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Genetic Studies on Drought Stress Tolerance in Wheat (*Triticum aestivum* L.) Accessions

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ABSTRACT
Water deficit conditions is considering one of the most important environmental constraints that reduce crop productivity to a large extent and hence the wheat crop. Therefore, the genetic improvement for increasing drought tolerance in wheat is one of the most important strategic challenges in this regard. Because of wheat is considering the artery of food not only for the human race, but also for all living things and this food has been known to man since the dawn of time.Five wheat cultivars and their F1 crosses with different reaction for water stress tolerance were estimated under normal and drought conditions to study the genetic behavior responsible for drought tolerance passed on some genetic parameters obtained from half diallel analysis through studying some yield attributes. Mean performances, heterosis over better-parent, general and specific combining ability effects and drought tolerance indices were the most genetic parameters calculated. The final results revealed that the entries; Sakha 94 and PGH-OR 12, Sakha 94 X Shandweel1, PGH-OR12 X Chah "s"/6/Maya/vul//Cmh 74 a. 630 /4*sxs.16342 and PGH-OR 12 X PFSW 343*2/Tukuru were the best genotypes for water stress tolerance and detected highly values of yield traits and revealed highly significant positively for the previous genetic measurements, respectively. The recent wheat accessions were exhibited highly water stress tolerance under the stress treatment compared to the control experiment through evaluationg all studied traits. The final results also indicated the great genetic value, which was transgressive segrgation of the seven wheat genotypes which gave excellent positive results for drought stress.

Keywords: Wheat, Water stress tolerance, Drought, Yield and its components traits, Half diallel analysis

1. Introduction
Wheat is considering one of the most important crops not only in Egypt but also in the worldwide. Wheat is the nominal food for the planet's population. It has many uses as food for humans, animals, birds and baked goods of all kinds, but in recent years, the areas of wheat grown in Egypt have declined due to environmental reasons such as high soil salinity, irrigation water and; water shortage. In this regard, we singled out the problem of the restriction or scarcity of water resources designated for agriculture and the completion of all growth and production processes, (Khatab *et al.,* 2021a). The problem of drougt is considered one of the most important environmental constraints that threaten agricultural production in general, especially the wheat crop. Because depriving plants of the necessary irrigation water will inevitably affect the biological and biochemical processes as well as severely affect mitotic division and ultimately cause severe sterility that affects 40-50% of the final output, (El-Mouhamady *et al.,* 2019). This, of course, will further exacerbate the widening gap in the bread industry in Egypt and affect its quality as well. On the other hand, we notice that the scarcity of irrigation water also leads to a high level of salinity in the soil and raises its toxicity, especially if this coincides with

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the lack of water needed for washing. Accordingly, this will lead to the destruction of the productivity of the winter crops grown in those lands damaged by excessive salinity, such as wheat, barley, beans and all other winter crops. Therefore, researchers and scientists interested in this matter joined efforts to quickly find radical solutions that would reduce the problem of being restricted to water sources. Ultrasound isolation has been evident in experiments with genetic improvement of water stress resistance in rice. Because the used genotypes showed a clear significant superiority in all field and physiological characteristics under study, especially the characteristics of the crop and its components under conditions of water stress experiment compared to the standard experiment. This proves that the obtained rice hybrids gave a large and striking crossbreed compared to their original parents descended from them, (El-Mouhamady, 2009). For these reasons, modern scientific papers has been directed to control high yielding wheat lines which are susceptible to water stress and difficult environmental conditions by importing some tolerate lines for water stress and crossing it with the Egyptian varieties that are sensitive for this environmental stress to produce cultivars with high yielding besides resistant to water deficit conditions after several years of in addition, highly genetic stability, (Abdelsalam, 2010 and Amiri *et al.,* (2013). (El-Mouhamady and El-Seidy, 2014 a) studied water stress tolerance in some wheat accessions with different response for drought tolerance throught generation mean analysis and determining some molelecular markers related with water deficit tolerance. The final results discovered some promising wheat entries succeed for keeping high yielding under drought treatment compared with the normal experiment. Besides, discovering some amplicons assiociated with drought tolerance in this regard. As well as, the recent scientific trends represented in the programs of biotechnology and genetic engineering which had the greatest credit for shedding light on serious attempts to improve the degree of water stress tolerance in wheat. In the following, the most important results of research which were conducted in this regard at the local and global levels. Results obtained by (El-Mouhamady *et al.,* 2016) confirmed that the genotypes; Sakha 8 and Sakha 94, Sakha 8 X Sakha 93, Sakha 8 X Sakha 94 and Sakha 8 X Shandweel were the most superior for drought tolerance measuring morphological under water stress treatment compared to the control experiment. Khatab *et al.,* (2017) confirmed that the sorghum genotypes; (PI534175), (CD550190), (CPI456765 × PI534175), (CP1987656 ×PI534175), (Dorado × PI534175) (CPI456765 × CD550190), (CP1987656 × CD550190) and (Hybrid Shadwell 2 × CD550190) were highly tolerance under water deficit conditions compared with the control for most evaluated genetic parameters in all traits under studying. Ramadan *et al.,* (2016) revealed the importance of water deficit conditions tolerance in some barley accessions and showed that RAPD-PCR markers successed to determine some fragments assiociated with drought tolerance. Fourt eight amplified fragments were generated using 10 ISSR primers and which could be used as molecular markers in barley breeding programs for water stress tolerance, (Khatab *et al.,* 2019). Tawfik and El-Mouhamady (2019) studied drought tolerance in some sorghum genotypes under water stress treatment compared to the normal experiment. They summarized the final results that all sorghum parents besides, the crosses; (P1 X P2, P1 X P3, P2 X P3 and P3 X P4) were gave highly limit of water stress tolerance measurments with all attributes under studying for the stress treatment compared with the normal conditions. (El-Mouhamady and Habouh, 2019) studied salinity tolerance in some rice acessions through six population analysis and rconfirmed that the three F1 rice crosses were scored a fruitful and positive results for salinity tolerance under salt stress treatment compared with the control experiment depending on all studied traits calculated in this regard and were scored values higher than the rest populations in most studied traits under both conditions, (Khatab *et al.,* 2019). Nine wheat genotypes (4 parents and 5 F1 crosses) were showed highly limit of drought tolerance in some yield and its components traits under normal and drought conditions, (El-Mouhamady *et al.,* 2019). Also, they revealed 13 positive specific markers related to water stress tolerance in wheat accessions using five RAPD-PCR primers. The present investigation aimed to screening some wheat genotypes for drought tolerance as a serious attempt to bring about a degree of genetic improvement to withstand water stress in wheat by obtaining a group of crosses which will be the nucleus for producing wheat varieties tolerate for water stress as well as its highly output. In addition, these promising genotypes resulting from the half diallel analysis will be the direct supporter for the simple selection process in the coming isolated generations to reach the maximum and ideal degree of genetic stability. Then, they are used in wheat crop breeding programs to water stress resistance by hybridizing them with susceptible varieties. This simply will be an enrichment of the genetic improvement in Egyptian wheat.

