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Selection Efficiency for Grain Yield under Normal Irrigation and Water Stress Conditions in grain sorghum (*Sorghum bicolor* L. Moench)

Aml A. Tag El-Din, Eatemad M. Hussien and Omar A.Y. Abd Elraheem

Department of Grain Sorghum Research, Field Crops Research Institute, Agriculture Research Center, Giza, Egypt

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ABSTRACT

The present research aims to study the efficiency of pedigree selection for grain yield/plant under normal irrigation and water stress conditions. Breeding fields were conducted in Arab El-Awamer at Assuit gov. during 2019, 2020, and 2021 seasons. Two cycles of pedigree selection for grain yield/plant were practiced separately under normal irrigation and water stress conditions. The base population was the F3 population of (ZSV -14 and MR -812). In the third year, selection under normal irrigation and water stress were evaluated in both environments. The phenotypic variance was slightly larger than the genotypic one and generally decreased from the F3 to the F5 generation. Broad-sense heritability was 87.53 and 71.99 % under normal irrigation compared to 88.22 and 80.87% under water stress after cycle1 and 2, respectively. The average observed gains of normal irrigation selections were 39.2 and 36.59 % from the bulk sample and 20.84 and 18.12 % from the better parent, while the average observed gains of water stress selections were 27.81 and 31.96% from the bulk sample and 10.93 and 14.11% from the better parent, when evaluation practiced under normal irrigation and water stress, respectively. Grain yield/plant revealed a positive and high phenotypic correlation with the the1000-kernel weight under normal irrigation and water stress after two cycles of selection for grain yield/plant. The results of the path-coefficient analysis revealed that 1000-kernel weight had the highest positive direct effect on grain yield/plant followed by panicle width after two cycles of pedigree selection for grain yield/plant under normal irrigation and water stress conditions.

Keywords: drought susceptibility, pedigree selection, path-coefficient, selection response, sorghum.

1. Introduction

Sorghum (*Sorghum bicolor L. Moench*) is commonly grown in semiarid areas as an important cereal where production is almost limited by severe water stress. In Egypt, the cultivated area from grain sorghum crop at Assuit and Sohag governorates is about 70% from the entire area of 400.000 feddan (feddan = 4200 m^2). The importance of sorghum increased more and more after adding 20% of the grain sorghum to making bread. Also, sorghum is the best surviving crop in harsh environments found in Upper Egypt. The ability of grain sorghum to with water deficits is associated with numerous plant traits that contribute to drought tolerance, where drought tolerance has been one of the major objectives likewise improving grain yield and adaptation.

Water stress is one of the main abiotic stress and an important factor in reducing the yield of cultivated plants in semi-arid agricultural lands (Amin-Alim, 2011). Therefore, breeding programs should aim to develop high-yielding cultivars over a wide range of stress and non-stress environments. The efficiency of a breeding program for drought tolerance depends largely on the selection criteria and selection method used to achieve genetic improvement through selection, in addition to the complexity of drought itself (Passioura, 2007). Pedigree selection can be used to identify superior genotypes for grain yield in a cultivar development program. Breeding for drought tolerance should focus on increasing genetic variance and choosing a selection environment that is representative of the target

Corresponding Author: Aml A. Tag El-Din, Department of Grain Sorghum Research, Field Crops Research Institute, Agriculture Research Center, Giza, Egypt.
E-mail: amltag@yahoo.com

environment. Some researchers believe in selection under favorable conditions (Betran *et al*., 2003), others prefer selection in a target stress condition (Rathjen, 1994), while others yet have chosen a mid-point and believe in selection under both favorable and stress conditions (Byrne *et al*., 1995). The pedigree selection method has become the most popular of plant breeding procedures. Most Egyptian sorghum cultivars were produced through this method. It is preferred by plant breeders because it is versatile, relatively rapid, and makes possible the conducting of genetic studies along with the plant breeding work. Evaluation and consequent selection of improved lines are the first step in the breeding process that largely depends on the knowledge and understanding of the magnitude of genetic variability, heritability, and correlations of crop traits (Ganesh and Thangavelu, 1995). Selection is considered the most ancient and basic procedure in plant breeding in which desired plants are selected from the genetically variable population. The relationship information between yield and yield-contributing attributes is very important for a successful breeding program (Ganesh and Sakila, 1999). Plant selection with the appropriate type of sorghum is essential for increasing grain yield and developing new sorghum varieties. Since grain yield is a polygenic trait, it is essential to identify yield-contributing attributes for selecting high-yielding sorghum cultivars (Biswas *et al*., 2001).

