yield trait under normal and drought conditions.

Crosse	Genotype	Yn	Ys	SSI	STI	MP	YI (%)	SM	RP
Cross I	P_1	73.33	63.84	0.86	0.89	68.59	12.94	0.87	0.74
	P_2	68.00	52.55	1.52	0.68	60.28	22.72	0.77	0.66
	F_1	77.17	67.78	0.81	0.99	72.48	12.17	0.88	0.75
	F_2	76.27	63.53	1.11	0.92	69.90	16.70	0.83	0.71
	BC_1	72.00	61.88	0.94	0.85	66.94	14.06	0.86	0.73
	BC_2	68.33	60.33	0.78	0.78	64.33	11.71	0.88	0.75
Means		72.52	61.65	1.00	0.85	67.08	15.05	0.85	0.72
Cross II	P_1	64.00	54.97	0.89	0.78	59.49	14.11	0.86	0.72
	P_2	62.00	48.77	1.35	0.67	55.39	21.34	0.79	0.66
	F_1	73.55	63.55	0.86	1.04	68.55	13.60	0.86	0.73
	F_2	70.26	58.60	1.05	0.92	64.43	16.60	0.83	0.70
	BC_1	67.33	56.77	0.99	0.85	62.05	15.68	0.84	0.71
	BC_2	65.00	55.66	0.91	0.81	60.33	14.37	0.86	0.72
Means		67.02	56.39	1.01	0.85	61.71	15.95	0.84	0.71

Where: Yn= grain yield without non-stress, Ys= grain yield with high stress level, SSI= stress susceptibility index, STI= stress tolerance index, MP= mean productivity, YI= yield injury, SM= superiority measure, RP= relative performance.

The genotypes (P_1, P_2, F_1, F_2, BC_1 and BC_2) were divided into two groups, for stress susceptibility (SSI) the first group is less than 1 and represented the most tolerant ones (P_1, F_1, BC_1 and BC_2), respectively, while the second group is greater than 1 and represented the genotypes that are less tolerant to drought (P_2 and F_2) in the two crosses. In the same context, stress tolerance index (STI) showed the superiority of F_1, followed by F_2 in the two crosses. According to yield injury (YI), P_2 (sensitive) recorded the highest deficiency in grain yield (22.72 and 21.34%) followed by F_2 (16.70 and 16.60%), respectively, in the two crosses. While, BC_2 recorded the lowest deficiency in grain yield (11.71 and 14.37%), respectively, followed by F_1 (12.17 and 13.60%) respectively in the two crosses. With regard to superiority measure (SM) and relative performance (RP), each of P_1, F_1 and BC_2 in the two crosses scored the highest mean compared to other genotypes, while P_2 has scored the lowest mean values of SM (0.77 and 0.79) and RP (0.66 and 0.66, respectively, in the two crosses. is finding is consistent with that of Badran (2020).

Heterosis, inbreeding depression and potence ratio for the studied traits under normal and drought conditions in the two crosses are shown in Table 6. Percentage of heterosis relative to the mid and better-parent values for the studied traits indicated that for the two studied crosses under drought condition, the two investigated crosses had highly significant positive heterosis percentages over the mid and better parent values, except for days to 50% flowering, which had highly significant negative (desirable) heterosis. Besides, relative to mid-parent heterosis (MP) under 40% ET was higher than 60% ET in most traits in the two crosses. Meanwhile the reverse was obtained for heterosis% relative to better parent (BP) were 60% ET > 40% ET in the most traits. The panicle width had the highest (MP) heterosis relative to mid parent and better parent under both 60% and 40% in the two crosses except cross II under 40% of (BP). These results are in harmony with those obtained by Prabahkar (2001), Premalatha *et al* (2006) and Mahdy *et al* (2011). Significant positive percentages of inbreeding were detected for most traits in both crosses under 40 and 60% ET, meaning that dominance plays the most significant role in heterosis manifested in the F_1 hybrid and such heterosis can not be maintained in the segregating generation. The findings are consistent with those of Vyas *et al* (2014) and Hafez *et al* (2015). Potence ratio values, considered as an indicator to the average degree of dominance in Table 6, showed that the over dominance is controlling inheritance of all traits in the two crosses under 60 and 40% ET. Also most traits had negative potence ratio under all environments in the two crosses toward to earlier parents in days to 50% flowering and towards lower parents in the studied traits. These findings are consistent with those of Hafez *et al* (2015).