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Methods
Plant Materials

Five wheat genotypes with different reactions for drought were used in half diallel analysis, where the cultivars Sakha 94 (P1) which is a good drought tolerant and Shandweel 1 (P2) which is moderately susceptible to drought, were kindly supplied by the Agricultural Research Center, Institute of Field Crops Research, Wheat Research Department, Giza, Cairo, Egypt. The other three lines were obtained from the Agricultural Scientific Research Center, Cans city, France. They are PGH-OR12 (P3) which is a good drought tolerant genotype, Chah"s"/6/Maya/vul//Cmh74a.630/4*sxs.16342 (P4) which is moderately susceptible to drought and PFSW 343*2/Tukuru (P5) which is susceptible to drought. The present investigation was carried out in the farm of the National Research Centre, Dokki, and Cairo, Egypt. Two experiments with controlled conditions (normal and drought treatments) during the period from 2014-2015 season, were carried out. In case of normal treatment the plants were irrigated with water regularly. The drought treatment was applied by water with holding, i.e., the plants were irrigated at the time of planting and only another irrigation one month later, no more irrigations were done until harvesting. The parental genotypes were grown in a randomized complete block design through three planting dates with ten days interval in order to overcome the differences in flowering time between parents in season 2014 to make hybridization between parents using the emasculation system by hot water (55c^o) through ten minutes. In season 2015 all genotypes (parents and their F1 crosses) were grown in two locations isolated from each of them (normal and drought conditions). The package of all other recommendations of wheat planting was followed as in the same season (2015).

Studied characters

This work aims to study the genetic behavior of some yield attributes. Thirty plants were taken from the parents and F1 crosses at random from each replicate to determine all characters.

1. Heading date (days).
2. Plant height (cm).
3. Flag leaf area (cm^2): It was determined by the method of (Yoshida *et al.,* 1976).
4. Chlorophyll content (mg/ds^{-1}): It was prepared by the formula of (Kozlowski, 1992).
5. Number of panicles per plant.
6. Number of filled grains per panicle.
7. 1000-grain weight (g).
8. Grain yield per plant (g).

Statistical analysis
Analysis of variance

All genetic parameters namely; heterosis over better-parent and both types of combining ability effects of half diallel analysis were conducted by (Griffing, 1956) mode 1, method 2 and (Wyanne *et al.,* 1970).

Estimation of drought tolerance indices

All tolerance indices were estimated according to (Fischer and Maurrer 1978; Bouslama and Schapaugh 1984; Lin *et al.,* 1986, Hossian *et al.,* 1990, Fernandez, 1992, Gavuzzi *et al.,* 1997 and Golestani and Assad, 1998).

GYP: is meaning the grain yield/plant for the control experiment, GYD: is meaning the grain yield/plant for the drought stress experiment, YSI: is meaning yield stability index = YS/YP Where: - YS is the average of yield under stress and YP=the average of yield under the control experiment, YI: is meaning yield index (YS for each genotype/mean of YS for all genotypes), MP is means (Average yield for both trials): YS + YP/2, DTI: is meaning drought stress tolerance index (YP X YS/ (mean of YP)^2, GMP: (YP X YS)$^{0.5}$ where YR: is meaning yield reduction (1-YS/YP) and DSI: is meaning drought susceptibility index = DSI = (1-YS/YW)/D where YS = mean yield under salt stress, Yw = mean yield under control condition, and D = environmental stress intensity = 1-(mean yield of all genotypes under stress/mean yield of all genotypes under irrigated conditions).