The correlation coefficient is an important statistical tool that can help breeders select the high-yield genotypes. Path analysis divides the correlation coefficients into direct and indirect effects. Consequently, correlation studies along with path analysis provide a better understanding of the association of different traits with grain yield.

The objectives of the present research were to study; 1) the efficiency of pedigree selection for grain yield/plant under normal irrigation and water stress conditions, 2) the sensitivity of selected lines to water stress, and 3) the correlation and path coefficient for yield and its components in the base population and cycle two of selection under normal irrigation and water stress.

2. Materials and Methods

The present research was carried out at Arab El-Awamer Station, Agricultural Research Center (ARC), Assiut, Egypt,(latitude 27°,′ 11 N and longitude 31°, 06 ′ E) during 2019, 2020, and 2021 growing seasons, Soil of the experimental site were analyzed in seasons according to (Chapman and Pratt, 1978) and results are shown in (Table 1). The families, original parents, and bulked plants were evaluated for drought tolerance under sprinkler irrigation system in sandy calcareous soil in two separate experiments:

1- First experiment (normal sprinkler irrigation) was grown in supplemental water and applied regularly as recommended, twice a week for an hour|(Normal irrigation).

2- Second experiment (water stress) in which the families, original parents, and bulked plants were irrigated by sprinkler irrigation, once a week for an hour (Water stress).

Table 1: Some physical and chemical properties of experimental site.

Chemical properties									
PH (1:1)	EC ds/m (1:1)	Soluble cations (meq /L)				Soluble anions (meq /L)			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^- + HCO_3^-	CL-	Available phosphorus (ppm)	Total nitrogen (%)
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 (Volumetric %)			Content	O.M (%)	$CaCO_3$ (%)	Bulk density
Sand	Silt	Clay		S.P	F.C	W.P.				
89.9	7.1	3.0	Sandy	23.3	10.9	4.5		0.19	30.9	1.63

The breeding materials used were 100 F3 families traced back to 100 random plants from the F1 generation origination from the cross (ZSV-14 × MR-812). The pedigree of the parents is presented in (Table 2).

Table 2. The pedigree of the parents of grain sorghum population.

Parent	Pedigree
ZSV-14	Zimbabwe
MR-812	Zambia

2.1. In 2019 season (F3 - generation):

Original parents for 100 F3 families, and F3 bulked random sample (a mixture of an equal weight of grains from each plant to represent the generation mean) were sown in two field experiments using a randomized complete block design with three replications. The experiment was under normal irrigation, while the experiment was under water stress. The experimental unit was one row, four meters long, 60 cm apart, and 20 cm between hills. The two experiments adopted the recommended cultural practices for grain sorghum production throughout the growing season. At the end of the season, a separate analysis of variance of the two treatments was applied on a plot mean basis. The best 20 high-yielding plants from the best 20 high-yielding families were saved to give the F4 families in each environment.

2.2. In 2020 season (F4 - generation):

The 20 F4 families selected under normal irrigation with the parents and F4 bulk sample were sown under normal irrigation and the 20 F4 families selected under water stress with the parents and F4 bulk sample were sown under water stress. The experimental design, number of replications and cultural practices were properly adopted as the same in the first season. Data were recorded as previously mentioned. At the end of the season, each group of families (20 families) for each environment of selection was analyzed separately. The best 10 high-yielding plants from the best 10 high-yielding families were saved in each environment to give the F5 families.

2.3. In 2021 season (F5 - generation):

The 10 high-yielding F5 families selected under normal irrigation + the 10 high-yielding F5 families selected under water stress environment + the two parents + the bulk sample were evaluated under both environments. Data were recorded on ten guarded plants from each family. The studied traits were 50% flowering (days), plant height (cm), panicle length (cm), panicle width (cm), 1000-Kernel weight (g), and grain yield/plant (g).

