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Research Article

Assessment of some Promising Bread Wheat Genotypes Under Water Deficit Conditions

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Abstract:

The current study was carried out at the Experimental Farm of El-Gemmeiza Agricultural Research Station, ARC, Egypt, in two seasons 2018/19 and 2019/20. Eight bread wheat promising lines consists of five promising lines (1, 2, 3, 4 and 5) and three commercial cultivars (Sahel 1, Sids1 and Gemmeiza 9). In first season, the eight wheat genotypes were crossed using a half diallel mating design excluding reciprocal. These crosses (28) with its parents (8) were evaluated under normal and water stress conditions through second season. The results cleared that both additive and non-additive genetic variances were found to be involved in the inheritance of the studied trails, however, non-additive gene effects more important. Water stress treatment decreased significantly means of all genotypes for all the studied characters. The reduction of grain yield plant^{-1} was showed values varied from 6.6% to 37.42%. Two genotypes Line 5 and Sahel 1 were found be the best general combiners for no. of days to maturity, no. of kernels spike-1 and 1000-kernel weight, The cross Line 5 x Sids 1 showed desirable SCA effects for both no. of spikes plant-1 and grain yield under both normal and water stress conditions and their combined data. Low heritability estimates in narrow sense were detected for no. of days to maturity and grain plant-1, meanwhile, the remaining characters had moderate to high estimates. The most tolerant genotype for water stress was line 3 and the combination Line 4 x Sids 1 according to SSI, TOL and YI indices. Moreover, the crosses Line 1 x Line 3, Line 2 x Gemmeiza 9, Line 3 x Sahel 1 and Line 4 x Line 5 were the most tolerant as they recorded lower values for both SSI and TOL indices. Positive and significant correlations were found among grain yield plant^{-1} with plant height.

1. Introduction

Wheat (*Triticum aestivum* L.) is the most important winter edible crop in Egypt. Global wheat production in the major production regions is being threatened by recurrent drought that is predicted to increase with climatic change (Li et al., 2009). Drought affects 60% of the wheat production in high-income countries and 30% in least developed ones (Ahmad et al., 2018). Up to 70% of yield, losses can occur due to lack or limited water as well as drought (Nouri-Ganbalani et al., 2009).

On the other hand, limited water resources in Egypt are the major factor facing expansion of wheat growing areas. Additionally, climate changes are expected to increase risks of drought. Thus, breeding drought tolerance crops is vital to both mild and severe stress conditions. This implies a need for better characterization of crop biodiversity in order to understand their response to drought as a drought resistance, and to develop better information on the physiological mechanisms crucial to increase production of a crop under drought conditions (Almeselmani et al., 2015).

The drought tolerant wheat varieties are the ultimate means of safeguarding the crop against adverse effects of drought. However, drought tolerance is a complex trait that is controlled by numerous genes, each with minor effects (Bernardo, 2008). Despite these challenges, determination of the genetic diversity existing within and between wheat populations remains the basis for elucidation of the genetic structure and for improvement of quantitative traits, including drought tolerance. Advance in tolerance of genotypes to water deficit is the main objective in long term breeding programs in dry and semidry regions (Mkhabela et al. 2019; Thungo et al., 2019).

The rates of yield increase are still too low to catch up with the projected 70% rise in wheat demand by 2050 (CIMMYT 2014). Much of the yield progress reported under low yielding environments has been based on evaluations under several biotic and abiotic constraints including drought and/or moisture stress, which in turn affects the characteristics and yield productivity of field crops, via wheat. Whereas the drought and moisture stress are known to reduce biomass, tillering ability, grains per at any stage, when it occurs. Therefore, the overall effect of spike and grain size moisture stress depends on intensity and length of stress (Bukhat, 2005). Water stress imposed during later stages might additionally cause a reduction in number of kernels ear-1 and kernel weight (Gupta et al., 2001). Moreover, Zareian and Hamidi (2014) reported that water stress through with holding irrigation at the ear emergence and grain filling phases reduced grain yield and its components. Esmail et al. (2016) evaluated 25 genotypes of bread wheat under deficit water conditions and they found highly significant differences among the genotypes for all characters studied, indicating the presence of considerable variability among them. Water stress not only affects the morphology, but also severely affects the metabolism of the plant. The extent of modification depends upon the cultivar, growth stage, and type of agronomic character, duration and intensity of stress (Mark and Antony, 2005; Noreldin and Mahmoud, 2017).

Therefore, the agronomic characters are essential cornerstones of breeding programs. A number of yield components are used not only in breeding programs, but also in genotype description. Monitoring such yield and yield components separately or their relationships each other lights the way for breeding programs, agronomic studies and genotype classification (Yang et al., 2009). Shortage of water was stated to have a negative effect on most agronomic characteristics in wheat similar to plant height and yield and yield components (Abd El-Kreem et al., 2019, Darwish et al., 2020; Shehab-Eldeen and Farhat, 2020).

On the other hand, selecting wheat cultivars based on their yield performance under drought conditions is a common approach; therefore, some drought stress indices or selection criteria have been suggested by different researches (Talebi et al., 2009; Pireivatlou et al., 2010). This is because losses of yield are the main concern of plant breeders and they emphasis on yield performance under water stress conditions (Nazari and Pakinyat, 2010). Sio-Semardeh et al. (2006) used drought tolerant indices in wheat and found that under moderate stress, mean productivity, geometric mean productivity and stress tolerance index were more effective in identifying high yielding cultivars in both drought-stressed and irrigated conditions. Several studies reported that water use efficiency values were higher under water deficit than high irrigation condition, especially when irrigation is applied in the critical growth stages of plant (Mandal et al., 2005). Singh et al. (2009) found that, grain yield and yield components of wheat were decreased with decreasing irrigation water amounts. El-Melegy (2005), Wang et al. (2012) and Noreldin (2017) concluded that maximum grain yield and minimum water use efficiency of wheat was recorded by irrigation with recommended requirements under sandy soils conditions whereas, water use efficiency generally decreased linearly with increasing seasonal irrigation rates and could be tolerance for water deficit.

Many tolerance indices for water deficit were used to describe the tolerant wheat genotypes and may be constructed using water stress tolerance or water sensitivity of genotypes. Yield index (Gauzzi et al., 1997), stress tolerance index (Fernandez, 1992), stress susceptibility index (Fischer and Maurer, 1978), tolerance index (Rosielle and Hamblin 1981).

On the other hand, most efficient use of such materials would be possible only when adequate information on the amount and type of genetic variation and combining ability effects in the materials is available. The combining ability analysis is a powerful tool for identifying the best combiners that can be used in crosses to exploit heterosis or accumulate productive genes. The combining ability analyses are widely used in wheat breeding programs to determine general combining ability (GCA) and specific combining ability (SCA) information of wheat populations for genetic diversity evaluation under normal and water stress conditions.

Therefore, the current investigation was undertaken to evaluate some promising wheat lines and Egyptian cultivars, find out good general combiners and best specific combinations, select the superior crosses and study the genetic behavior of some agronomic characters under normal and water stress conditions.

2. Materials and Methods

Six spring bread wheat-promising lines along with three cultivars were used as parent's materials. These parents' materials were brought from different sources by Agricultural Research Center, El-Giza, Egypt. The studied parents represent a wide range of drought tolerance variability. The name, pedigree, selection history and origin of the used genotypes are presented in Table 1.

-*Experimental sites and growing seasons:*

This study was carried out at the Experimental Farm of El-Gemmeiza Agricultural Research Station, ARC, Egypt, in both seasons. In 2018/19 season, the used parents were crossed and the hybrid seeds of twenty-eight F1 crosses were produced using half diallel mating design. On 26th November, 2019/20, the eight parents and their twenty-eight F1's were evaluated.

-Experimental design and its Experimental field characterization

Randomized Complete Block Design (RCBD) with four replications was used. Each genotype was planted in rows 2 m long and 30 cm apart and 15 cm within rows. The studied genotypes were evaluated under two separated experiments.

In the first experiment (normal), the genotypes were irrigated four times after planting irrigation (five irrigations). Under the second experiment, (water stress) plants were irrigated only one surface-irrigation, 35 days after planting (two irrigations). Each experiment was surrounded by a wide border (5m) to minimize the underground water permeability. The site of this experiment was close to the main drain with 5-meter depth, indicating the remoteness of the soil water level.

-Experimental management and average Monthly temperature and rainfall

For experimental management, the field trials were kept clean of weeds throughout the growing cycle, whereas all agricultural practices were applied as recommended. Monthly mean air temperature (ºC), and rainfall (mm/month) during the growing season at the experimental site are shown in tables 2 and 3.

Table 1: The studied bread wheat genotypes, pedigree, selection history and origin.

Genotypes	Pedigree	Selection history	Origin
Line 1	OASIS/SKAUZ//4*BCN/3/2*PASTOR/ 5/FRET2*2/4/...	CMSS06B00959T-099TOPY-099ZTM-099NJ-099NJ-2WGY-0B-OGM	CIMMYT
Line 2	WAXWING*2/HEILO	CMSS06B-00915T-099TOPY-099ZITM-099Y-099M-8WGY-0B-0EGY-OGM	CIMMYT
Line 3	WBLLI 2/KU-RUKU/3/WHEAR/VIVITSI//WHEAR	CMSS07B00243S-099M-099Y-099M-15WGY-0B-OGM	CIMMYT
Line 4	HUBARA-1/GOUMRIA-8	ICW02-00606-11AP/OTS-0AP-DAP-SAP-GAP-0DZ/OAP-ODZ/OKUL/OSIN/0AP-ONJ/0AP-OGM	ICARDA
Line 5	WBLLI 2/KURUK U/6/CNDO/R143//ENTE/MEXI_2/3/...	CMSS06B00802T-199TOPY-099ZTM-099Y-099M-12WGY-0B-OGM	CIMMYT
Sahel 1	N.S.732/PIMA//VEE"S"	CR735-4SD-ISD-ISD-0SD	Egypt
Sids1	HD 2172 / PAVON “S” // 1158.57/ MAYA 74 “S”	SD46-4SD-2SD-1SD-0SD	Egypt
Gemmeiza 9	ALD"S"/HUAC"S"//CMH-74A630/5X	CGM4583-5Gm-1Gm-0Gm	Egypt

Table 2: Monthly mean air temperature (ºC), and rainfall (mm/month) during the growing seasons at the experimental site.

Month	2018/2019			
	Relative humidity (%)	Temperature ºC		
		Min	Max	Mean
November	59.22	13.04	25.15	19.10
December	69.41	11.52	20.81	16.17
January	65.22	9.73	17.25	13.49
February	62.15	11.36	25.85	18.61
March	42.66	13.05	27.36	20.21
April	41.09	14.67	32.51	23.59

Table 3: Monthly mean air temperature (ºC), and rainfall (mm/month) during the growing seasons at the experimental site.

Month	2019/2020			
	Relative humidity (%)	Temperature ºC		
		Min	Max	Mean
November	59.63	16.09	29.15	22.62
December	65.97	11.17	21.81	16.49
January	71.82	8.80	18.34	13.57
February	70.21	8.77	20.72	14.75
March	65.88	10.28	24.32	17.30
April	62.94	12.57	27.06	19.81

-Data recorded and statistical analysis:

Data of the studied traits were recorded on the mean of 10 individual plants for each wheat genotype These data represented by: number of days to maturity, plant height (cm), number of spikes plant-1, number of kernels spike-1, 1000-kernel weight (g) and grain yield plant-1.