List of Abbreviations
*: Significant at 5%, **: Significant at 1%, LSD at 5%: List significant differences at 5%, LSD at 1%: List significant differences at 1%, GCA: General combining ability effects, SCA: Specific combining ability effects, P1: parent one, P2: parent two, P3: parent three, P4: parent four and P5: parent five.

Results

Field evaluation

Mean performance

The mean values of genotypes for studied characters under normal and drought conditions are presented in (Table 1 and Fig. 1 (A to H forms). For heading date and plant height traits, the earlier and shorter plants which gave the lowest mean values towards dwarfism were obtained from parents; Sakha 94 and PGH-OR 12, besides the crosses; Sakha 94 X Shandweel 1 , PGH-OR 12 X Chah "s"/6/Maya/vul//Cmh 74 a. 630 /4*sxs.16342 and PGH-OR 12 X PFSW 343*2/Tukuru. While, the same genotypes (parents and their F1 crosses) recorded the best results for the traits, flag leaf area, chlorophyll content, number of panicles per plant, number of filled grains per panicle, 1000-grain weight and grain yield per plant under normal and drought conditions, respectively.

Analysis of variance

Mean squares of half diallel analysis for all traits studied are presented in (Table 2). The results showed that mean squares of all genotypes of wheat accessions were revealed to be highly significant for all traits studied in half diallel analysis under normal and water deficit conditions.

Heterosis over better – parents

Table 3 revealed the percentages of heterosis over better parents for all traits studied under all conditions. With respect to heading date, heterosis percentages were highly significant and negative in two crosses for the normal and drought conditions. The highest negative percentages were obtained for the crosses; (PGH-OR 12 X Chah"s"/6/Maya/vul //Cmh74a.630/4*sxs.16342 and PGH-OR 12 X PFSW 343* 2/Tukuru) under normal and drought conditions. While, the cross (Sakha 94 X Shandweel 1) was showed highly significant and negative under normal irrigation only for plant height trait, respectively. The negative values were important in these two traits because when plants of wheat were earlier and shorter the grain yield becomes higher, so the relationship between them is counterproductive. For flag leaf area, the crosses; Sakha 94 X Shandweel 1, PGH-OR 12 X Chah "s"/6/Maya/vul//Cmh 74 a. 630 /4*sxs.16342 under normal and drought conditions and the cross Chah "s"/6/Maya/vul//Cmh 74 a. 630 /4*sxs.16342 X PFSW 343*2/Tukuru under normal conditions only were highly significant and positive of heterosis over better-parent, respectively. But, the crosses; Sakha 94 X Shandweel 1, PGH-OR 12 X Chah"s"/6/Maya/vul//Cmh74a.630/4*sxs. 16342 and PGH-OR 12 X PFSW 343*2/Tukuru were revealed the same results in chlorophyll content trait and not any significant positively of heterosis over better-parents was observed in number of panicles per plant, respectively. On the other hand, the crosses Shandweel 1 X PFSW 343*2/Tukuru, PGH-OR 12 X PFSW 343*2/Tukuru and Chah "s"/6/Maya/vul//Cmh 74 a. 630 /4*sxs.16342 X PFSW 343*2/Tukuru were recorded significant and highly significant positively of heterosis over better-parent for number of filled grains per panicles. While, the two crosses; PGH-OR 12 X Chah "s"/6/Maya/vul//Cmh 74 a. 630 /4*sxs.16342 and PGH-OR 12 X PFSW 343*2/Tukuru under normal conditions for the the first one and all conditions for the second cross were showed highly significant positively of heterosis over better- parent for 1000-grain weight, respectively. With respect to grain yield per plant; significant and highly significant positively of heterosis over better-parent were observed in the crosses; Sakha 94 X Shandweel 1, Shandweel 1 X PFSW 343*2/Tukuru under normal conditions only and PGH-OR 12 X PFSW 343*2/Tukuru under normal and water stress conditions for grain yield per plant showed the effective of additive and additive x additive gene action in the controlling of these traits for water stress tolerance.