2.4. Statistical analysis:

According to Steel and Torrie (1997), data were subjected to proper statistical analysis. Two analyses of variance were done, the first was for families + parents + bulk sample), and the second was for the selected families to calculate heritability, genotypic and phenotypic coefficient of variations. Genotype means were compared using Revised Least Significant Differences (LSD) test at 5 and 1% levels of probability, according to El-Rawi and Khalafala (1980). The phenotypic ($\sigma 2$ p) and genotypic ($\sigma 2$ g) variances and heritability in the broad sense (H %) were calculated according to Walker (1960). The phenotypic (P.C.V %) and genotypic (G.C.V %) coefficients of variability were calculated as outlined by Burton (1952), where: -

a) The phenotypic coefficient of variability (p.c.v %) = $(\sigma p / \bar{\bar{X}}) \times 100$.
b) The genotypic coefficient of variability (g.c.v %) = $(\sigma g / \bar{\bar{X}}) \times 100$.

Drought susceptibility index (DSI) was computed according to the method of Fischer and Maurer (1978). The sensitivity and relative merits of selected families were assessed as described by Falconer .(1990)

2.5. Path coefficient analysis:

Path coefficient analysis was done according to the procedure followed by Dewey and Lu (1959) for yield and its components under normal irrigation and water stress in the base population and the second cycle of selection.

3. Results and Discussion

3.1. Description of the base population:

The analysis of variance (Table 3) indicated highly significant differences among the F_3 families for all studied traits under normal and water stress environments, indicating that selection in the base population would be effective. Comparing the population mean for grain yield/plant with mean of the two parents indicates over-dominance under normal irrigation, in which the population mean (53.01 g) outyielded the higher yielding parent, ZSV-14 (48.93 g) and tended to show complete dominance (47.51 g) towards the higher parent ZSV-14 (44.60 g) under water stress. The reduction caused by water stress in the F_3 families was 1.775, -0.747, 9.091, 14.94, 19.02 and10.38 % for Plant height, days to 50% flowering, panicle length, panicle width, 1000-kernel weight, and grain yield /plant, respectively. These results are in harmony with those obtained by Chigwe (1984), Al-Naggar *et al.* (1999), Mahdy *et al.* (2000), Ali (2002), Amir (2004), Amir (2008), Mohamed (2012), Mahmoud *et al.* (2013), Soliman *et al.* (2015) and Tag El-din (2015).

The phenotypic (P.C.V. %) and genotypic (G.C.V. %) coefficient of variations were sufficient for selection in the base population and ranged from (4.82 – 16.89 %) and (4.57– 15.87%) under normal irrigation, and from (4.54–18.79 %) and (4.33 – 16.27 %) under water stress; for days to 50% flowering, panicle length and 1000- kernel weight, respectively. These results indicate that selection among F_3 families for grain yield could be effective. These findings are in line with those reported by Ali (2002), Kenga *et al*. (2006), El-Morshidy *et al*. (2010), Ali *et al*. (2012), Ali (2012), Ali *et al.* (2007), Abd-El-Haleem *et al*. (2012), Mahdy (2012) and Hassaballa *et al.* (2018). Heritability estimate is considered one of the most important parameters for selection response in early generations. Estimates of broad sense heritability were high for all studied traits. In general, high estimates of broad-sense heritability Table 3 indicate that the environmental effects were small compared to genetic effects. These results are in line with those reported by Mahdy *et al.* (2000), Ali *et al*. (2012), Salous *et al*. (2014), and Soliman *et al*. (2015), they found that heritability estimate for grain yield under non-stress conditions was slightly higher than that under stress conditions, in this study heritability estimate for grain yield under stress conditions was slightly higher than that under non-stress conditions.

Table 3: Means, Mean squares, phenotypic (P.C.V %), and genotypic (G.C.V. %) coefficients of variability and heritability in broad sense (H %) for the studied traits in the base population (F3) under normal irrigation and water stress environments.