Table 6. Mid- and better-parent heterosis (%), potence ratio and inbreeding depressing (I.D. %) for studied traits, using six populations data in the two grain sorghum crosses under 60 and 40% ET of irrigation watering.

Trait	Cross	Irrigation treatment	Heterosis (%)		Potence ratio	Inbreeding depressing
			Mid-parent	Better parent		
Days to 50% flowering	Cross I	60%	-3.31**	-2.94**	-8.60	-2.90**
		40%	-3.43**	-2.93**	-6.62	-1.51**
	Cross II	60%	-2.67**	-1.35**	-2.00	-0.82**
		40%	-4.99**	-5.53**	8.75	-1.80**
Plant height (cm)	Cross I	60%	14.13**	10.64**	-4.47	9.21**
		40%	5.88**	4.27**	-3.82	-1.32
	Cross II	60%	20.95**	17.00**	-6.20	6.23
		40%	19.16**	15.27**	-5.68	0.95**
Panicle length (cm)	Cross I	60%	14.53**	12.40**	-7.67	3.16**
		40%	14.87**	13.57**	-13.00	5.58**
	Cross II	60%	9.35**	5.41**	-2.50	-2.82**
		40%	11.51**	6.18**	4.36	-2.29**
Panicle width (cm)	Cross I	60%	16.44**	13.91**	-7.40	16.64**
		40%	22.11**	16.00**	4.20	21.38**
	Cross II	60%	26.78**	19.59**	-4.45	13.21**
		40%	27.96**	5.45**	1.31	14.01**
1000-grain weight (g)	Cross I	60%	11.34**	10.32**	-12.25	0.71**
		40%	14.66**	7.88**	1.33	-2.33**
	Cross II	60%	10.98**	8.80**	2.21	-5.47**
		40%	7.70**	5.10**	-2.87	-3.11**
Grain yield/plant (g)	Cross I	60%	10.77**	7.73**	-3.82	2.22
		40%	16.46**	6.17**	-1.70	6.26**
	Cross II	60%	7.02**	4.95**	-3.57	1.92
		40%	23.00**	16.49**	-4.11	7.79**

*** and ** significant at 0.05 and 0.01 probability levels, respectively. Cross I (R Sh-13 × R Sh-37) and Cross II (R Sh-18 × R Sh-14).**

The results of the scaling test, shown in Table 7 for the studied characters under drought stress conditions, indicated that at least one of the scaling test values is significant or highly significant for all of the studied traits in the two crosses, implying the adequacy of estimating different types of gene action controlling the traits in the two crosses. Robinson and Cockerham (1961) reported that, significant F_2 deviation from average F_1

and mean parental performance indicates the presence of epistatic gene action.

Table 7. Estimates of scaling test, F_2 deviation (E1) and backcross deviation (E2) for the studied traits, using the six generation means in two grain sorghum crosses under 60 and 40% ET of irrigation watering.