The data obtained for each trait were analyzed using the mean of 10 individual plant. Analysis of variance of each water treatment was estimated using randomized complete block design according to Snedecor and Cochran (1980). The effects of genotypes and water treatments were assumed to be fixed. Genotype variances were partitioned to parents, crosses and parents vs. crosses. Homogeneity of error's variances for the two water treatments was assessed according to levene (1960). In case of homogeneity of experimental errors, the combined analysis over the two water treatments was performed. The combined analysis was carried out to estimate the genetic parameter × water interaction. The mean of the studied genotypes was compared by LSD test at 0.01 and 0.05 probability levels according to Steel et al. (1997).

-Genetic parameters estimates:

General (GCA) and specific (SCA) combining ability effects were estimated using Griffing (1956) method 2 model 1 as described by Singh and Chaudhary (2010). Partitioning the total genetic variance to its consistent parts: additive and dominance genetic effects were estimated using diallel analysis technique as outlined by Hayman (1954 and 1958). Test of significant among parameter estimates were made using the standard error estimation technique suggested by Hayman (1954). The above estimates were then used in computing other parameters that were obtained following according to Hayman (1958). Graphical analysis was carried out for the studied characters, following the procedures suggested by Hayman (1954 and 1958).

-Stander's parameters of water stress estimates:

Four selection indices were estimated as follow: (1) Stress susceptibility index (SSI) = [(1-(Ys/Yp)] / SI = 1-($\bar{Y}$ s/$\bar{Y}$p) according to Fischer and Maurer in (1978). (2) Tolerance index (TOL) = Yn-YS according to Rosielle and Hamblin (1981). (3) Stress tolerance index (STI) =

[(Yp) × (Ys)] / (Ȳp)2 according to Fernandez (1992). (4) Yield index (YI) = YS /ȲS according to Gauzzi et al., (1997). Where, Yp and Ys are mean yields of genotypes under normal and water stress conditions, respectively and Ȳp and Ȳs are mean of yield of all genotypes under normal and water stress.

3. Results and Discussions

Analysis of variance

Mean squares of the studied traits for water treatments, genotypes, parents, crosses, parents vs crosses and their interactions are shown in tables 4 and 5. Variances due water treatments, genotypes, parents and crosses were significant for all traits. The parents vs crosses mean squares were significant for no. of days to maturity under normal and water stress conditions, plant height under the combined, no. of spikes plant-1 under normal condition, no. of kernels spike-1 and grain yield plant-1 under normal and the combined and 1000-kernel weight under stress the combined. Mean squares due interaction of water treatments with the wheat genotypes were significant for all studied traits. In addition, the water treatments interaction with parents were significant for no. of kernels spike-1. Moreover, the water treatments interaction with crosses variances were significant for all studied traits, except for no. of kernels spike-1. Furthermore, the water treatments interaction with parents vs crosses were significant only for no. of days to maturity, no. of kernels spike-1 and grain yield plant-1. In this respect, EL Shal et al. (2022) obtained significant mean square of genotypes of all studied genotypes for the traits. In addition, Mdluli et al. (2020) revealed significant variance of genotypes, water treatments and their interactions for each of plant height, thousand kernel weight, no. of kernels spike-1 and grain yield. Moreover, Furthermore, El-Gammaal (2018) found significant irrigation mean squares for all studied traits, indicating that the two irrigation regimes behaved differently for these characters, which agree with the results reported herein.

Table 4: Mean squares of the studied characters under the two water treatments and the combined (Comb) analysis.

SOV	df		No. of days to maturity			Plant height			No. of spikes plant^{-1}		
	Single	Comb	Normal	Stress	Comb	Normal	Stress	Comb	Normal	Stress	Comb
Replication (Rep)	2	-	16.5**	0.3	-	20.8**	5	-	7.95**	0.17	-
Water (W)	-	1	-	-	2526.6**	-	-	1634.7**	-	-	159.94**
Rep within W	-	4	-	-	8.40	-	-	12.90	-	-	4.10
Genotypes (G)	35	35	15.3**	38.0**	39.6**	54.7**	52**	101.2**	23.08**	17.93**	39.5**
Parents (P)	7	7	39.9**	38.3**	76.7**	114**	83.9**	191.4**	27.92**	25.31**	52.85**
Crosses (C)	27	27	9.3**	38.1**	31.2**	36.4**	38.8**	70**	22.59**	16.68**	37.46**
P vs C	1	1	5.1*	33.6*	6.2	131.8	185.5	315**	2.43*	0.002	1.14
G × W	-	35	-	-	13.7**	-	-	5.4*	-	-	1.51**
P × W	-	7	-	-	1.5	-	-	6.5	-	-	0.39
C × W	-	27	-	-	16.2**	-	-	5.2*	-	-	1.8**
P vs C × W	-	1	-	-	32.4**	-	-	2.3	-	-	1.29
Error	70	140	2.9	4.5	3.70	3.9	3.2	3.60	0.78	0.38	0.60
Total	107	215									
CV			1.11	1.45	1.29	1.73	1.65	1.69	9.03	7.58	22.53

Mean performance:

Mean performance of the studied characters is presented in Table 4. Water stress treatment were decreased significantly the means of all studied characters as: no. of days to maturity by 6.84 days (4.48 % reduction), plant height by 5.50 cm (4.81 % reduction), no. of spikes plant^{-1} by 1.72 spikes (17.52 % reduction), no. of kernels spike^{-1} by 7.81 kernel (9.43 % reduction), 1000-kernel weight by 3.73 g (6.58 % reduction) and grain yield plant^{-1} by 5.32 g (17.36 % reduction).

The average of all crosses was lower than the average of all parents for the no. of kernels spike^{-1} under normal and water stress conditions and the combined and no. of days to maturity under water stress and the combined, while was higher than the average of all parents for the plant height, 1000-kernel weight and grain yield plant^{-1} under all conditions and no. of spikes plant^{-1} under water stress condition.

The mean of reduction % in parents was lower than their crosses for no. of days to maturity, no. of spikes plant^{-1}, 1000-kernel weight and grain yield plant^{-1}, while was higher than their crosses for plant height and no. of kernels spike^{-1}.

The wheat genotype Line 5 and Line 1 × Line 3 cross were the earliest in maturity. Moreover, the cultivar Sahel 1 and the combination Sahel 1 × Sids 1 gave the shortest plant height. The cultivar Gemmeiza 9 and the cross Sids 1 × Gemmeiza 9 showed the highest no. of spikes plant^{-1}. Whereas, Line 5 and the cross Line 5 × Sahel 1 had the highest values of no. of kernels spike^{-1}. While, Line 3 and the hybrids Line 3 × Sahel 1 1 and Line 5 × Sahel 1 gave the heaviest 1000-kernel weight. The two genotypes Line 2 and Line 4 and the crosses Line 2 × Line 5, Line 3 × Sids 1, Line 3 × Gemmeiza 9 and Line 4 ×Sahel 1showed the highest grain yield plant^{-1}

Table 5: Mean squares of the studied characters under the two water treatments and the combined (Comb) analysis.

SOV	df		No. of kernels spike^{-1}			1000-kernel weight			Grain yield		
	Single	Comb	Normal	Stress	Comb	Normal	Stress	Comb	Normal	Stress	Comb
Replication (Rep)	2	-	28.9	1.5	-	4.02	5.63	-	0.1	1.2	-
Water (W)	-	1	-	-	3290.4**	-	-	749.95**	-	-	1526.3**
Rep within W	-	4	-	-	15.20	-	-	4.80	-	-	0.70
Genotypes (G)	35	35	385.9**	338.1**	703.7**	77.83**	61.78**	119.37**	48.1**	21**	57.2**
Parents (P)	7	7	726.9**	515.6**	1187.3**	52.95**	38.87**	88**	27.3**	20.4**	44**
Crosses (C)	27	27	285.4**	300.2**	578.2**	84.38**	68.02**	127.19**	49.9**	21.9**	59.6**
P vs C	1	1	710.6**	120.4	707.9**	75.1	53.63**	127.83*	147.3*	0.9	85.6**
G × W	-	35	-	-	20.3**	-	-	20.23**	-	-	11.9**
P × W	-	7	-	-	55.2**	-	-	3.82	-	-	3.7
C × W	-	27	-	-	7.4	-	-	25.21**	-	-	12.2**
P vs C × W	-	1	-	-	123*	-	-	0.9	-	-	62.7**
Error	70	140	12.4	6.3	9.40	4.58	1.93	3.30	2.4	2.5	2.50
Total	107	215									
CV			4.25	3.35	3.88	3.90	2.72	4.15	5.30	6.50	5.84

Table 6: Mean performance of the studied characters for the parents and their hybrids under normal and water stress conditions and the combined (Com) in addition to the reduction % (, Respectively %).

Genotypes	No. of days to maturity				Plant height (cm)				No. of spikes plant^{-1}			
	Normal	Stress	Com	R %	Normal	Stress	Com	R %	Normal	Stress	Com	R %
					Parents							
Line 1 (P1)	157.25	151.83	154.54	3.44	111.03	106.00	108.51	4.53	7.82	5.50	6.66	29.67
Line 2 (P2)	150.67	143.80	147.23	4.56	116.14	108.49	112.31	6.59	8.83	7.99	8.41	9.55
Line 3 (P3)	154.50	148.67	151.58	3.78	110.66	105.54	108.10	4.63	9.16	7.71	8.44	15.86
Line 4 (P4)	154.58	149.40	151.99	3.35	114.92	109.28	112.10	4.90	12.34	10.85	11.60	12.13
Line 5 (P5)	147.00	142.33	144.67	3.17	120.31	115.36	117.83	4.11	5.83	5.00	5.42	14.29
Sahel 1 (P6)	147.92	143.98	145.95	2.66	101.84	97.68	99.76	4.08	6.26	4.95	5.61	21.02
Sids 1 (P7)	151.53	144.94	148.24	4.35	116.94	106.65	111.80	8.80	11.27	10.02	10.65	11.12
Gemmeiza 9 (P8)	155.13	150.50	152.82	2.99	105.58	101.31	103.44	4.04	14.66	12.72	13.69	13.23
					Hybrids							
P1 × P2	153.67	148.64	151.16	3.27	115.18	108.25	111.72	6.01	7.99	5.68	6.84	28.91
P1 × P3	148.67	134.17	141.42	9.75	112.79	108.65	110.72	3.67	9.22	6.27	7.75	32.02
P1 × P4	152.67	145.44	149.06	4.73	116.58	110.94	113.76	4.84	11.15	8.40	9.78	24.66
P1 × P5	152.50	143.00	147.75	6.23	116.71	107.47	112.09	7.92	5.38	3.53	4.46	34.32
P1 × P6	152.00	144.75	148.38	4.77	110.67	102.97	106.82	6.95	7.08	5.90	6.49	16.62
P1 × P7	150.00	149.00	149.50	0.67	116.24	110.57	113.40	4.88	10.92	10.54	10.73	3.42
P1 × P8	153.00	145.33	149.17	5.01	110.42	107.81	109.11	2.36	12.62	10.00	11.31	20.74
P2 × P3	152.36	145.67	149.01	4.39	116.73	112.57	114.65	3.57	12.13	7.07	9.60	41.76
P2 × P4	156.58	148.39	152.49	5.23	120.65	110.94	115.80	8.05	10.40	8.20	9.30	21.16
P2 × P5	156.07	147.83	151.95	5.28	122.09	117.10	119.59	4.08	5.79	5.13	5.46	11.46
P2 × P6	152.13	144.33	148.23	5.13	114.97	110.34	112.66	4.03	7.31	6.17	6.74	15.55