Table 1: Estimation of mean performances for all traits studied in wheat under normal and drought conditions

Genotypes	Heading date		Plant height		Flag leaf area		chlorophyll content		Number of panicles per plant		Number of filled grains per panicle		1000-grain weight		Grain yield per plant	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
P1	81.67	75.00	81.00	62.00	52.33	47.33	52.00	48.33	22.67	18.67	105.3	101.00	54.00	45.00	63.67	59.67
P2	110.17	103.00	95.33	92.00	39.00	32.33	28.00	24.33	16.67	10.33	41.00	33.00	15.33	11.67	26.33	23.00
P3	86.85	78.67	74.00	65.33	63.00	59.00	45.67	42.67	26.00	22.67	91.33	86.00	42.33	38.67	52.33	48.67
P4	106.00	114.00	103.33	87.67	20.33	14.33	22.33	16.33	12.33	8.33	30.33	25.00	27.33	22.00	18.83	13.83
P5	114.00	117.00	113.00	105.00	26.00	22.67	35.33	31.67	14.00	7.33	25.00	17.67	14.67	10.33	30.33	27.33
P1 x P2	90.00	79.33	70.00	63.00	76.33	72.33	57.67	55.00	22.67	20.00	111.0	105.33	32.67	28.67	68.33	62.00
P1 x P3	120.00	117.00	115.00	111.00	27.67	24.67	24.00	19.33	11.00	5.33	34.33	22.67	20.00	17.00	24.00	18.67
P1 x P4	119.00	113.67	119.00	114.00	40.33	37.67	19.33	17.00	12.00	8.67	60.33	51.67	32.00	27.33	33.33	29.67
P1 x P5	117.00	110.67	106.67	99.67	27.67	23.33	37.33	34.33	12.33	10.00	22.33	16.33	18.00	14.33	15.67	11.67
P2 x P3	116.67	114.00	101.33	95.33	38.00	29.00	30.00	26.00	10.67	7.33	48.33	40.00	16.67	7.33	23.33	15.33
P2 x P4	120.00	117.00	109.00	99.67	23.33	18.33	27.33	21.00	15.67	11.00	27.67	23.67	29.33	23.00	21.67	18.33
P2 x P5	107.33	102.00	106.00	102.00	34.67	31.00	39.00	35.33	9.00	5.67	54.00	44.67	13.67	7.00	33.00	25.67
P3 x P4	82.00	74.00	81.00	74.00	70.00	65.00	66.00	58.67	27.67	22.33	92.00	87.00	49.67	34.00	49.00	43.67
P3 x P5	77.67	72.00	83.67	72.00	58.33	53.33	61.67	55.33	28.00	25.00	114.0	109.33	57.67	50.33	65.67	55.67
P4 x P5	119.67	116.33	102.33	86.67	32.00	22.33	37.00	34.00	14.33	10.67	53.00	31.67	21.33	16.67	35.67	30.00
LSD 0.05	**3.85**	**3.59**	**5.26**	**7.70**	**5.09**	**5.54**	**4.25**	**4.96**	**3.56**	**3.25**	**11.20**	**13.71**	**5.58**	**5.26**	**2.65**	**3.57**
LSD 0.01	**5.20**	**4.85**	**7.09**	**10.39**	**6.86**	**7.48**	**5.73**	**6.70**	**4.80**	**4.39**	**15.12**	**18.50**	**7.52**	**7.09**	**3.58**	**4.82**

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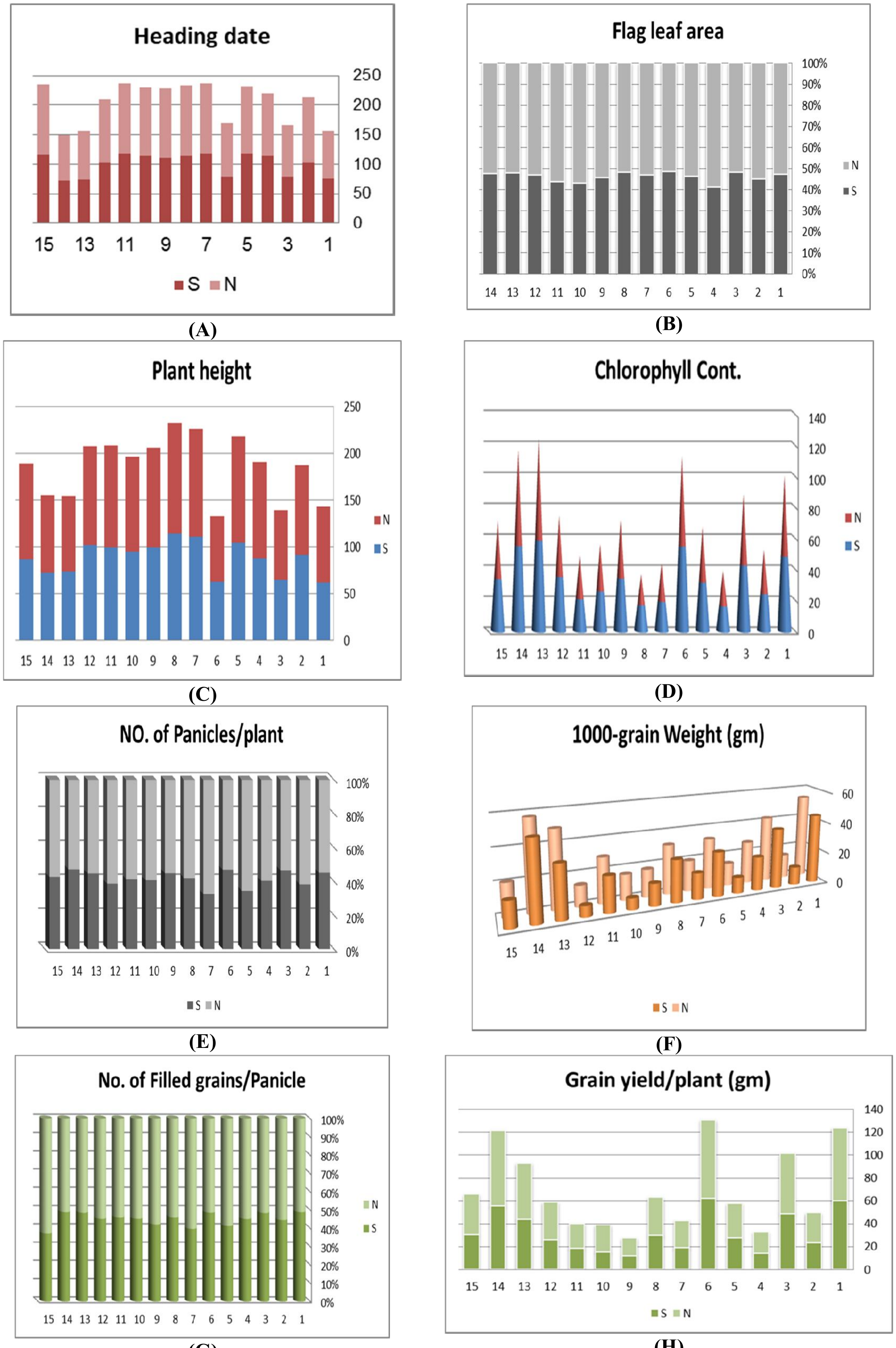