Env.	Trait	Mean Squares			Mean				Red.* %	P.C.V. %	G.C.V. %	H.b.s. %
		Reps.	Families	Error	F_3	P_1	P_2	Bulk				
Normal irrigation	Plant height	60.81	314.9**	12.38	169.0	172.0	168.7	164.5		6.30	5.94	89.07
	50% flowering	74.52	46.22**	1.648	84.36	77.67	80.33	80.67		4.82	4.57	90.02
	P.L.	106.5	34.84**	1.47	21.01	20.53	22.40	18.10		16.89	15.87	88.33
	P.W.	32.82	1.481**	0.276	7.194	6.833	6.667	5.900		11.44	8.81	59.27
	1000- k. W	3.780	50.08**	1.604	26.18	24.93	22.70	21.07		16.10	15.35	90.97
	G.Y\P	10.17	128.7**	2.632	53.01	48.93	47.37	45.10		12.61	12.23	94.11
Water stress	Plant height	30.17	315.2**	10.20	166.0	170.4	165.6	163.4	1.775	6.37	6.07	90.88
	50% flowering	9.943	42.02**	1.334	84.99	82.00	84.33	86.33	-0.747	4.54	4.33	91.04
	P.L.	54.85	31.80**	3.417	19.10	18.13	19.70	16.47	9.091	18.79	16.10	73.47
	P.W.	1.669	1.209**	0.247	6.119	6.200	5.933	5.467	14.94	12.31	9.25	56.49
	1000- k. W	1.328	37.32**	1.631	21.20	20.53	20.30	19.77	19.02	17.35	16.27	87.94
	G.Y	0.710	137.1**	1.252	47.51	44.60	42.07	40.47	10.38	14.36	14.16	97.31

*. Reduction

3.1. Selection for grain yield/plant

3.1.1. Variability and heritability estimates:

After two cycles of selection for grain yield/plant, there were significant indices differences among selected families for grain yield/plant and other studied traits under both environments Table 4. These results indicate the presence of variability for further cycles of selection. Similar results were obtained by, Ali (2002), Mahdy *et al.* (2000), Mahdy (2012), Ahmed *et al*. (2014), and Soliman *et al*. (2015). The effect of selection for two cycles on variability and heritability estimates of grain yield plant is shown in Table 5. The phenotypic and genotypic variances in grain yield/ plant were high in the F_3 generation under both normal and water stress conditions and dropped rapidly after cycle one (C_1) and cycle two (C_2). This may be due to the increase of homozygosity in the F_5 generation. The

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phenotypic and genotypic variances were (44.7, 12.7 and 2.8 %) and (42.0, 11.1 and 2.0 %) under normal irrigation, then under water stress (46.5, 10.4 and 5.0%) and (45.3, 9.1and 4.1%) in C_0, C_1 and C_3, respectively. The phenotypic (P.C.V. %) and genotypic (G.C.V. %) coefficient of variability under normal irrigation were (12.61 and 12.23 %) for grain yield/plant in the base population and decreased to (5.68 and 5.32 %) after C_1 and to (2.57 and 2.18 %) after C_2. The phenotypic and genotypic coefficient of variability under water stress showed the same trend. The P.C.V. % and G.C.V. % under water stress were very close to those under normal irrigation. The G.C.V% was slightly less than the P.C.V% under both environments. The close estimates of phenotypic and genotypic variability resulted in high estimates of broad sense heritability in the two cycles of selection. Notably, heritability estimates for grain yield/plant were 94.11 and 97.31% in the base population (F3) and decreased to 87.53 and 88.22 % after C1 and 71.99 and 80.87 % after C2 under normal irrigation and water stress, respectively. These results are in agreement with those of Ali (2002), Ali *et al.* (2007), Abd El-Kader (2011), Ali *et al.* (2012), Ali (2012), Mahdy (2012), Soliman *et al.* (2015), and Hassaballa *et al.* (2018).

Table 4: Mean squares for families selected for high grain yield/plant and correlated traits in F4 and F5 generations under normal irrigation (N) and water stress (D) conditions.

Item	Env.	S.O.V.	d.f	Selection criterion	Correlated traits				
				GY/P	Plant height	50%Flowering	P.L.	P.W.	1000-k.W
F4	N	Rep.	2	1.166	9.921	3.617	5.500	1.781	10.25
		Families	19	34.91**	416.9**	76.09**	47.43**	1.204**	16.07**
		Error	38	1.583	5.616	0.757	0.925	0.058	2.538
	D	Rep.	2	1.536	15.70	1.117	2.781	0.416	0.804
		Families	19	28.64**	443.0**	66.17**	31.43**	0.600**	7.093**
		Error	38	1.221	5.895	1.029	1.132	0.068	0.851
F5	N	Rep.	2	2.152	5.126	3.050	0.987	0.005	0.426
		Families	19	6.750**	220.6**	32.26**	37.06**	1.361**	56.18**
		Error	38	0.775	4.381	0.752	0.475	0.070	0.908
	D	Rep.	2	4.796	4.681	0.650	0.117	0.078	0.604
		Families	19	13.16**	211.7**	34.35**	32.74**	1.102**	34.01**
		Error	38	0.962	4.144	0.492	0.315	0.076	0.931

N = normal irrigation, D = water stress ** Significant at 1% level of probability.