P2 × P7	153.42	144.50	148.96	5.81	115.56	111.79	113.67	3.26	10.95	9.73	10.34	11.14
P2 × P8	152.67	151.67	152.17	0.66	113.08	108.95	111.02	3.66	12.58	10.80	11.69	14.20
P3 × P4	151.67	146.33	149.00	3.52	114.21	109.43	111.82	4.19	11.75	9.33	10.54	20.59
P3 × P5	154.33	143.17	148.75	7.24	117.99	113.79	115.89	3.56	6.68	5.69	6.19	14.82
P3 × P6	154.57	142.89	148.73	7.56	111.44	106.89	109.16	4.08	7.18	6.30	6.74	12.21
P3 × P7	152.90	146.93	149.92	3.90	115.69	110.77	113.23	4.26	13.03	10.17	11.60	21.99
P3 × P8	155.00	148.67	151.83	4.09	112.36	109.14	110.75	2.86	12.08	11.22	11.65	7.09
P4 × P5	153.44	139.00	146.22	9.41	118.40	114.83	116.62	3.02	9.63	7.48	8.56	22.39
P4 × P6	154.33	144.20	149.27	6.57	115.63	106.44	111.04	7.94	8.71	7.05	7.88	19.10
P4 × P7	153.00	148.72	150.86	2.80	115.36	110.58	112.97	4.15	10.22	9.80	10.01	4.17
P4 × P8	153.67	148.00	150.83	3.69	114.10	107.43	110.77	5.85	12.35	11.47	11.91	7.07
P5 × P6	150.53	144.22	147.38	4.19	115.32	107.38	111.35	6.88	4.80	4.66	4.73	2.99
P5 × P7	151.58	142.03	146.81	6.30	117.58	113.18	115.38	3.74	11.93	8.89	10.41	25.53
P5 × P8	153.58	150.00	151.79	2.33	118.49	113.69	116.09	4.06	7.22	6.13	6.68	15.18
P6 × P7	149.90	144.19	147.04	3.81	105.97	100.95	103.46	4.74	10.30	8.51	9.41	17.35
P6 × P8	152.45	147.61	150.03	3.17	112.14	108.14	110.14	3.57	10.98	9.13	10.05	16.85
P7 × P8	153.00	147.89	150.44	3.34	108.96	103.36	106.16	5.14	16.36	13.01	14.68	20.46
Means of parents	152.32	146.93	149.63	3.54	112.18	106.29	109.23	5.21	9.52	8.09	8.81	15.86
Means of hybrids	152.85	145.59	149.22	4.74	114.83	109.44	112.14	4.69	9.88	8.08	8.98	17.99
Means of all genotypes	152.73	145.89	149.31	4.48	114.24	108.74	111.49	4.81	9.80	8.08	8.94	17.52
$LSD_{0.05}$	2.76	3.45	3.18		3.22	2.92	3.20		1.46	0.93	0.83	
$LSD_{0.01}$	3.67	4.58	4.29		4.27	3.88	4.36		2.03	1.29	1.12	

Table 7: Mean performance of the studied characters for the parents and their hybrids under normal and water stress conditions and the combined (Com) in addition to the reduction % (, Respectively %).

Genotypes	No. of kernels spike-1				1000-kernel weight (g)				Grain yield plant-1 (g)			
	Normal	Stress	Com	R %	Normal	Stress	Com	R %	Normal	Stress	Com	R %
Parents												
Line 1 (P1)	98.61	91.94	95.28	6.76	49.79	44.65	47.22	10.31	28.74	23.69	26.22	17.59
Line 2 (P2)	77.17	67.51	72.34	12.52	55.99	53.39	54.69	4.66	30.19	27.06	28.63	10.37
Line 3 (P3)	77.85	63.27	70.56	18.73	60.05	54.16	57.11	9.81	24.48	22.87	23.68	6.60
Line 4 (P4)	91.32	80.60	85.96	11.75	49.27	48.28	48.77	2.01	29.50	26.74	28.12	9.35
Line 5 (P5)	116.12	92.34	104.23	20.48	56.41	51.84	54.13	8.11	28.29	22.32	25.30	21.11
Sahel 1 (P6)	93.52	87.33	90.43	6.61	55.27	52.23	53.75	5.49	21.27	19.17	20.22	9.86
Sids 1 (P7)	80.53	74.76	77.65	7.17	50.40	47.72	49.06	5.32	29.08	25.21	27.15	13.30
Gemmeiza 9 (P8)	66.18	58.52	62.35	11.57	48.81	45.85	47.33	6.08	27.20	25.29	26.24	7.03
Hybrids												
P1 × P2	79.27	73.02	76.15	7.88	50.16	47.36	48.76	5.57	24.99	22.09	23.54	11.59
P1 × P3	93.97	90.34	92.15	3.87	51.85	48.36	50.11	6.73	25.35	23.45	24.40	7.52
P1 × P4	66.08	58.48	62.28	11.51	55.21	51.38	53.30	6.94	32.16	25.01	28.59	22.21
P1 × P5	96.13	86.25	91.19	10.27	59.73	56.49	58.11	5.42	27.35	24.16	25.75	11.68
P1 × P6	87.38	77.14	82.26	11.72	60.19	59.25	59.72	1.56	30.82	22.60	26.71	26.66
P1 × P7	71.71	62.55	67.13	12.77	58.12	53.93	56.02	7.21	30.18	24.65	27.42	18.33
P1 × P8	78.17	74.64	76.40	4.52	48.95	46.80	47.88	4.38	29.01	23.64	26.32	18.50
P2 × P3	71.40	65.57	68.49	8.17	58.29	56.32	57.31	3.39	32.99	28.08	30.53	14.89

P2 × P4	83.28	70.74	77.01	15.06	59.52	52.97	56.25	11.00	32.46	26.37	29.42	18.77
P2 × P5	88.01	83.94	85.98	4.62	64.47	56.18	60.32	12.86	37.79	28.61	33.20	24.29
P2 × P6	93.35	87.76	90.55	5.99	59.12	58.40	58.76	1.21	32.80	24.70	28.75	24.70
P2 × P7	74.07	69.17	71.62	6.61	52.23	50.95	51.59	2.45	31.04	24.57	27.81	20.84
P2 × P8	72.85	67.72	70.28	7.05	49.20	47.20	48.20	4.07	26.28	24.18	25.23	7.97
P3 × P4	81.04	76.50	78.77	5.60	49.01	46.65	47.83	4.82	30.67	19.19	24.93	37.42
P3 × P5	88.57	79.77	84.17	9.94	58.96	57.09	58.03	3.17	29.26	20.18	24.72	31.04
P3 × P6	88.66	82.39	85.53	7.08	67.34	44.88	56.11	33.35	25.53	23.57	24.55	7.70
P3 × P7	72.38	63.00	67.69	12.96	51.96	50.82	51.39	2.20	37.01	27.25	32.13	26.38
P3 × P8	75.99	69.68	72.84	8.31	49.64	47.37	48.51	4.57	35.76	28.48	32.12	20.36
P4 × P5	77.18	71.06	74.12	7.93	54.97	49.56	52.27	9.85	27.54	25.64	26.59	6.89
P4 × P6	94.25	88.66	91.46	5.94	58.67	53.73	56.20	8.41	33.38	29.19	31.28	12.54
P4 × P7	75.09	68.51	71.80	8.76	51.76	50.37	51.07	2.68	22.25	20.75	21.50	6.74
P4 × P8	70.27	62.87	66.57	10.53	50.53	45.14	47.84	10.67	26.60	20.47	23.53	23.04
P5 × P6	97.00	89.55	93.28	7.68	64.23	62.65	63.44	2.46	25.42	22.24	23.83	12.49
P5 × P7	96.18	86.55	91.37	10.02	52.95	49.25	51.10	6.98	34.73	27.01	30.87	22.21
P5 × P8	88.86	82.87	85.86	6.74	58.24	55.20	56.72	5.23	35.94	25.33	30.63	29.53
P6 × P7	74.84	68.79	71.82	8.08	53.15	47.80	50.47	10.07	27.18	21.89	24.53	19.45
P6 × P8	81.06	72.86	76.96	10.12	49.23	46.61	47.92	5.31	27.47	21.35	24.41	22.28
P7 × P8	64.80	55.50	60.15	14.35	49.47	48.13	48.80	2.70	32.35	24.67	28.51	23.76
Means of parents	87.66	77.03	82.35	11.95	53.25	49.76	51.51	6.47	27.34	24.04	25.69	11.90
Means of hybrids	81.49	74.50	77.99	8.72	55.26	51.46	53.36	6.62	30.15	24.26	27.21	18.92
Means of all genotypes	82.87	75.06	78.96	9.43	54.81	51.08	52.95	6.58	29.53	24.21	26.87	17.36
LSD0.05	5.73	4.10	5.01		3.59	1.72	1.90		2.55	2.56	2.51	
LSD0.01	7.61	5.44	6.73		4.99	2.38	2.56		3.38	3.40	3.33	

These results were in agreements with Siyal (2021), EL Shal et al. (2022), Galal et al. (2023); Mady (2023) who stated that the no. of days to maturity, plant height, no. of spikes plant-1, no. of kernels spike-1, kernel weight and grain yield plant-1 were decreased significantly under water stress condition. Also, in this regard, Hussein et al. (2015) found that drought stress reduced no. of spikes plant-1 by 18.38 %, no. of grains spike-1 by 9.40, 1000-grain weight by 11.15 % and grain yield plant-1 by 25.07%.

In addition, Siyal (2021); Mady (2023) were reported that the reduction % of grain yield ranged from 0.41 to 22.39 %. Al-Naggar et al. (2020) found that water stress caused a significant reduction of 9.54 % in grain yield.

Combining ability :

Mean squares of general and specific combining ability and its interactions with water treatment for the studied traits are presented in tables 8 and 9. The mean squares of GCA and SCA were significant for all studied traits under both conditions.

This would indicate the importance of both additive and non-additive genetic variances in determining the performance of all characters studied. Mean squares estimate of GCA interactions with water treatments were significant for no. of days to maturity, no. of kernels spike-1 and 1000-kernel weight. In addition, the SCA × water treatment mean squares were significant for most studied traits. Moreover, The SCA variance was found to be higher than the GCA for all traits under the study, indicating that non-additive gene effects were more important than additive in the expression of these investigated traits.