Fig. 1: The forms from (A to H) show the impact of water stress on all studied attributes; (Agro-morphological, yield and its components) for all wheat genotypes from 1 : 15 where the parents from 1 to 5 and the crosses from 6 to 15, respectively.

Table 2: Mean squares of all entries of wheat for all traits studied under all conditions

S.O.V	df	Heading date		Plant height		Flag leaf area		chlorophyll content		Number of panicles per plant		Number of filled grains per panicle		1000-grain weight		Grain yield per plant	
		Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Replication	2	2.43	2.02	5.49	22.02	6.47	3.82	0.42	2.96	5.60	11.82	45.27	31.27	2.02	17.62	** 43.01	** 82.41
Genotypes	14	** 777.21	** 1029.78	** 732.47	** 920.33	** 952.20	** 992.90	** 654.04	** 627.71	** 130.00	** 138.94	** 3296.05	** 3581.57	** 666.64	** 554.22	** 955.01	** 895.05
GCA	4	** 195.57	** 325.85	** 214.71	** 169.27	** 341.44	** 367.23	** 138.27	** 151.22	** 36.72	** 41.18	** 1025.61	** 1165.06	** 292.29	** 251.93	** 242.68	** 234.11
SCA	10	** 284.47	** 350.22	** 255.94	** 361.78	** 307.78	** 316.46	** 249.91	** 232.44	** 45.98	** 48.37	** 1127.91	** 1205.38	** 194.18	** 157.87	** 348.60	** 324.05
Error	28	5.31	4.62	9.89	21.21	9.25	10.99	6.45	8.81	4.53	3.78	44.89	67.27	11.12	9.88	2.52	4.56
Error term		1.77	1.54	3.30	7.07	3.08	3.66	2.15	2.94	1.51	1.26	14.96	22.42	3.71	3.29	0.84	1.52
GCA/SCA		0.10	0.13	0.12	0.07	0.16	0.17	0.08	0.09	0.11	0.12	0.13	0.14	0.22	0.23	0.10	0.10

*:- Significant at 0.05, **:- Significant at 0.01

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Table 3: Estimates of heterosis over better parent (B.P) of F1 wheat entries for all traits studied under all conditions