Trait	Cross	Irrigation treatment	Scaling tests				F2	BC
			A	B	C	D	E1	E2
Days to 50% flowering	Cross I	60%	7.67	5.33	3.31	-4.84**	0.83**	6.50**
		40%	5.52	3.19	-0.76	-4.73**	-0.19	4.35**
	Cross II	60%	2.56	-1.00	-1.60	-1.58**	-0.40	0.78
		40%	0.78	-0.33	-2.44	-1.44**	-0.61**	0.22
Plant height (cm)	Cross I	60%	-3.33	-15.00	-0.02	9.16**	-0.01**	-9.17**
		40%	-0.89	-5.56	27.56	17.00**	6.89**	-3.22
	Cross II	60%	-4.78	1.22	17.02	10.29**	4.26**	-1.78
		40%	13.11	4.22	45.64	14.16**	11.41**	8.67**
Panicle length (cm)	Cross I	60%	-1.11	-1.22	3.84	3.09**	0.96**	-1.17**
		40%	-2.44	-2.56	1.00	3.00**	0.25	-2.50**
	Cross II	60%	0.22	0.44	7.38	3.36*	1.84**	0.33**
		40%	-0.96	-1.68	0.77	1.70**	0.19	-1.32
Panicle width (cm)	Cross I	60%	-1.44	-3.17	-2.79	0.91**	-0.70**	-2.31**
		40%	-0.89	-2.11	-3.18	-0.09**	-0.79**	-1.50*
	Cross II	60%	-1.61	-0.11	-0.68	0.52**	-0.17	-0.86**
		40%	-1.38	0.12	-0.64	0.31**	-0.16	-0.63**
1000-grain weight (g)	Cross I	60%	1.28	-2.28	4.69	2.84**	1.17**	-0.50**
		40%	0.33	1.33	4.93	1.63**	1.23**	0.83**
	Cross II	60%	-0.56	1.06	2.86	1.18**	0.71**	0.25
		40%	-1.39	-0.51	6.23	4.07**	1.56**	-0.95**
Grain yield/plant (g)	Cross I	60%	-13.50	-10.50	7.60	15.80**	1.90	-12.00**
		40%	-7.84	0.33	2.18	4.84**	0.55	-3.75**
	Cross II	60%	-5.44	-5.48	3.44	7.18**	0.86	-5.46**
		40%	-4.55	-1.00	3.96	4.76**	0.99	-2.77

***and** significant at 0.05 and 0.01 probability levels, respectively. Cross I (R Sh-13 × R Sh-37) and Cross Π (R Sh-18 × R Sh-14).**

All the traits examined in the present study (Table 7) showed highly significant F_2 deviation in the two crosses under drought stress conditions, with the exception of days to 50% flowering in cross I under 40% ET and in cross II under 60% ET, panicle length under 40% ET in cross I and II respectively, panicle width under 60 and 40% ET in cross II and grain yield per plant in the two crosses which showed insignificant F_2 deviations under 60 and 40% ET, indicating the role of epistatic gene action in the inheritance of the traits studied.

The deviation of the backcross from the expected value are shown in Table 7. The backcross deviation (E2) was significant in all cases except, the BC deviation for days to 50% flowering in cross II under 60 and 40% ET, plant height in cross I under 40% ET and in cross II under 60%, panicle length and grain yield/plant in cross II under 40% ET and 1000-grain weight in cross II under 60% ET, which was non-significant. Meantime, the F_2 deviation was accompanied by backcross deviation in most cases under study, and that would ascertain the presence of epistasis in such large magnitude as to warrant great deal of attention in the breeding program for improving traits.

The estimates of the six parameters, i.e. additive (a), dominance (d) and the three epistatic types, additive × additive (aa), additive × dominance (ad) and dominance × dominance (dd) are presented in Table (8). The two crosses under normal and drought stress conditions exhibited highly significant mean effects (m) for all studied traits, indicating that these traits are quantitatively inherited. According to the obtained positive and significant results of different types of gene effects in (Table 6) it indicated the importance of additive (a) and dominance gene effect (d) and their interactions except additive gene effect, additive × dominance epistatic types of gene action in the cross II under normal conditions and dominance × dominance epistatic types of gene action was negative and significant in the cross I under normal and drought conditions suggest the less effect for (dd) in the inheritance of days to 50% flowering in the two crosses.

Table 8. Gene effects for the studied traits, using the six populations means in two grain sorghum crosses under 60 and 40% ET of irrigation watering.