In this respect, Kumari ; Sharma (2022), Ahangar ; Ghojogh (2023) ; Galal et al. (2023) observed significant differences for general and specific combining ability for the studied traits under both irrigations' treatments and in the combined analysis. Kumari; Sharma (2022) obtained significant mean squares due to GCA x E and SCA x E for all characters, whereas revealed influence of environment on GCA and SCA, respectively.

General combining ability effects :

General combining ability of parents for the studied characters under normal and water stress conditions and the combined are illustrated in tables 10 and 11. The use of the best parents in crossing represents an excellent way for the next generation of elite segregating populations to be targeted by selection. From the plant breeder's point of view, high positive values of GCA effects would be of interest in most traits, while for maturity and plant height, high negative values would be useful.

Table 8: Mean squares of general (GCA) and specific (SCA) combining ability and its interactions with water treatment (W) for the studied traits.

SOV	df		No. of days to maturity			Plant height			No. of spikes plant^{-1}		
	Single	Comb	Normal	Stress	Comb	Normal	Stress	Comb	Normal	Stress	Comb
GCA	7	7	7.3**	19.9**	11.3**	65.9**	57.9**	60.9**	30.96**	26.6**	28.58**
SCA	28	28	4.5**	10.9**	5.4**	6.3**	7.2**	5.9**	1.87**	0.82**	1.08**
GCA × Water (W)	-	7	-	-	2.4**	-	-	1.0	-	-	0.2
SCA × W	-	28	-	-	2.3**	-	-	0.9	-	-	0.26**
Error	70	140	1.0	1.5	0.60	1.3	1.1	0.60	0.26	0.13	0.10
$\sigma^2_{GCA}/\sigma^2_{SCA}$			0.76	0.79	0.81	0.95	0.94	0.95	0.97	0.98	0.98

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

Table 9: Mean squares of general (GCA) and specific (SCA) combining ability and its interactions with water treatment (W) for the studied traits.

SOV	df		No. of kernels spike^{-1}			1000-kernel weight			Grain yield		
	Single	Comb	Normal	Stress	Comb	Normal	Stress	Comb	Normal	Stress	Comb
GCA	7	7	415.7**	321.5**	364.6**	67.82**	41.59**	52.82**	11.4**	6.6**	8.4**
SCA	28	28	56.8**	60.5**	55.5**	15.47**	15.34**	11.66**	17.2**	7.1**	9.8**
GCA × Water (W)	-	7	-	-	4.0*	-	-	1.88**	-	-	0.6
SCA × W	-	28	-	-	3.2**	-	-	3.74**	-	-	2.3**
Error	70	140	4.1	2.1	1.60	1.53	0.64	0.50	0.8	0.8	0.40
$\sigma^2_{GCA}/\sigma^2_{SCA}$			0.94	0.91	0.93	0.90	0.84	0.90	0.57	0.65	0.63

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

General combining ability effects :

General combining ability of parents for the studied characters under normal and water stress conditions and the combined are illustrated in tables 10 and 11. The use of the best parents in crossing represents an excellent way for the next generation of elite segregating populations to be targeted by selection. From the plant breeder's point of view, high positive values of GCA effects would be of interest in most traits, while for maturity and plant height, high negative values would be useful.

Table 10: General combining ability of parents for the studied characters under normal and water stress conditions and the combined.

Parent	No. of days to maturity			Plant height			No. of spikes plant^{-1}		
	Normal	Stress	Comb	Normal	Stress	Comb	Normal	Stress	Comb
Line 1	0.24	0.1	0.17	-0.75	-1*	-0.88**	-0.82**	-1.14**	-0.98**
Line 2	0.37	0.56	0.46	2.24**	1.82**	2.03**	-0.34	-0.4**	-0.37**
Line 3	0.39	-0.79	-0.2	-0.56	0.36	-0.1	0.22	-0.13	0.05
Line 4	1*	0.59	0.79*	1.66**	1.05*	1.35**	1.07**	1.07**	1.07**
Line 5	-0.85*	-1.91**	-1.38**	3.9**	3.95**	3.93**	-2.51**	-2.12**	-2.32**
Sahel 1	-1.28**	-1.29**	-1.28**	-3.84**	-4.02**	-3.93**	-1.94**	-1.51**	-1.72**
Sids 1	-0.77*	0.01	-0.38	0.11	-0.42	-0.16	1.8**	1.79**	1.8**
Gemmeiza 9	0.91*	2.72**	1.81**	-2.75**	-1.75**	-2.25**	2.53**	2.45**	2.49**
SE for GCA effect	0.29	0.36	0.23	0.34	0.31	0.23	0.15	0.10	0.09
$LSD_{0.05}$ (gi-gj)	0.87	1.09	0.69	1.02	0.92	0.68	0.46	0.32	0.27
$LSD_{0.01}$ (gi-gj)	1.16	1.45	0.92	1.35	1.23	0.90	0.61	0.42	0.36

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

The genotypes Sahel 1 and Line 5 were the good combiners for no. of days to maturity, no. of kernels spike-1 and 1000-kernel weight. Whereas, the two cultivars Sahel 1 and Gemmeiza 9 as well as Line 1 were good combiners for plant height. The genotypes Gemmeiza 9, Line 4 and Sids 1 were good combiners for giving more no. of spikes plant-1. Moreover, Line 2 and Sids 1 were proved to be good combiners for grain yield plant-1.

Table 11: General combining ability of parents for the studied characters under normal and water stress conditions and the combined.

Parent	No. of kernels spike-1			1000-kernel weight			Grain yield plant-1		
	Normal	Stress	Comb	Normal	Stress	Comb	Normal	Stress	Comb
Line 1	2.41**	3.08**	2.74**	-0.95*	-0.68*	-0.82**	-0.84*	-0.49	-0.67**
Line 2	-2.92**	-2.26**	-2.59**	1.17*	1.64**	1.41**	1.3**	1.48**	1.39**
Line 3	-1.81*	-2.17**	-1.99**	1.39**	0.01	0.7*	-0.02	-0.2	-0.11
Line 4	-1.6*	-1.75**	-1.67**	-1.51**	-1.34**	-1.42**	-0.17	0.22	0.02
Line 5	11.84**	8.91**	10.38**	3.31**	3.04**	3.17**	0.88*	-0.01	0.44
Sahel 1	5.78**	6.63**	6.2**	2.92**	1.8**	2.36**	-2.06**	-1.4**	-1.73**
Sids 1	-5.57**	-5.19**	-5.38**	-2.29**	-1.31**	-1.8**	0.71*	0.33	0.52*
Gemmeiza 9	-8.14**	-7.24**	-7.69**	-4.04**	-3.16**	-3.6**	0.2	0.08	0.14
SE for GCA effect	0.60	0.43	0.37	0.37	0.24	0.22	0.27	0.27	0.19
LSD0.05 (gi-gj)	1.81	1.30	1.10	1.10	0.71	0.65	0.81	0.81	0.57
LSD0.01 (gi-gj)	2.41	1.72	1.46	1.46	0.95	0.86	1.07	1.08	0.75

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

Those parents showing high GCA values for yield and other agronomic characteristics are the most promising ones to be incorporated into a program of genetic improvement, because those characteristics are transmitted to their progeny as a result of the importance of additive effects. High values of GCA show a greater proportion of additive genetic effect and an efficient gene transfer to progenies. In general, these results were in agreement with Galal et al. (2023); Mady (2023) who indicated that non-additive gene effects were more important than additive ones in the inheritance of all studied traits. On the other hand, Kumari; Sharma (2022) and Ahangar and Ghojogh (2023) indicated the importance effect of additive and non-additive effects of genes in controlling traits and found that additive gene effects for all traits except 1000-seed weight was higher than non-additive gene effects.

Specific combining ability :

Specific combining ability of the crosses for the studied characters under normal and water stress conditions and the combined are shown in tables 12 and 13. The crosses with higher SCA values may be considered useful for the development of new recombinants in wheat breeding program. High values of specific combining ability (SCA) detect the best hybrid combinations resulting from the non-additive effects of genes.

The wheat cross Line 1 x Line 3 showed highly significant specific combining ability effects for no. of days to maturity at the two studied environments and their combined data. Meanwhile, the crosses Sahel 1 × Sids 1, Sids 1 × Gemmeiza 9 and Line 1 × Line 5 had desirable SCA effects for plant height. Moreover, Line 1 × Line 3, Line 2 × Sahel 1, Line 4 × Sahel 1 and Line 5 × Sids 1, Line 3 × Gemmeiza 9, Line 3 × Line 4, Line 5 × Gemmeiza 9, Line 2 × Line 4 and Line 1 × Gemmeiza 9 hybrids showed highly significant SCA effects for no. of kernels spike-1. The most desirable combinations for 1000-kernel weight under both conditions were Line 1 × Line 4, Line 1 × Sahel 1, Line 1 × Sids 1, Line 5 × Gemmeiza 9 and Line 5 × Sahel 1. The crosses Line 2 × Line 3, Line 2 × Line 5, Line 3 × Gemmeiza 9, Line 3 × Sids 1, Line 4 × Sahel 1 and Line 5 × Sids 1 showed desirable SCA effects for grain yield plant-1 in addition to the cross Line 5 x Sids 1 for no. of spikes plant-1 under both normal and water stress conditions as well as the combined data

Table 12: Specific combining ability of the crosses for the studied characters under normal and water stress conditions and the combined.

Cross	No. of days to maturity			Plant height			No. of spikes plant-1		
	Normal	Stress	Comb	Normal	Stress	Comb	Normal	Stress	Comb
Line 1 x Line 2	0.33	2.09	1.21	-0.54	-1.31	-0.93	-0.65	-0.86*	-0.75*
Line 1 x Line 3	-4.7**	-11.04**	-7.87**	-0.13	0.55	0.21	0.03	-0.54	-0.26
Line 1 x Line 4	-1.3	-1.13	-1.22	1.44	2.15	1.79*	1.11*	0.39	0.75*
Line 1 x Line 5	0.38	-1.08	-0.35	-0.68	-4.22**	-2.45**	-1.09	-1.28**	-1.19**
Line 1 x Sahel 1	0.31	0.05	0.18	1.02	-0.75	0.13	0.03	0.47	0.25
Line 1 x Sids 1	-2.2*	3*	0.4	2.64*	3.24*	2.94**	0.13	1.81**	0.97*
Line 1 x Gemmeiza 9	-0.88	-3.37*	-2.13*	-0.32	1.82	0.75	1.11*	0.61	0.86*