Crosses	Heading date		Plant height		Flag leaf area		chlorophyll content		Number of panicles per plant		Number of filled grains per panicle		1000-grain weight		Grain yield per plant	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
P1XP2	** 10.20	* 5.77	** -13.58	1.61	** 45.86	** 52.82	* 10.90	* 13.80	0.00	7.12	5.38	4.29	** -39.50	** -36.29	** 7.32	3.90
P1XP3	** 46.93	** 56.00	** 55.41	** 79.03	** -56.08	** -58.19	** -53.85	** -60.00	** -57.69	** -76.49	** -67.41	** -77.55	** -62.96	** -62.22	** -62.31	** -68.71
P1XP4	** 45.71	** 51.56	** 46.91	** 83.87	** -22.93	** -20.41	** -62.83	** -64.83	** -47.07	** -53.56	** -42.72	** -48.84	** -40.74	** -39.27	** -47.65	** -50.28
P1XP5	** 43.26	** 47.56	** 31.69	** 60.76	** -47.12	** -50.71	** -28.21	** -28.97	** -45.61	** -46.44	** -78.80	** -83.83	** -66.67	** -68.16	** -75.39	** -80.44
P2XP3	** 34.34	** 44.91	** 36.93	** 45.92	** -39.68	** -50.85	** -34.31	** -39.07	** -58.96	** -67.67	** -47.08	** -53.49	** -60.62	** -81.04	** -55.42	** -68.50
P2XP4	** 13.21	** 13.59	** 14.34	** 13.69	** -40.18	** -43.30	-2.39	-13.69	-6.00	6.49	* -32.51	-28.27	7.32	4.55	** -17.70	* -20.30
P2XP5	-2.58	-0.97	** 11.19	* 10.87	-11.10	-4.11	10.39	11.56	** -46.01	** -45.11	* 31.71	* 35.36	-10.83	-40.02	* 8.80	-6.07
P3XP4	* -5.58	* -5.94	* 9.46	* 13.27	* 11.11	* 10.17	** 44.51	** 37.50	6.42	-1.50	0.73	1.16	* 17.34	-12.08	* -6.36	** -10.27
P3XP5	** -10.57	** -8.48	** 13.07	10.21	-7.41	* -9.61	** 35.03	** 29.67	7.69	10.28	* 24.82	* 27.13	** 36.24	** 30.15	** 25.49	** 14.38
P4XP5	** 12.90	2.04	-0.97	-1.14	* 23.08	-1.50	4.73	7.36	2.36	28.09	** 74.74	* 26.68	* -21.95	* -24.23	17.61	9.77
LSD 0.05	3.85	3.59	5.26	7.70	5.09	5.54	4.25	4.96	3.56	3.25	11.20	13.71	5.58	5.26	2.65	3.57
LSD 0.01	5.20	4.85	7.09	10.39	6.86	7.48	5.73	6.70	4.80	4.39	15.12	18.50	7.52	7.09	3.58	4.82

*:- Significant at 0.05, **:- Significant at 0.01

Combining ability effects

General and specific combining ability effects

Results in (Table 4) detected that the parents; Sakha 94 and PGH-OR 12 achieved highly significant and negatively of general combining ability effects for heading date, plant height traits under different conditions. While, the same parents in addition, the parent PFSW 343*2/Tukuru showed highly significant and positively of general combining ability effects for chlorophyll content under normal and drought conditions. On the other hand, the parent PGH-OR 12 showed highly significant and positively of general combining ability effects for number of panicles per plant under all conditions. But, the Parents; Sakha 94 and PGH-OR 12 recorded highly significant and positively of general combining ability effects for number of filled grains per panicle, 1000-grain weight and grain yield per plant under both conditions.

In the same track, results in (Table 5) revealed that the crosses ; Sakha 94 X Shandweel 1, Shandweel 1 X PFSW 343*2/Tukuru , PGH-OR 12 X Chah "s"/6/Maya/vul//Cmh 74 a. 630 /4*sxs.16342 and PGH-OR 12 X PFSW 343*2/Tukuru exhibited significant and highly significant negatively of specific combining ability effects for heading date and plant height traits under all conditions except the cross; Shandweel1 X PFSW 343*2/Tukuru for plant height , respectively. Significant and highly significant positively of specific combining ability effects were observed in the crosses; Sakha 94 X Shandweel1, PGH-OR 12 X Chah"s"/6/Maya/vul// Cmh74a.630/4*sxs.16342 and PGH-OR12 X PFSW343*2/ Tukuru for the other traits studied under normal irrigation and water stress conditions. In addition, the crosses; Chah "s"/6/Maya/vul//Cmh74a.630/4*sxs.16342 X PFSW343*2/ Tukuru for flag leaf area under normal conditions, the same cross for chlorophyll content under drought conditions; Shandweel 1 X PFSW 343*2/Tukuru under all conditions and Chah "s"/6/Maya/vul//Cmh 74 a. 630 /4*sxs.16342 X PFSW 343*2/Tukuru under normal conditions only for number of filled grains per panicle; Shandweel 1 X P4 is Chah "s"/6/Maya/vul//Cmh74a.630/4*sxs.16342 under all conditions for 1000-grain weight and the cross; Chah "s"/6/Maya/vul// Cmh 74 a. 630 /4*sxs.16342 X PFSW 343*2/Tukuru for grain yield per plant under normal and drought conditions were exhibited the same results.

Water Stress Tolerance indices

Data presented in (Table 6) confirmed that the accessions; (P1, P2, P3, P1 X P2, P3 X P4 and P3 X P5) for the parameter (YSI) and the same genotypes except P3 (for (MP and GMP) were exhibited the highest mean values for water stress tolerance indices test in this investigation which confirmed that these wheat entries were highly tolerance for drought conditions compared to the control treatment. On the same context, the genotypes; (P1, P3, P1 X P2, P3 X P4 and P3 X P5) for (YI) and (DTI) parameters were exhibited mean values higher than the unity which revealed that these superior wheat genotypes were detected highly water stress tolerance under drought conditions compared to the normal experiment, respectively. On the other hand, all wheat genotypes under studying for the parameter (YR) and the genotypes; (P1, P2, P3, P5, P1 X P2, P1 X P4 and P3 X P4) for the parameter DSI were recorded values lower than one which indicated that these excellent wheat accessions were gave highly tolerance for drought stress in this regard