Trait	Cross	Irrigation treatment	Gene effects					
			m	A	d	aa	ad	dd
Days to 50% flowering	Cross I	60%	71.80**	0.89*	7.30**	9.69**	1.17**	-22.69**
		40%	73.47**	0.78**	6.89**	9.47**	1.17**	-18.17**
	Cross II	60%	73.60**	0.78	1.16	3.16**	1.78**	-4.71**
		40%	75.33**	1.00*	-1.00	2.89**	0.56	-3.33
Plant height (cm)	Cross I	60%	176.47**	11.33**	-13.70**	-18.31**	5.83**	36.64**
		40%	170.33**	4.78**	-24.67**	-34.00**	2.33	40.44**
	Cross II	60%	164.20**	1.89	9.76**	-20.58**	-3.00	24.13**
		40%	159.47**	9.00**	-2.42	-28.31**	4.44*	10.98
Panicle length (cm)	Cross I	60%	29.27**	0.56	-2.34	-6.18**	0.06	8.51**
		40%	26.33**	0.33	-2.39	-6.00**	0.06**	11.00**
	Cross II	60%	26.73**	0.78**	-4.49**	-6.71**	-0.11	6.04**
		40%	23.02**	1.44**	-0.92	-3.40**	0.36	6.04**
Panicle width (cm)	Cross I	60%	5.59**	-0.44**	0.32	-1.04**	-0.75**	2.76**
		40%	5.07**	0.89**	1.34*	0.18	0.61**	2.82**
	Cross II	60%	5.59**	-0.44**	0.32	-1.04**	-0.75**	2.76**
		40%	4.43**	0.11	0.00	-0.62	-0.25**	2.88**
1000-grain weight (g)	Cross I	60%	26.53**	2.00**	-2.97**	-5.69**	1.78**	6.69**
		40%	24.01**	0.83**	-0.15	-3.26**	-0.50	1.60
	Cross II	60%	26.53**	2.00	-2.97	-5.69**	1.78**	6.69
		40%	25.53**	-0.33	0.23**	-2.36**	-0.81	1.86**
Grain yield/plant (g)	Cross I	60%	70.40**	0.33	-24.60	-31.60	-1.50	55.60**
		40%	63.53**	1.56	-0.11	-9.69**	-4.09*	17.20**
	Cross II	60%	62.33**	1.18	-10.20*	-14.37**	0.02	25.29**
		40%	58.60**	1.11	2.37	-9.51**	-1.78	15.06**

***and** significant at 0.05 and 0.01 probability levels, respectively. Cross I (R Sh-13 × R Sh-37) and Cross Π (R Sh-18 × R Sh-14). m = F2 mean, a = additive effect, d = dominance effect, aa = additive × additive interaction, ad = additive × dominance interaction and dd = dominance × dominance interaction.**

Concerning plant height, the important role in the inheritance of this trait was the additive gene effects and dominance × dominance epistatic types of gene action in the cross I under drought conditions (60 and 40% ET) and additive × dominance epistatic types of gene action in cross I under 60 % of irrigation water while, the dominance gene effect and dominance ×

dominance epistatic types of gene action in cross II under 60 % of irrigation water, additive gene action and additive × dominance epistatic types of gene action in cross II under 40 % of irrigation water in inheritance of these trait. Meanwhile, dominance × dominance epistatic types of gene action in the two crosses under 60 and 40% of irrigation water and additive × dominance epistatic types of gene in cross I under 40% of irrigation water, additive gene effects in cross II under 60 and 40% of irrigation water were found to be important in inheritance of panicle length than other types of gene effects. The results also showed the important role of additive gene effects, dominance gene effects, additive × dominance epistatic type of gene action in cross I under 40 % of irrigation water as well as the important role of dominance × dominance epistatic type of gene action under 60% and 40 % of irrigation water in the two crosses, in the inheritance of panicle width. In the case of 1000 grain weight, additive gene effects in cross I under both conditions (60 and 40% ET), additive × dominance and dominance × dominance types of epistasis in cross I under 60 % of irrigation water, also, dominance × dominance type of epistasis under 40 % of irrigation water in cross II and additive x dominance in cross II under 60% ET showed important role in inheritance of this trait.

Concerning grain yield/plant, it is appeared the more important role of dominance × dominance type of epistasis than the other types of gene action in the two crosses under both conditions in the inheritance of this trait. This result is supported by the findings of Audilakshmi *et al* (2005) and Setimela *et al* (2007).

The six parameters of gene action, as previously proven, had a significant influence on the investigated traits, with varying degrees of effect. Meanwhile, the positive and significant estimates for various types of gene action revealed that the dominance × dominance type of epistatic gene action, which accounted for 17 cases out of a total of 24 cases (70.8%), followed by the additive gene effect (45%) contributed by a large portion of the genetic components controlling the inheritance of the studied traits.