Line 2 x Line 3	-1.13	0	-0.56	0.82	1.64	1.23	2.45**	-0.49	0.98*
Line 2 x Line 4	2.49*	1.35	1.92*	2.52*	-0.67	0.92	-0.13	-0.55	-0.34
Line 2 x Line 5	3.82**	3.29*	3.56**	1.71	2.59*	2.15*	-1.16*	-0.43	-0.79*
Line 2 x Sahel 1	0.32	-0.83	-0.26	2.33	3.79**	3.06**	-0.22	0	-0.11
Line 2 x Sids 1	1.09	-1.97	-0.44	-1.03	1.64	0.31	-0.31	0.25	-0.03
Line 2 x Gemmeiza 9	-1.34	2.5	0.58	-0.65	0.14	-0.26	0.59	0.67	0.63
Line 3 x Line 4	-2.45*	0.64	-0.91	-1.13	-0.73	-0.93	0.67	0.31	0.49
Line 3 x Line 5	2.06	-0.03	1.02	0.41	0.74	0.57	-0.83	-0.14	-0.48
Line 3 x Sahel 1	2.73*	-0.93	0.9	1.6	1.8	1.7*	-0.91	-0.14	-0.52
Line 3 x Sids 1	0.55	1.82	1.18	1.91	2.08	1.99*	1.21*	0.42	0.81*
Line 3 x Gemmeiza 9	0.97	0.85	0.91	1.43	1.79	1.61	-0.47	0.82*	0.18
Line 4 x Line 5	0.57	-5.57**	-2.5**	-1.4	1.09	-0.15	1.28*	0.45	0.86*
Line 4 x Sahel 1	1.89	-0.99	0.45	3.56*	0.67	2.12*	-0.23	-0.59	-0.41
Line 4 x Sids 1	0.04	2.23	1.14	-0.65	1.2	0.28	-2.45**	-1.15**	-1.8**
Line 4 x Gemmeiza 9	-0.97	-1.19	-1.08	0.95	-0.61	0.17	-1.05	-0.12	-0.59
Line 5 x Sahel 1	-0.06	1.52	0.73	1.01	-1.29	-0.14	-0.56	0.21	-0.17
Line 5 x Sids 1	0.48	-1.97	-0.75	-0.67	0.91	0.12	2.84**	1.13**	1.99**
Line 5 x Gemmeiza 9	0.8	3.3*	2.05*	3.1*	2.75*	2.92**	-2.59**	-2.28**	-2.44**
Sahel 1 x Sids 1	-0.78	-0.43	-0.6	-4.54**	-3.36**	-3.95**	0.63	0.15	0.39
Sahel 1 x Gemmeiza 9	0.1	0.29	0.19	4.48**	5.17**	4.83**	0.58	0.11	0.35
Sids 1 x Gemmeiza 9	0.13	-0.73	-0.3	-2.64*	-3.21*	-2.93**	2.22**	0.69	1.46**
SE for SCA effect	0.89	1.11	0.71	1.03	0.94	0.70	0.46	0.32	0.28
LSD0.05 (Sij-gik)	2.62	3.27	2.08	3.05	2.77	2.04	1.37	0.95	0.82
LSD0.01 (Sij-gik)	3.48	4.35	2.75	4.05	3.68	2.70	1.82	1.26	1.09
LSD0.05 (gij-kl)	2.47	3.09	1.96	2.88	2.62	1.93	1.29	0.89	0.78
LSD0.01 (gij-kl)	3.28	4.10	2.59	3.82	3.47	2.55	1.71	1.19	1.03

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

Table 13: Specific combining ability of the crosses for the studied characters under normal and water stress conditions and the combined.

Cross	No. of kernels spike-1			1000-kernel weight			Grain yield plant-1		
	Normal	Stress	Comb	Normal	Stress	Comb	Normal	Stress	Comb
Line 1 x Line 2	-3.09	-2.85	-2.97*	-4.87**	-4.67**	-4.77**	-5**	-3.11**	-4.05**
Line 1 x Line 3	10.5**	14.38**	12.44**	-3.4*	-2.04*	-2.72**	-3.31**	-0.07	-1.69*
Line 1 x Line 4	-17.6**	-17.9**	-17.75**	2.86*	2.32*	2.59**	3.64**	1.08	2.36**
Line 1 x Line 5	-0.99	-0.8	-0.89	2.56	3.06**	2.81**	-2.22*	0.45	-0.89
Line 1 x Sahel 1	-3.68	-7.62**	-5.65**	3.41*	7.05**	5.23**	4.2**	0.29	2.24**
Line 1 x Sids 1	-8.01**	-10.39**	-9.2**	6.55**	4.84**	5.69**	0.78	0.6	0.69
Line 1 x Gemmeiza 9	1.03	3.74*	2.38	-0.87	-0.43	-0.65	0.11	-0.16	-0.02
Line 2 x Line 3	-6.74**	-5.06**	-5.9**	0.93	3.59**	2.26*	2.19*	2.58*	2.38**
Line 2 x Line 4	4.93*	-0.31	2.31	5.05**	1.59	3.32**	1.81	0.46	1.13
Line 2 x Line 5	-3.77	2.23	-0.77	5.18**	0.42	2.8**	6.08**	2.92**	4.5**
Line 2 x Sahel 1	7.63**	8.33**	7.98**	0.23	3.88**	2.05*	4.04**	0.41	2.22**
Line 2 x Sids 1	-0.31	1.57	0.63	-1.47	-0.47	-0.97	-0.5	-1.45	-0.98
Line 2 x Gemmeiza 9	1.05	2.15	1.6	-2.74*	-2.36*	-2.55**	-4.75**	-1.59	-3.17**

Line 3 x Line 4	1.58	5.37**	3.47*	-5.68**	-3.1**	-4.39**	1.33	-5.04**	-1.85*
Line 3 x Line 5	-4.32	-2.03	-3.18*	-0.55	2.97**	1.21	-1.13	-3.83**	-2.48**
Line 3 x Sahel 1	1.83	2.87	2.35	8.23**	-8.01**	0.11	-1.91	0.96	-0.48
Line 3 x Sids 1	-3.11	-4.69**	-3.9*	-1.95	1.03	-0.46	6.79**	2.9**	4.85**
Line 3 x Gemmeiza 9	3.08	4.03*	3.55*	-2.52	-0.56	-1.54	6.05**	4.39**	5.22**
Line 4 x Line 5	-15.93**	-11.16**	-13.55**	-1.64	-3.22**	-2.43**	-2.7*	1.22	-0.74
Line 4 x Sahel 1	7.2**	8.72**	7.96**	2.45	2.18*	2.32*	6.08**	6.16**	6.12**
Line 4 x Sids 1	-0.61	0.4	-0.11	0.74	1.94*	1.34	-7.82**	-4.01**	-5.92**
Line 4 x Gemmeiza 9	-2.86	-3.2*	-3.03*	1.27	-1.45	-0.09	-2.97**	-4.04**	-3.5**
Line 5 x Sahel 1	-3.48	-1.05	-2.26	3.19*	6.73**	4.96**	-2.93**	-0.55	-1.74*
Line 5 x Sids 1	7.04**	7.77**	7.41**	-2.89*	-3.56**	-3.22**	3.6**	2.48*	3.04**
Line 5 x Gemmeiza 9	2.3	6.13**	4.21**	4.16**	4.24**	4.2**	5.32**	1.05	3.19**
Sahel 1 x Sids 1	-8.24**	-7.7**	-7.97**	-2.29	-3.79**	-3.04**	-1	-1.25	-1.13
Sahel 1 x Gemmeiza 9	0.56	-1.59	-0.52	-4.46**	-3.11**	-3.79**	-0.2	-1.53	-0.87
Sids 1 x Gemmeiza 9	-4.36*	-7.13**	-5.74**	0.98	1.51	1.25	1.91	0.05	0.98
SE for SCA effect	1.84	1.32	1.13	1.12	0.73	0.67	0.82	0.82	0.58
LSD0.05 (Sij-gik)	5.44	3.89	3.31	3.31	2.14	1.95	2.42	2.43	1.70
LSD0.01 (Sij-gik)	7.22	5.16	4.38	4.39	2.85	2.58	3.21	3.23	2.24
LSD0.05 (gij-kl)	5.13	3.66	3.12	3.12	2.02	1.84	2.28	2.29	1.60
LSD0.01 (gij-kl)	6.81	4.87	4.13	4.14	2.68	2.43	3.03	3.04	2.12

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

Hayman approach:

Testing of diallel assumptions:

Results in table 14 indicate that the values of t2 were insignificant for all studied traits at normal and water stress conditions, except main spike weight under normal and the combined and 1000-kernel weight under normal and water stress conditions.

As obvious in table 14, the regression coefficients were significantly different from zero but not from unity for no. of days to heading, maturity, plant height, no. of spikes plant-1 at all conditions, confirming further validity of diallel assumptions. However, the other characters at both normal and water stress conditions and their combined did not significantly differ from zero and significantly or insignificantly differed from unity, reflecting a partial failure of the assumptions. In spite of partial failures of most traits, its genetic components and parameters were estimate.

Estimates of the components of variance and gene actions:

The estimates of genetic and environmental components of variation for the studied traits are given in tables 15 and 16. The additive (D) genetic variance and dominance (H1) and (H2) reached the level of significance for all traits, with some exceptions. Kamara et al. (2021) found significant dominance components H1 and H2 for all evaluated traits, except no. of spikes/plant.

Additive genetic variances (D) were greater than those of dominance genetic variances (H1) for plant height, no. of spikes plant-1 at both environments and the combined and no. of kernels spike-1 under normal condition, indicating that selection for these traits might be effective in early generations for improving such traits, while the dominance genetic variances were the greatest in the remaining. El-Said (2018); Kamara et al. (2021) reported that the magnitude of dominance component (H1) was higher than the additive component (D) for all evaluated traits. Ahangar and Ghojogh (2023) obtained significant parameters of D and H1, but the high contribution of variance D showed that the additive effects of genes action had greatest importance in genetic control of agronomic characters.

Negative and significant or insignificant (F) value was recorded for no. of spikes plant-1 at both conditions, indicating excess of recessive alleles in the parents. However, (F) value was positive and significant or insignificant for the other traits, reflecting that the dominant genes were more frequent than recessive ones. In this situation, Kamara et al. (2021) who reported that the distributions of the relative frequencies of dominant versus recessive gene (F) were positive and insignificant for most traits obtained similar results.

The estimates of (h2) values were found to be significant or insignificant with positive signs for all traits, except no. of spikes plant-1 and grain yield plant-1 at water stress condition, indicating the prevalence of positive genes controlling these characters and suggesting that dominance was unidirectional.

The average degree of dominance as indicated by (H1/D) 1/2 was lower than unity (1) for plant height and no. of spikes plant-1 under both conditions and no. of kernels spike-1 under normal condition, suggesting the importance of partial dominance gene effects in the genetics of these characters. Meanwhile, the value of (H1/D) 1/2 for the remaining characters were greater than unity, suggesting the importance of over dominance gene effects in the genetics of these traits. These results are in agreement with those obtained by Qabil (2017); El-Said (2018); Kamara et al. (2021) who found that the average degree of dominance (H1/D)0.5 was larger than one in all studied traits across all tested environments.

Table 14: Values of t2, regression coefficients of covariance (Wr) on variance (Vr) and t-values for b=0 and b=1 for the studied characters under normal (N), water stress (S) conditions and the combined (C).