Table 5: Variability and heritability estimates of grain yield/plant after two cycles of selection under normal irrigation (N) and water stress (D) conditions.

Selection cycle	σ^2 p		σ^2 g		P.C.V. %		G.C.V. %		H %	
	N	D	N	D	N	D	N	D	N	D
F3 (C0)	44.7	46.5	42.0	45.3	12.61	14.36	12.23	14.16	94.11	97.31
F4 (C1)	12.7	10.4	11.1	9.1	5.68	5.57	5.32	5.23	87.53	88.22
F5 (C2)	2.8	5.0	2.0	4.1	2.57	4.05	2.18	3.64	71.99	80.87

3.1.2. Means and observed gains under normal irrigation evaluation:

The two groups of families selected for high grain yield/plant for two cycles, either under normal irrigation or water stress were evaluated in the F_5 generation under both environments and resented in Table 6. The group of F_5 families selected for high grain yield/plant under normal irrigation and evaluated under normal irrigation ranged from 61.67 for family No. 59 to 67.80 g for family No. 44 with an average of 65.34 g/plant. The average direct observed gain from selection significantly ($P<0.01$) out yielded the bulk sample by 39.23 % and from the better parent by 20.84%. All selected families selected for grain yield/plant showed highly significant observed gain from the bulk sample and better parent ranged from 31.41 to 44.47 and from 14.06 to 25.39%, respectively.

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The group of F5 families selected for high grain yield/plant under water stress and evaluated under normal irrigation ranged from 58.00 for family No. 6 to 63.00 for family No. 65 with an average of 59.98 g/plant. The average direct observed gain from selection significantly (P<0.01) out yielded the bulk sample by 27.81 % and from the better parent by 10.93 %. Furthermore, all the selected families highly significant observed gain from the bulk sample ranged from 19.75 to 34.24 %, nine of them showed highly significant observed gain from the better parent ranging from 7.27 % for family No. 6 to16.52 % for family No.65.

Table 6: Mean grain yield/plant and observed gain from the bulk sample (OG% Bulk) and from the better parent (OG% BP) for the selected families after two cycles of selection for grain yield under normal irrigation and water stress conditions.

Item		Fam. No.	Environment of evaluation					
			Normal irrigation			Water stress		
			Mean	OG % Bulk	OG % BP	Mean	OG % Bulk	OG % BP
Environment of selection	Normal irrigation	4	65.03	38.57**	20.27**	60.53	37.98**	19.32**
		12	65.27	39.08**	20.71**	59.97	36.70**	18.21**
		22	67.17	43.13**	24.23**	62.40	42.24**	23.00**
		23	67.27	43.34**	24.41**	59.60	35.86**	17.48**
		32	65.17	38.87**	20.53**	61.93	41.17**	22.08**
		44	67.80	44.47**	25.39**	60.63	38.20**	19.52**
		59	61.67	31.41**	14.06**	59.83	36.38**	17.94**
		65	63.23	34.73**	16.94**	59.00	34.49**	16.30**
		71	66.43	41.55**	22.86**	55.67	26.90**	9.74**
		83	64.33	37.08**	18.98**	59.63	35.92**	17.54**
		Avg.	65.34	39.23**	20.84**	59.92	36.59**	18.12**
	Water stress	6	58.00	23.59**	7.27**	53.40	21.72**	5.26**
		14	58.27	24.16**	7.77**	54.50	24.23**	7.43**
		23	62.97	34.18**	16.46**	59.07	34.65**	16.44**
		32	61.93	31.96**	14.54**	58.13	32.51**	14.59**
		35	59.33	26.42**	9.73**	54.00	23.09**	6.45**
		44	60.63	29.19**	12.13**	56.50	28.79**	11.37**
		61	56.20	19.75**	3.94	51.67	17.78**	1.85
		65	63.00	34.24**	16.52**	59.60	35.86**	17.48**
		71	60.67	29.28**	12.21**	55.00	25.37**	8.42**
		84	58.77	25.23**	8.69**	54.73	24.75**	7.88**
		Avg.	59.98	27.81**	10.93**	57.89	31.96**	14.11**
		ZSV-14	54.07			50.73		
		MR-812	49.27			47.10		
		Bulk	46.93			43.87		
L.S.D. 0.05			1.792			1.826		

OG = observed gain *, ** Significant at 5 and 1% levels of probability, respectively.