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Table 4: Estimates of general combining ability effects of all wheat entries for all traits under all conditions

Parents	Heading date		Plant height		Flag leaf area		chlorophyll content		Number of panicles per plant		Number of filled grains per panicle		1000-grain weight		Grain yield per plant	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
P1	-2.55**	-4.40**	-1.66*	-2.87**	3.58**	4.51**	1.32*	2.09**	0.19	0.57	10.67**	11.43**	4.69**	5.14**	6.31**	6.87**
P2	3.88**	2.41**	-1.04	1.75	-0.18	-0.82	-3.30**	-3.10**	-1.52**	-1.81**	-5.86**	-5.48**	-7.84**	-7.43**	-3.64**	-3.70**
P3	-8.17**	-9.59**	-7.90**	-6.96**	9.77**	9.85**	5.70**	5.28**	3.90**	4.00**	15.33**	16.14**	7.26**	6.38**	6.03**	5.34**
P4	3.64**	6.79**	4.82**	2.56**	-6.47**	-7.01**	-5.53**	-6.34**	-1.10*	-1.14**	-10.05**	-10.57**	1.30	0.52	-6.73**	-6.28**
P5	3.21**	4.79**	5.77**	5.51**	-6.70**	-6.53**	1.80**	2.09**	-1.48**	-1.62**	-10.10**	-11.52**	-5.41**	-4.62**	-1.97**	-2.23**
LSD 0.05	0.92	0.86	1.26	1.84	1.22	1.33	1.01	1.19	0.85	0.78	2.68	3.28	1.33	1.26	0.63	0.85
LSD 0.01	1.24	1.16	1.70	2.48	1.64	1.79	1.37	1.60	1.15	1.05	3.61	4.42	1.80	1.70	0.86	1.15

*:- Significant at 0.05, **:- Significant at 0.01

Table 5: Estimates of specific combining ability effects of all wheat genotypes for all characters under all conditions

Crosses	Heading date		Plant height		Flag leaf area		chlorophyll content		Number of panicles per plant		Number of filled grains per panicle		1000-grain weight		Grain yield per plant	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
P1XP2	-15.86**	-18.92**	-24.68**	-24.51**	31.00**	31.79**	20.79**	21.40**	7.00**	8.35**	45.52**	46.38**	6.17**	7.40**	28.25**	26.63**
P1XP3	26.19**	30.75**	27.17**	32.21**	-27.62**	-26.54**	-21.87**	-22.65**	-10.10**	-12.13**	-52.33**	-57.90**	-21.59**	-18.08**	-25.75**	-25.75**
P1XP4	13.38**	11.03**	18.46**	25.68**	1.29	3.32	-15.30**	- 13.37**	-4.10**	-3.65**	-0.95	-2.19	-3.63*	-1.89	-3.66**	-3.13**
P1XP5	11.81**	10.03**	5.17**	8.40**	-11.14**	-11.49**	-4.63**	-4.46**	-3.38**	-1.84	-38.90**	-36.57**	-10.92**	-9.75**	-26.09**	-25.18**
P2XP3	16.42**	20.94**	12.89**	11.92**	-13.52**	-16.87**	-11.25**	-10.79**	-8.71**	-7.75**	-21.81**	-23.67**	-12.40**	-15.17**	-16.47**	-18.52**
P2XP4	7.95**	7.56**	7.84**	6.73**	-11.95**	-10.68**	-2.68*	-4.17**	1.29	1.06	-17.10**	-13.29**	6.22**	6.35**	-5.37**	-3.90**
P2XP5	-4.28**	-5.44**	3.89*	6.11*	-0.38	1.51	1.65	1.73	-5.00**	-3.79**	9.29*	8.67*	-2.73	-4.51**	1.20	-0.61
P3XP4	-18.00**	-23.44**	-13.30**	-10.22**	24.76**	25.32**	26.98**	25.11**	7.86**	6.59**	26.05**	28.43**	11.46**	3.54*	12.29**	12.39**
P3XP5	-21.91**	-23.44**	-11.59**	-15.17**	13.33**	13.17**	15.32**	13.35**	8.57**	9.73**	48.10**	51.71**	26.17**	25.02**	24.20**	20.34**
P4XP5	8.29**	4.51**	-5.63**	-10.03**	3.24**	-0.97	1.89	3.63*	-0.10	0.54	12.48**	0.76	-4.21*	-2.79	6.96**	6.29**
LSD 0.05	2.38	2.22	3.25	4.75	3.14	3.42	2.62	3.06	2.20	2.01	6.91	8.46	3.44	3.24	1.64	2.20
LSD 0.01	3.21	2.99	4.38	6.41	4.24	4.62	3.54	4.13	2.96	2.71	9.33	11.42	4.64	4.38	2.21	2.97

*:- Significant at 0.05, **:- Significant at 0.01

Table 6: Estimation of drought stress tolerance indices parameters for all wheat genotypes especially for grain yield trait under normal and water deficit conditions