		DM	PH	SP	KS	KW	GY
	N	1.44	1.16	0.27	0.01	11.76**	0.04
t2	S	4.48	0.86	1.03	0.004	7.09*	0.65
	C	2.39	2.86	0.23	0.004	0.91	0.3
	N	0.75±0.5	0.56±0.2	0.62±0.2	0.07±0.4	0.62±0.1	0.51±0.4
Regression Coefficient	S	-0.14±0.2	0.55±0.2	0.73±0.2	-0.04±0.4	0.04±0.2	0.06±0.3
	C	-0.21±0.2	0.51±0.2	0.72±0.2	-0.25±0.4	0.46±0.2	0.52±0.5
	N	1.39	2.79*	2.56*	0.18	7.32**	1.32
t value for b=0	S	-0.77	2.49*	4.72**	-0.11	0.25	0.22
	C	-0.94	3*	3.38*	-0.61	1.93	1.16
	N	0.47	2.15	1.54	2.19	4.55**	1.28
t value for b=1	S	6.21**	2.05	1.71	2.62*	6.04**	3.18*
	C	5.54**	2.91*	1.29	3.08*	2.29	1.06

b=0 and b=1 indicate difference of regression coefficient value from 0 and 1 (unit), respectively.
*, ** = significant at 0.05 and 0.01, probability levels, respectively.

Table 15: Estimation of components of variation for the studied characters under normal (N), water stress (S) conditions and their combined (C).

		DM	PH	SP	KS	KW	GY
	N	12.22**±2.3	36.54**±3.4	8.98**±0.9	238**±33.3	-	8.31±4.2
D	S	11.32±8.4	26.87**±2.7	8.31**±0.5	169.79**±34.6	-	5.98±3.5
	C	12.15*±4.3	31.26**±2.7	8.69**±0.6	196.29**±32.6	14.12*±4.2	6.94±3.1
	N	19.46*±5.4	17.71±8	-3.14±2.1	131.93±78.8	-	9.58±10
F	S	14.73±20	6.74±6.3	-2.02±1.1	111.23±81.7	-	6.61±8.3
	C	17.38±10.3	11.31±6.5	-2.47±1.4	110.17±77	0.98±10	7.63±7.2
	N	21.14**±5.3	22.46*±7.8	7.45*±2	233.32*±76.6	-	67.38**±9.7
H1	S	46.88±19.4	23.62**±6.1	3.64*±1.1	279.02*±79.5	-	28.1*±8.1
	C	25.89*±10	20.55*±6.3	4.75*±1.4	245.73*±74.9	51.23**±9.8	39.71**±7
	N	11.8*±4.6	16.85*±6.8	6.19*±1.8	182.34*±66.7	-	61.58**±8.5
H2	S	34.33±16.9	21.46**±5.3	2.58*±1	205.23*±69.2	-	25.42*±7.1
	C	16.39±8.7	17.45*±5.5	3.61*±1.2	187.55*±65.1	39.29**±8.5	35.95**±6.1
	N	0.36±3.1	20.98**±4.6	0.26±1.2	114.72*±44.7	-	23.82**±5.7
h2	S	4.87±11.3	29.96**±3.6	-0.05±0.6	18.84±46.4	-	-0.21±4.7
	C	0.23±5.8	25.56**±3.7	0.04±0.8	57.38±43.7	10.25±5.7	6.84±4.1
	N	1.09±0.8	1.46±1.1	0.33±0.3	4.29±11.1	-	0.79±1.4
E	S	1.46±2.8	1.09±0.9	0.12±0.2	2.07±11.5	-	0.81±1.2
	C	0.64±1.4	0.64±0.9	0.11±0.2	1.59±10.9	0.55±1.4	0.4±1

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

Table 16: Proportion of genetic components for the studied characters under normal (N) and water stress (S) conditions and their combined (C).

Parameter		DM	PH	SP	KS	KW	GY
	N	1.32	0.78	0.91	0.99	-	2.85
(H1/D)1/2	S	2.03	0.94	0.66	1.28	-	2.17
	C	1.46	0.81	0.74	1.12	1.90	2.39
	N	0.14	0.19	0.21	0.20	-	0.23
H2/4H1	S	0.18	0.23	0.18	0.18	-	0.23
	C	0.16	0.21	0.19	0.19	0.19	0.23
	N	4.07	1.90	0.68	1.78	-	1.51
KD/KR	S	1.94	1.31	0.69	1.69	-	1.68
	C	2.92	1.57	0.68	1.67	1.04	1.60
	N	0.03	1.25	0.04	0.63	-	0.39
h2/H2 (k)	S	0.14	1.40	-0.02	0.09	-	-0.01
	C	0.01	1.47	0.01	0.31	0.26	0.19
	N	-0.57	-0.51	-0.21	0.45	-	-0.66
r	S	0.36	-0.22	-0.04	-0.54	-	-0.58
	C	0.16	-0.45	-0.13	-0.18	0.67	-0.73
	N	20.58	68.29	78.09	61.16	-	12.26
h(n)	S	31.28	63.33	88.12	55.35	-	12.49
	C	31.10	69.75	85.84	59.81	54.73	14.06
	N	78.64	91.85	96.17	96.66	-	95.69
h(b)	S	90.02	93.80	98.09	98.27	-	90.06
	C	90.74	96.14	98.43	98.68	97.60	96.32

The dominance component (H1) was approximately equal to (H2) for plant height, no. of spikes plant-1, no. of kernels spike-1 and grain yield plant-1 under both conditions and the combined data, no. of days to maturity under water stress condition and 1000-kernel weight under the combined, confirming the findings of (H2/4H1) values, which approximately equal to 0.25. However, the other traits exhibited unequal distribution. These results are in harmony with those observed before by Kamara et al. (2021) who showed that the proportion of genes in the parents with positive and negative effects (H2/4H1) was less than 0.25 for all the traits in both environments. El-Said (2018) found that percentage of negative and positive genes (H2/4H1) in the parents ranged from 0.18 for plant height to 0.23 for no. of kernels /spike and grain yield /plant hence, negative and positive alleles are consistent distributed in these traits.

The ratio of dominant to recessive alleles (KD/KR) in the parents was more than one for most studied characters, suggesting the preponderance of dominant alleles, except no. of spikes plant-1 at both conditions showing an excess of recessive alleles among parents. Similar results were obtained by Kamara et al. (2021) who are found that the ratio of dominant to recessive genes in the parents (KD/KR) was more than unity (1) for all the studied traits, except no. of days to heading, plant height and no. of grains/spike.

The plant height at both conditions is governed at least by two gene blocks, since h2/H2 (K) values were higher than one, while the other traits had values less than one, indicating that these traits are governed at least by one gene block. In this respect, Mohammed (2001) showed that grain yield plant-1 is governed at least by three gene blocks and no. of spikes plant-1 is governed at least by five gene blocks.

The correlation coefficient (r) values were found to be high and positive for 1000-kernel weight under the combined, suggesting that expression of low scores is associated with dominant genes, showing unidirectional dominance in the parents for this trait, i.e., completely dominant. In addition, the remaining characters had low (r) values, in spite of its sign, suggesting that dominance is am bidirectional in the parents.

The broad sense heritability values were found to be high for all the studied characters. In addition, low heritability estimates in narrow sense (hn) were detected for no. of days to maturity and grain yield plant-1 at both conditions, reflecting the role of environmental factors and dominance gene action in inheritance system of these traits. Meanwhile, the remaining characters had moderate to high (hn) estimates, reflecting the importance of additive gene action in controlling these traits, therefore selection could be practiced in early segregating generations. According to finding of Rashid et al., (2012), the traits controlled by additive genes and partial dominance should be selected in early segregating generation. While, the traits governed by over dominance type of gene action may cause problem for selection in early generations, so delayed selection would be preferred. Generally, these results are in accordance with those previously obtained by Subhani et al. (2000); Mohamed (2004).

Graphical analysis of the diallel set of crosses

The graphic representation of the Wr/Vr relations for the studied characters are presented in Figures 1-6. The regression coefficient of Wr on Vr did not differ significantly from unity for all studied traits, which is expected when non-additive genetic variation was present. But, as dominance only, except for no. of spikes plant-1 under both conditions, plant height under normal and water stress conditions, no. of days to maturity, no. of kernels spike-1 and grain yield plant-1 under normal condition and 1000-kernel weight and grain yield plant-1 under the combined.

The regression line cut the Wr axis above the origin point, indicating that partial dominance operates for plant height, no. of spikes plant-1, no. of kernels spike-1 under both conditions, no. of days to maturity under water stress condition and the combined and 1000-kernel weight and grain yield plant-1 under water stress condition, confirming the previous results of (H1/D) 1/2. In addition, over dominance was operating in the inheritance of no. of days to maturity and 1000-kernel weight at normal condition and grain yield plant-1. Moreover, complete dominance was involved in the inheritance of 1000-kernel weight under the combined. Qabil (2017) found that the regression lines cuts Wr axis below origin for grain yield/plant, demonstrating that overdominance gene effects are the prevailed type.

The regression line was nearly touching the parabola limit and array points of the parents, plant height and no. of spikes plant-1 at the all conditions, confirming that additive gene effects play an important role in the genetic control of these traits. However, no. of days to maturity, no. of kernels spike-1, 1000-kernel weight and grain yield plant-1 at both conditions were found to be controlled by dominance gene effects.

The position of the parental array points on the Wr-Vr graph were widely scattered for no. of days to maturity under water stress condition and no. of kernels spike-1 and grain yield plant-1 under normal and the combined, indicating that these traits had high genetic diversity among the parents. Meanwhile, the remaining traits had low genetic diversity.

The relative position of array points on Wr-Vr graph indicated that the frequency of dominant alleles was observed Sids 1, Line 4 and Gemmeiza 9 for 1000-kernel weight and Line 1 for grain yield plant-1 under normal, water stress and the combined. The same trend was observed for no. of days to maturity in the genotypes Sids 1, Gemmeiza 9 and Line 4 under normal condition, Sahel 1 and Gemmeiza 9 under water stress condition and Sahel 1, Sids 1 and Gemmeiza 9 under the combined, for plant height in Line 4 and Line 5 under normal condition, Line 1, Line 2, Line 3, Line 4 under water stress condition, Line 1, Line 2, Line 3, Line 4 and Line 5 under the combined, for no. of spikes plant-1 in Line 4, Sids 1 under water stress condition, Sids 1, Sahel 1 and Line 5 under water stress condition and Line 4 and Sids 1 under the combined and for no. of kernels spike-1 in Line 2, Line 3, Sahel 1 and Gemmeiza 9 under normal condition, Line 5 and Sahel 1 under water stress condition and Sahel 1 and Line 2 under the combined. Mohammed (2001) showed that Sakha 8 had maximum number of recessive alleles for 100-KWT at water stress condition.