The group of F_5 families selected for high grain yield/plant under normal irrigation and evaluated under water stress ranged from 55.67 for family No. 71 to 62.40 for family No.22 with an average of 59.92 g /plant. The average direct observed gain from selection significantly (P<0.01) out yielded the bulk sample by 36.59 % and from the better parent by 18.12%. All selected families selected for grain yield/plant showed highly significant observed gain from the bulk sample and better parent ranged from 26.90 to 42.24 and from 9.74 to 23.00%, respectively.

The group of F5 families which selected for high grain yield/plant under water stress and evaluated under water stress ranged from 51.67 for family No. 61 to 59.60 for family No. 65 with an average of 57.89 g/plant. The average direct observed gain from selection significantly ($P<0.01$) out yielded the bulk sample by 31.96 % and from the better parent by 14.11 %. Furthermore, all the selected families highly significant observed gain from the bulk sample ranged from 17.78 to 35.86 %, nine of them showed highly significant observed gain from the better parent ranging from 5.26 % for family No. 6 to17.48% for family No.65.

3.1.3. Drought susceptibility index and sensitivity to environments:

The drought susceptibility index (DSI) and sensitivity to environments of the selected families for grain yield/plant are presented in Table 7. The results of the selected families for two cycles under normal irrigation (normal group), when evaluated under both environments, indicated that six families, i.e., No. 4, 22, 32, 59, 65, and 83 showed drought susceptibility index (DSI) of 0.89, 0.91, 0.64, 0.38, 0.86 and 0.94, respectively. The six families which gave DSI less than one, gave also values less than one (less sensitive) in the sensitivity test. These families could be used as a source of drought tolerance. Furthermore, it could be noticed that six superior families, were less susceptible and less sensitive to drought and showed a highly significant observed gain over the better parent under normal irrigation and water stress. These families could be promising families. The results of families which selected under water stress and evaluated under both environments showed that, five families, No. 12, 22, 23, 44, and 65 gave drought susceptibility indexes of 0.94, 0.90, 0.89, 0.99, and 0.78, indicating less susceptibility. All these families gave also values less than one in the sensitivity test**.** Similar results were obtained by, Abd-Elrahman (1985), Ali (2002), and Hassaballa *et al.* (2018).

Table 7: Drought susceptibility index (DSI) and sensitivity (S) to environments of selected families under normal irrigation and water stress after two cycles of selection for grain yield/plant.

Environment of selection									
Normal irrigation selections					**Water stress selections**				
Fam. No.	**N**	**D**	**DSI**	**S**	**Fam. No.**	**N**	**D**	**DSI**	**S**
4	65.03**	60.53**	0.89	0.865	**6**	58.00**	53.40**	1.15	0.991
12	65.27**	59.97**	1.04	1.015	**14**	58.27**	54.50**	0.94	0.809
22	67.17**	62.40**	0.91	0.888	**23**	62.97**	59.07**	0.90	0.774
23	67.27**	59.60**	1.46	1.425	**32**	61.93**	58.13**	0.89	0.767
32	65.17**	61.93**	0.64	0.621	**35**	59.33**	54.00**	1.30	1.123
44	67.80**	60.63**	1.35	1.322	**44**	60.63**	56.50**	0.99	0.851
59	61.67**	59.83**	0.38	0.373	**61**	56.20**	51.67**	1.17	1.008
65	63.23**	59.00**	0.86	0.836	**65**	63.00**	59.60**	0.78	0.675
71	66.43**	55.67**	2.07	2.025	**71**	60.67**	55.00**	1.35	1.168
83	64.33**	59.63**	0.94	0.913	**84**	58.77**	54.73**	1.00	0.859
ZSV-14	54.07	50.73	0.79	0.772	**ZSV-14**	54.07	50.73	0.90	0.772
MR-812	49.27	47.10	0.56	0.551	**MR-812**	49.27	47.10	0.64	0.551
Bulk	46.93	43.87	0.83	0.815	**Bulk**	46.93	43.87	0.94	0.815
Avg.	65.34**	59.92**		1.037	**Avg.**	59.98**	57.89**		0.436

N = normal irrigation , D = water stress, S = sensitivity
*, ** significant observed gain from the better parent at 0.05 and 0.01 levels of probability; respectively.