Genetic variances for the studied traits in the two crosses under drought stress conditions are presented in Table 9.

Table 9. Heritability estimates in broad (h_{bs}) and narrow (h_{ns}) sense and genetic advance (Δg) and the percentage (Δg%) for the studied traits, using the six populations data in the two grain sorghum crosses under 60 and 40% ET of irrigation watering.

Trait	Cross	Irrigation treatment	VP	VE	VG	V½D	V¼H	Heritability		Genetic advance	
								h_{bs}	h_{ns}	Δg	Δg%
Days to 50% flowering	Cross I	60%	17.23	1.88	15.35	12.95	2.40	89.11	75.16	6.43	8.95
		40%	19.18	2.04	17.14	14.81	2.33	89.36	77.20	6.97	9.48
	Cross II	60%	18.07	2.26	15.81	11.86	3.95	87.50	65.64	5.75	7.81
		40%	16.46	2.48	13.97	9.64	4.33	84.91	58.58	4.90	6.50
Plant height (cm)	Cross I	60%	295.18	48.58	246.61	117.50	129.11	83.54	39.81	14.09	7.98
		40%	301.16	52.09	249.07	121.00	128.06	82.70	40.18	14.36	8.43
	Cross II	60%	241.23	25.62	215.61	98.35	117.25	89.38	40.77	13.04	7.94
		40%	260.78	38.53	222.26	104.70	117.56	85.23	40.15	13.36	8.38
Panicle length (cm)	Cross I	60%	17.93	2.49	15.44	7.61	7.82	86.09	42.45	3.70	12.65
		40%	17.66	2.63	15.02	7.53	7.49	85.08	42.67	3.69	14.03
	Cross II	60%	14.33	2.50	11.83	5.02	6.81	82.58	35.05	2.73	10.22
		40%	14.55	3.30	11.25	6.96	4.29	77.33	47.84	3.76	16.33
Panicle width (cm)	Cross I	60%	2.20	0.59	1.61	1.32	0.29	73.29	60.13	1.84	30.26
		40%	2.46	0.76	1.71	1.57	0.14	69.25	63.62	2.06	40.59
	Cross II	60%	11.93	1.69	10.24	4.78	5.46	85.82	40.03	2.85	10.74
		40%	12.14	1.80	10.34	4.23	6.11	85.17	34.83	2.50	10.41
1000-grain weight (g)	Cross I	60%	11.93	1.69	10.24	4.78	5.46	85.82	40.03	2.85	10.74
		40%	12.14	1.80	10.34	4.23	6.11	85.17	34.83	2.50	10.41
	Cross II	60%	12.15	1.39	10.77	3.36	7.40	88.59	27.68	1.99	7.79
		40%	13.23	1.66	11.56	5.30	6.27	87.42	40.04	3.00	12.07
Grain yield/plant (g)	Cross I	60%	210.24	27.63	182.61	112.71	69.90	86.86	53.61	16.01	22.75
		40%	217.58	30.93	186.66	117.29	69.37	85.79	53.91	16.38	25.78
	Cross II	60%	160.39	28.08	132.31	60.44	71.87	82.49	37.69	9.83	15.77
		40%	175.57	33.30	142.27	74.53	67.74	81.03	42.45	11.59	19.77

VP = phenotypic variance, VE = environmental variance, VG = genotypic variance, V½D = additive variance, V¼H = dominance variance, Cross I (R Sh-13 × R Sh-37) and Cross Π (R Sh-18 × R Sh-14).

The variance due to additive genetic variance ($V^1/_2D$) was greater than dominance variance ($V^1/_4H$) in cross I and cross II under 60 and 40% ET for days to 50% flowering, in cross I and cross II under 40% ET for panicle length, in cross I under 60 and 40% ET for panicle width and grain yield/ plant in cross II under 40% ET. Meanwhile $V^1/_4H$ was greater than variance $V^1/_2D$ in cross I and cross II under 40% ET for plant height and 1000 grain weight, in cross I and cross II under 60% ET for panicle length in cross II under 60 and 40% ET for panicle width and under 40% ET for grain yield/ plant. In general, out of total 24 cases (two crosses under 60 and 40% ET for six traits) the dominance genetic variance ($V^1/_4H$) was controlling 54% of cases meanwhile additive genetic variance ($V^1/_2D$) was controlling 45% cases.