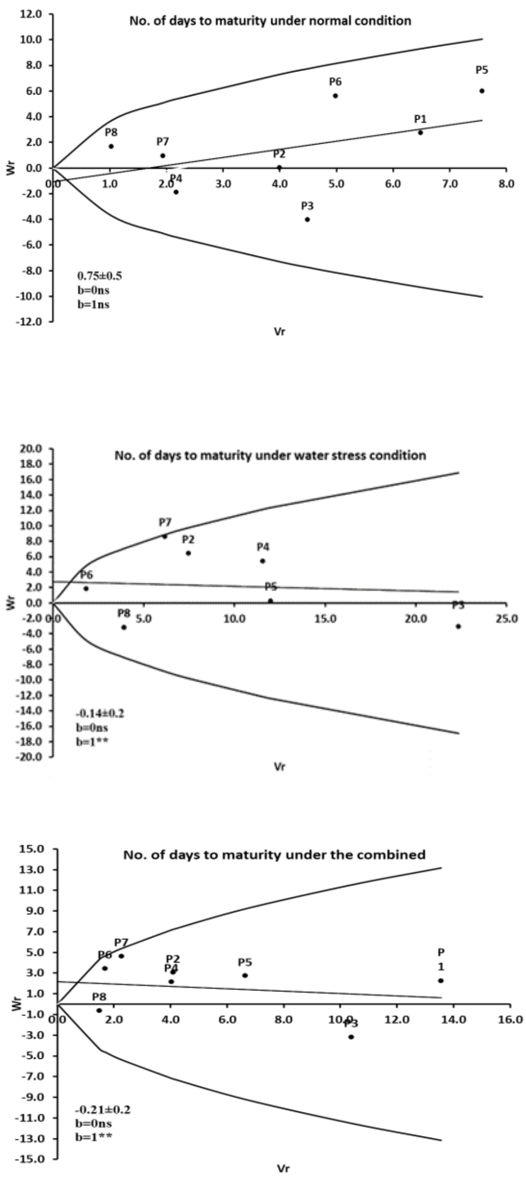

Fig. 1: Graphic representation of Wr/Vr for no. of days to maturity under normal and water stress conditions and the combined in bread wheat: P1 = Line 1, P2 = Line 2, P2 = Line 2, P3 = Line 3, P4 = Line 4, P5 = Line 5, P6 = Sahel 1, P7 = Sids 1 and P8 = Gemmeiza 9.

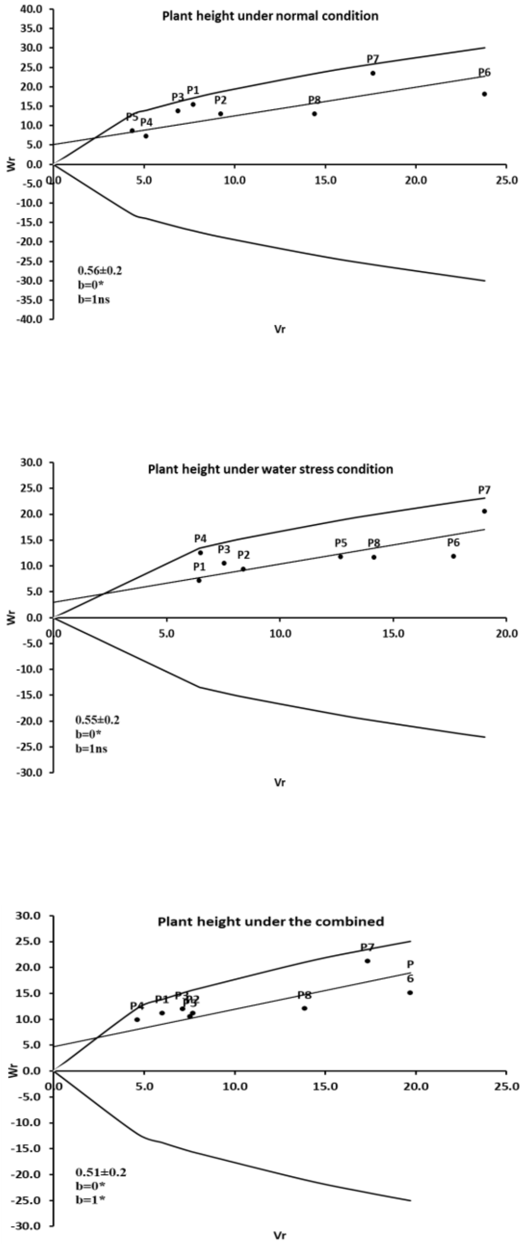

Fig. 2: Graphic representation of Wr/Vr for plant height under normal and water stress conditions and the combined in bread wheat: P1 = Line 1, P2 = Line 2, P2 = Line 2, P3 = Line 3, P4 = Line 4, P5 = Line 5, P6 = Sahel 1, P7 = Sids 1 and P8 = Gemmeiza 9.

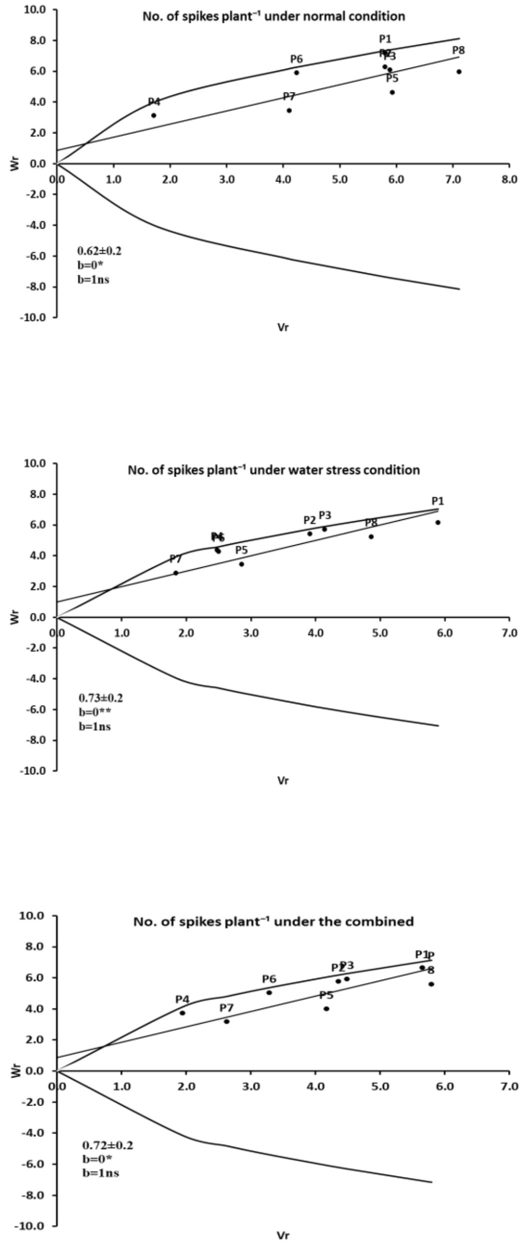

Fig. 3: Graphic representation of Wr/Vr for no. of spikes plant-1 under normal and water stress conditions and the combined in bread wheat: P1 = Line 1, P2 = Line 2, P2 = Line 2, P3 = Line 3, P4 = Line 4, P5 = Line 5, P6 = Sahel 1, P7 = Sids 1 and P8 = Gemmeiza 9.

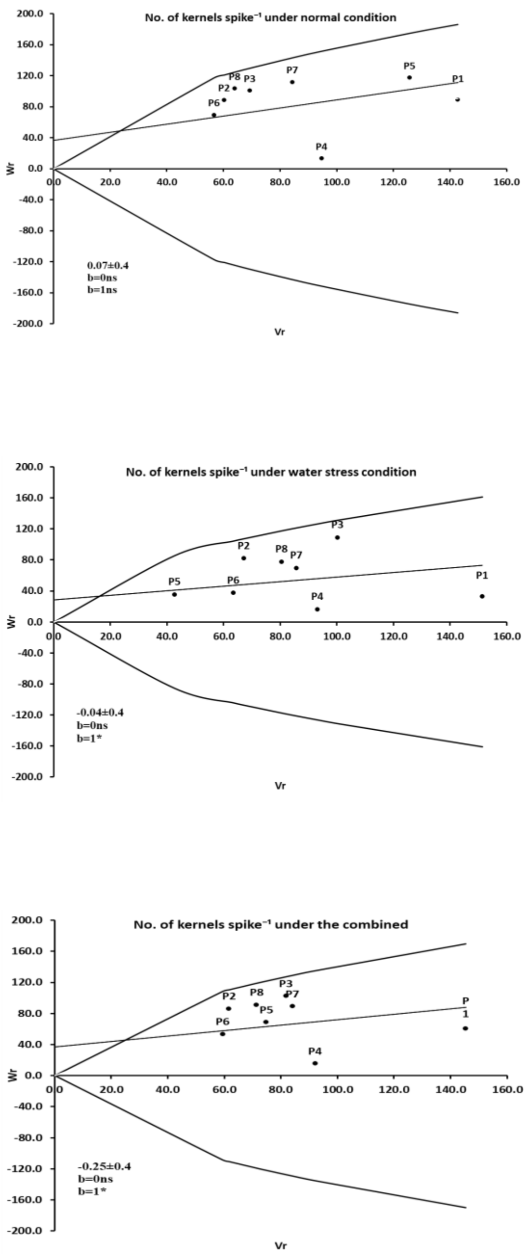

Fig. 4: Graphic representation of Wr/Vr for no. of kernels spike-1 under normal and water stress conditions and the combined in bread wheat: P1 = Line 1, P2 = Line 2, P2 = Line 2, P3 = Line 3, P4 = Line 4, P5 = Line 5, P6 = Sahel 1, P7 = Sids 1 and P8 = Gemmeiza 9.

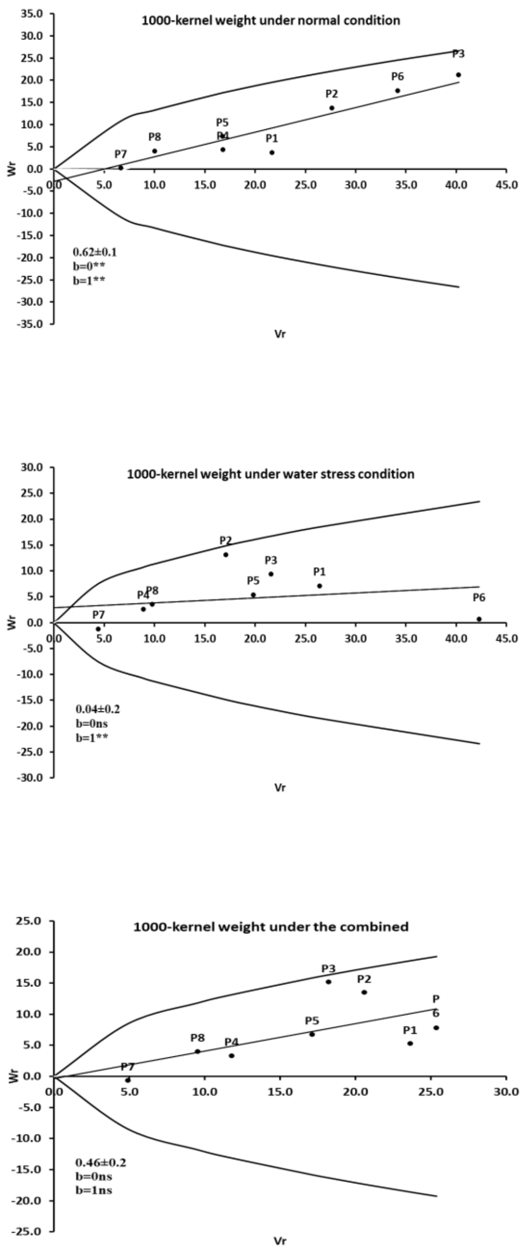

Fig. 5: Graphic representation of Wr/Vr for 1000-kernel weight under normal and water stress conditions and the combined in bread wheat: P1 = Line 1, P2 = Line 2, P2 = Line 2, P3 = Line 3, P4 = Line 4, P5 = Line 5, P6 = Sahel 1, P7 = Sids 1 and P8 = Gemmeiza 9.