3.2. The phenotypic correlation after two cycles of selection for grain yield/plant:

The phenotypic correlations among traits after two cycles of selection for grain yield/plant under normal irrigation and water stress are shown in Table 8. After two cycles of selection the coefficients of phenotypic correlation under normal irrigation between grain yield/plant and each of plant height, days to 50% flowering, panicle length, panicle width, and 1000-kernel weight were 0.085, -0.328, 0.130, 0.534 and 0.681, respectively. These results indicate that the most effective components in the grain yield of sorghum grain could be panicle width and 1000-kernel weight. This means that, selection played on the highest correlated trait with grain yield/plant (panicle width and 1000-kernel weight) in the base population. The coefficients of phenotypic correlation under water stress were 0.090, -0.062, 0.225, 0.558, and, 0.563 between grain yield/plant and the above- mentioned traits, respectively. These results indicated that selection under water stress increased the correlation between grain yield and each panicle width and 1000-kernel weight. These results are in agreement with those of, Ali (2002), Tag El-din (2015), and Hassaballa *et al.* (2018).

Table 8: Phenotypic correlation among the studied traits for the F5 generation under normal (above diagonal) and water stress (below diagonal) conditions.

Trait	Plant height	50% flowering	Panicle length	Panicle width	1000 - k. W	Grain yield
Plant height	--	-0.095	0.252	0.089	-0.050	0.085
50% flowering	-0.138	--	0.111	-0.344	0.0001	-0.328
Panicle length	0.169	0.146	---	0.339	0.478*	0.130
Panicle width	0.026	-0.306	0.280	---	0.387	0.534*
1000- K.W	-0.125	0.230	0.458*	0.329	---	0.681**
Grain yield	0.090	-0.062	0.225	0.558*	0.563**	---

*, ** Significant at 5 and 1% levels of probability, respectively.

3.3. Path coefficient analysis after two cycles (F5) of selection for grain yield/plant:

The Partitioning of phenotypic correlation into direct and indirect effects by path analysis under normal irrigation revealed that the highest direct effect on grain yield/plant was exerted by 1000-kernel weight 0.692 in cycle two F_5 Table 9.

Table 9: Partitioning of phenotypic correlation coefficients into direct and indirect effects by path coefficient analysis for cycle two (F5) of pedigree selection for grain yield /plant under normal and water stress conditions.

Correlation		Normal irrigation	Water stress
		Cycle two (F_5)	Cycle two (F_5)
1-P.L VS G.Y/P	**r**	0.130	0.225
Direct effect	P_{14}	-0.329	-0.113
Indirect effects via P.W	$r_{12}P_{24}$	0.128	0.122
Indirect effects via 1000-KW	$r_{13}P_{34}$	0.331	0.216
	Total	0.130	0.225
2-P.W VS G.Y \ P	**r**	0.534	0.558
Direct effect	P_{24}	0.378	0.434
Indirect effects via P.L	$r_{12}P_{14}$	-0.111	-0.0315
Indirect effects via 1000- KW	$r_{23}P_{34}$	0.268	0.155
	Total	0.534	0.558
3-1000- K-W VS G.Y \ P	**r**	0.681	0.563
Direct effect	P_{34}	0.692	0.472
Indirect effects via P.L	$r_{13}P_{14}$	-0.157	-0.0516
Indirect effects via P.W	$r_{23}P_{24}$	0.146	0.143
	Total	0.681	0.563
Residual factor		0.608	0.719

P.W= panicle width, P.L = panicle length, G.Y\ P = grain yield per plant , K.W= Kernel weight

Moreover, the highest indirect effects on grain yield /plant were also1000-kernel weight 0.331. These results suggested that 1000-kernel weight exhibited to be powerful traits as a yield component and must be given preference in selection to improve grain yield/plant. The Partitioning of phenotypic correlation into direct and indirect effects by path analysis under water stress revealed that the highest direct effect on grain yield/plant was exerted by 1000-kernel weight 0.472 followed by panicle width 0.434. Moreover, the highest indirect effects were correlated also with also1000-kernel weight across cycle two of selection 0.216. These results are in agreement with those of Mahdy *et al*. (1982), Saadalla (1983), Bakheit (1989), Bakheit (1990), Ali (2002), Tag El-din (2015), Hassaballa *et al.* (2018) and Abebe *et al.,* (2020).

Declaration of competing interest
The authors declare no competing interests.

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