Estimates of heritability in broad and narrow senses and expected genetic advance from selection for the six traits in the two crosses are given in Table 9. Estimates of broad-sense heritability were high (>80%) for all the studied traits in both conditions except panicle length under 40% ET in cross II and panicle width under 60 and 40% ET in cross I. These high values suggest that genetic variation accounts for a greater share of total variation in F_2 plants. Meanwhile, the values of heritability in the narrow sense ranged from low to moderate in all investigated traits, which reflect important role of the non-additive gene action in the genetic behavior of these traits in the two crosses. These results are in harmony with Basnayake *et al* 1995, Nguyen *et al* 1998, Arunkumar *et al* 2004, Bello *et al* 2007, Elangovan *et al* (2012) and Tsegau Senbetay *et al* 2020

The expected genetic advance from selection is shown (Table 8) in the F_2 mean ($\Delta g\%$) for the studied traits, under drought conditions, was found to be low high with values ranging from 1.84% for panicle width in cross I under 60% ET to 40.59% for Panicle width under 40% ET in cross I, generally values of $\Delta g\%$ in most cases were suitable for successful selection gain.

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تقدير المعالم الوراثية للمحصول ومكوناته في الذرة الرفيعة للحبوب تحت ظروف الجفاف

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قسم بحوث الذرة الرفيعة – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية

تم إجراء هذا البحث بالمزرعة البحثية في محطة بحوث شندويل التابعة لمعهد بحوث المحاصيل الحقلية، مركز البحوث الزراعية، مصر، في المواسم من ٢٠١٩ إلى ٢٠٢١؛ لتقدير بعض المعالم الوراثية لمحصول الحبوب وبعض صفات المحصول ذات الصلة، باستخدام العشائر الستة مثل P_1 و P_2 و F_1 و F_2 و BC_1 و BC_2 لهجينين من الذرة الرفيعة هما RSh-13 × RSh-37 (Cross I) and RSh-18 × RSh-14 (Cross II) حيث تم تقييم P1 , P2 وF1 تحت ثلاث مستويات من الري (١٠٠% و ٦٠% و٤٠% من البخر نتح) فى ثلاث تجارب منفصلة مع إضافة F2 و BC1 وBC2 لتجارب تحت مستويات (٦٠ % و٤٠% من البخر نتح) في تجربتين منفصلتين. اشارت نتائج تحليل التباين إلى وجود فروق معنوية بين الأجيال المدروسة من كل هجين للصفات المدروسة. كما تم العثور على الفروق الوراثية داخل مجموعة F2 حيث انها معنوية لجميع الصفات المدروسة في الهجينين. كانت قيم اختبار التحجيم لــ A و B و C و D معنوية لمختلف الصفات المدروسة، مما يشير إلى وجود تفاعل غير أليلي. أوضحت التقديرات الإيجابية والمعنوية لأنواع المختلفة من الفعل الجيني أن نوع السيادي × السيادي من النوع التفوقى ، ويمثل ١٧ حالة من إجمالي ٢٤ حالة (٧٠,٨٪) ، يليه التأثير الجيني المضيف (٤٠%). ساهم بجزء كبير من المكونات الجينية التي تتحكم في وراثة الصفات المدروسة. اعطت قيم كفاءة التوريث بمعناها العام (اكبر من ٨٠%) فى معظم الصفات المدروسة تحت مستويات (٦٠ % و٤٠% من البخر نتح)، كما تراوحت قيم كفاءة التوريث بمعناها الخاص من منخفضه الى متوسطة فجميع الصفات التى تم دراستها تحت معاملتى الجفاف. قيم التحسين الوراثي المتوقع من الانتخاب كنسبة مئوية من متوسط F2 للصفات المدروسة عالية بدرجة كافية للانتخاب لتحسين الصفات المدروسة فى الاجيال الانعزالية

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