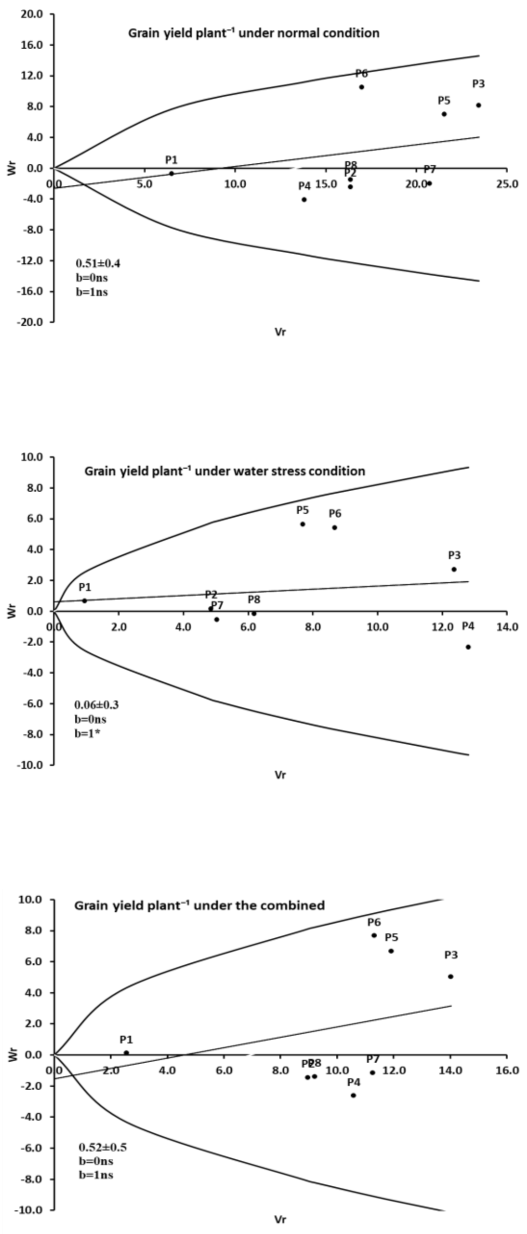

Fig. 6: Graphic representation of Wr/Vr for grain yield plant-1 under normal and water stress conditions and the combined in bread wheat: P1 = Line 1, P2 = Line 2, P2 = Line 2, P3 = Line 3, P4 = Line 4, P5 = Line 5, P6 = Sahel 1, P7 = Sids 1 and P8 = Gemmeiza 9.

However, high frequencies of recessive alleles were observed for plant height in the two cultivars Sahel 1 and Sids 1, 1000-kernel weight and grain yield plant-1 in Line 3 under all conditions. While, the same trend was observed for no. of days to maturity in Line 5 under normal condition, Line 3 under water stress condition and Line 1 and Gemmeiza 9 under the combined, no. of spikes plant-1 in the cultivar Gemmeiza 9 under normal condition, Line 1 under water stress condition and Line 1 and Gemmeiza 9 under the combined and for no. of kernels spike-1, Line 1 and Line 5 under normal condition, Line 1 and Line 3 under water stress condition and Line 1 under the combined.

Based on such results and coefficient of correlation values (r), it could be suggested that crosses involving Line 1, Line 2, Line 3, Sahel 1 and Gemmeiza 9 may result in high level of heterozygosity and transgressive segregation for grain yield and its components under all conditions.

Water stress tolerance indices:

Screening indices are mathematical expressions that consider the performance of plants under both stress and normal conditions. The lower values of stress susceptibility index (SSI), tolerance index (TOL) and Yield index (YI) distinguish the desirable genotypes under stress conditions, while the stress tolerance index (STI) was used to determine higher yields and stress tolerance and the genotypes with high values will be tolerant to water shortage. As shown in table 17, the most tolerant genotype was Line 3 according to SSI, TOL and YI indices, Line 2 and Line 4 gave SSI values less than one and maximum STI value followed by the cultivar Sahel 1 which recorded SSI value less than unity and lowest yield index (YI) value and thus could be considered the most water stress tolerant ones. Meanwhile, the crosses Line 1 × Line 3, Line 2 × Gemmeiza 9, Line 3 × Sahel 1 and Line 4 × Line 5 were the most tolerant according to the stress susceptibility index and tolerance index. While, the cross Line 4 × Sids 1 was recorded lower values for SSI, TOL and YI indices and thus considered the most tolerant one in addition to the cross Line 4 × Sahel 1, which pronounced its water stress tolerance using both SSI and STI indices. Moreover, the crosses Sahel 1 × Sids 1, Line 3 × Gemmeiza 9 and Line 2 × Sids 1 gave SSI values near to one and could be considered moderately tolerant crosses.

Al-Naggar et al. (2020) reported that the most drought tolerant genotypes were the highest yielders under both water stress and normal condition and could therefore be recommended for the future wheat breeding programs. Solangi et al. (2021) reported that stress tolerance index is appropriate to detect the high yielding wheat genotypes under normal and water deficit conditions, while the tolerance index and stress susceptible index could be used to explain the tolerance levels. Gomaa et al. (2014) reported that Sahel 1 had the lowest drought susceptibility index value followed by Gemmieza 9 and F1's crosses Sahel 1 × Gemmieza 9 followed by Gemmieza-9 × Line 1 and Sahel 1 × Misr 1 and would be classified as drought tolerance due to the lowest reduction in yield under water stress compared to non-stress conditions. Qabil (2017) found that Gemmeiza 9 x Gemmeiza 11 cross showed drought sensitivity index (DSI) value less than unity and was considered as more tolerant to drought stress.

Correlation:

The correlation coefficients between the studied traits under the studied irrigation treatments and their combined are shown in table 18. The grain yield plant^{-1} was showed significant and positive correlation with plant height under all conditions. In addition, positive and significant correlation estimates were detected between 1000-kernel weight and no. of kernels spike-1 under normal condition and the combined. In addition, no. of spikes plant-1 correlated positively and significantly with no. of days to maturity under water stress condition and the combined.

Table 17: Water stress tolerance indices using the grain yield under normal and water stress conditions.

Genotype	SSI	TOL	STI	YI
		Parents		
Line 1 (P1)	0.98	5.1	0.78	0.98
Line 2 (P2)	0.58	3.1	0.94	1.12
Line 3 (P3)	0.37	1.6	0.64	0.94
Line 4 (P4)	0.52	2.8	0.90	1.10
Line 5 (P5)	1.17	6.0	0.72	0.92
Sahel 1 (P6)	0.55	2.1	0.47	0.79
Sids 1 (P7)	0.74	3.9	0.84	1.04
Gemmeiza 9 (P8)	0.39	1.9	0.79	1.04
		Hybrids		
P1 × P2	0.64	2.9	0.63	0.91
P1 × P3	0.42	1.9	0.68	0.97
P1 × P4	1.23	7.1	0.92	1.03
P1 × P5	0.65	3.2	0.76	1.00
P1 × P6	1.48	8.2	0.80	0.93
P1 × P7	1.02	5.5	0.85	1.02
P1 × P8	1.03	5.4	0.79	0.98
P2 × P3	0.83	4.9	1.06	1.16
P2 × P4	1.04	6.1	0.98	1.09
P2 × P5	1.35	9.2	1.24	1.18
P2 × P6	1.37	8.1	0.93	1.02
P2 × P7	1.16	6.5	0.87	1.01
P2 × P8	0.44	2.1	0.73	1.00
P3 × P4	2.08	11.5	0.68	0.79
P3 × P5	1.72	9.1	0.68	0.83
P3 × P6	0.43	2.0	0.69	0.97
P3 × P7	1.47	9.8	1.16	1.13
P3 × P8	1.13	7.3	1.17	1.18
P4 × P5	0.38	1.9	0.81	1.06
P4 × P6	0.70	4.2	1.12	1.21
P4 × P7	0.37	1.5	0.53	0.86
P4 × P8	1.28	6.1	0.62	0.85
P5 × P6	0.69	3.2	0.65	0.92
P5 × P7	1.23	7.7	1.08	1.12
P5 × P8	1.64	10.6	1.04	1.05
P6 × P7	1.08	5.3	0.68	0.90
P6 × P8	1.24	6.1	0.67	0.88
P7 × P8	1.32	7.7	0.92	1.02

SSI = stress susceptibility index between, TOL = tolerance index, STI = stress tolerance index and YI = yield index

Table 18: Simple correlation among the studied traits under normal (N), water stress (S) and the combined (C) data.

Character		DM	PH	SP	KS	KW
	N					
No. of days to maturity (DM)	S					
	C					
	N	0.16				
Plant height (PH)	S	-0.12				
	C	-0.01				
	N	0.18	-0.24			
No. of spikes plant-1 (SP)	S	0.409*	-0.15			
	C	0.333*	-0.2			
	N	-0.25	0.23	-0.73		
No. of kernels spike-1 (KS)	S	-0.4	0.13	-0.73		
	C	-0.36	0.18	-0.75		
	N	0.01	0.32	-0.7	0.368*	
1000-kernel weight (KW)	S	-0.19	0.22	-0.56	0.26	
	C	-0.2	0.31	-0.69	0.349*	
	N	0.31	0.48**	0.19	-0.06	0.1
Grain yield plant-1 (GY)	S	0.06	0.338*	0.16	-0.08	0.12
	C	0.24	0.48**	0.19	-0.08	0.16

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

Mady (2023) obtained significant and positive correlations between grain yield and each of plant height, no. of spikes plant-1 and 1000-kernel weight under normal and water stress conditions. Mondal et al. (2020) reported that thousand-kernel weight was associated with grain yield progress under optimum condition, whereas grain weight per tiller associated with progress under drought. Fouad et al. (2020) found significant and positive genotypic correlation between grain yield with no. of grains spike-1 and 1000-grain weight. Ganno et al. (2017) found that grain yield was positively and significantly correlated with plant height and thousand-kernel weight that agrees with our findings herein.

4. Conclusion:

Most tolerant genotype for water stress was line 3 and the combination Line 4 x Sids 1 according to SSI, TOL and YI indices. Moreover, the crosses Line 1 x Line 3, Line 2 x Gemmeiza 9, Line 3 x Sahel 1 and Line 4 x Line 5 were the most tolerant as they recorded lower values for both SSI and TOL indices. Water stress treatment decreased significantly means of all genotypes for grain yield plant-1 with a reduction of 17.36 % for grain yield-1 with values varied from 6.6% to 37.42%. Both additive and non-additive genetic variances were found to be involved in the inheritance of the studied trails, however, non-additive gene effects more important. Line 5 and Sahel 1 were found be the best general combiners for no. of days to maturity, no. of kernels spike-1 and 1000-kernel weight as well as Line 2 and the cultivar Sids 1 for grain yield plant^{-1}. The cross Line 5 x Sids 1 showed desirable SCA effects for both no. of spikes plant-1 and grain yield under both normal and water stress conditions and their combined data. Positive and significant correlations were found among grain yield plant-1 with plant height, spike weight with plant height and no of kernels spike-1

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