Genotypes	GYP	GYD	YSI	YI	MP	DTI	GMP	YR	DSI
P1	63.67	59.67	**0.93**	**1.85**	61.67	**2.71**	61.63	0.07	0.50
P2	26.33	23.00	**0.87**	0.71	24.66	0.43	24.60	0.13	0.94
P3	52.33	48.67	**0.93**	**1.51**	50.50	**1.81**	50.46	0.07	0.50
P4	18.83	13.83	0.73	0.42	16.33	0.18	16.13	0.27	1.95
P5	30.33	27.33	**0.90**	0.84	28.83	0.59	28.79	0.10	0.72
P1XP2	68.33	62.00	**0.90**	**1.92**	**65.16**	**3.02**	**65.08**	0.10	0.72
P1XP3	24.00	18.67	**0.77**	**0.57**	**21.33**	0.32	**21.16**	0.23	**1.66**
P1XP4	33.33	29.67	0.89	0.92	31.50	0.70	31.44	0.11	0.79
P1XP5	15.67	11.67	**0.74**	**0.36**	**13.67**	**0.13**	**13.52**	0.26	1.88
P2XP3	23.33	15.33	0.65	0.47	19.33	0.25	18.91	0.35	2.53
P2XP4	21.67	18.33	0.84	0.56	20.0	0.28	19.93	0.16	1.15
P2XP5	33.00	25.67	**0.77**	**0.79**	**29.33**	**0.60**	**29.10**	0.23	**1.66**
P3XP4	49.00	43.67	**0.89**	**1.35**	**46.33**	**1.52**	**46.25**	0.11	**0.79**
P3XP5	65.67	55.67	**0.84**	**1.72**	**60.67**	**2.61**	**60.46**	0.16	**1.15**
P4XP5	35.67	30.00	0.84	0.93	32.83	0.76	32.71	0.16	1.15

Discussion

Genetic improvement of wheat's tolerance to various environmental stresses is one of the most important scientific foundations in our current century, especially water stress in Egypt. Given that this large and ancient country is severely exposed to water poverty due to the expansion of the agricultural land necessary for cultivating strategic crops that are very voracious for water such as rice and sugar cane. On the other hand, due to the regional challenges that Egypt faces, especially after the construction of the Grand Ethiopian Renaissance Dam, which will negatively affect Egypt's international share of the Blue Nile water. That is why thousands of researches and studies were launched in an attempt to find radical solutions to this great crisis. As part of the search for new water resources, such as treating wastewater, catching seasonal rains and directing it to agriculture. In addition, the introduction of new wheat lines that are resistant to water stress as well as high yield.The field assessment under the conditions of water stress that afflicts countries that are exposed to the scarcity of water resources necessary for agriculture and all means of life is considering one of the most reliable tests. Because, it helps to know the genetic behavior of each wheat genotype responsible for resistance to water deficit or sensitivity to it. Moreover, conventional breeding programs have already succeeded in classifying the different plant species and identifying their resistance in order to use it for genetic improvement to water stress tolerance in the susceptible wheat materials under testing. For this desired purpose, that study used the system half diallel analysis, that is without using reverse hybrids to prevent cytoplasmic inheritance by mother or mother genetics (reciprocals). So that, the source of resistance genes is coming from the resistance parent only. This has already succeeded in obtaining multiple genetic differences and classifications across this type of crossing. So that, scientists can perform the differentiation process to successfully obtain drought-resistant genotypes which appeared from the second generation. Moreover, the ten hybrids resulting from half diallel analysis are considered the actual kernel which may be the way to obtain water stress-resistant wheat lines in addition, their high yield. This will do through continuing to cultivate these promising hybrids and make selection process in the segregation generations to reach complete genetic stability. All this confirms the importance of all wheat genotypes used in this investigation to have a different reaction and response to this dangerous environmental factor, and that they also be of different origin and source. Because of, this gives the breeder a great opportunity to obtain various genes for the wheat genome before starting the study. In another context, we find that diallel crosses provide fruitful genetic tests that would reveal genotypes that are resistant to water deficit conditions, such as heterosis, general and specific combing ability effects besidesm drougt tolerance indices for all genetic materials under the stress treatment compared to the control experiment. Results in (Table 1 and Fig. 1 (A to H forms) indicated that the previous genotypes succeed for increasing the water limits during water deficit conditions which reflected on increasing water stress tolerance in wheat. As well as, these traits played an importance role in clarifying the natural test for drought tolerance in wheat by early syphilis exudation, reducing the vegetative period and speeding up the fullness of grains before entering the stage of water deficit intensity, (El-Keredy *et al.,* 2003 a; El-Mouhamady, 2003, El-Mouhamady, 2009; El-Mouhamady *et al.,* 2010 a & b; Zian *et al.,* 2013; El-

Mouhamady *et al.,* 2013 a and El-mouhamady *et al.,* 2021 a). This also confirmed that the aforementioned superior genotypes have already succeeded in reducing the time required to reach flowering. This of course has resulted in reducing their total needing for irrigation water. Further, the process of speeding up flowering also leads to speeding up all biological and biochemical processes by limiting and how to ensure plant life while reducing transpiration and preserving water to complete its life cycle, (Naghavi *et al.,* 2015; Kashiwagi *et al.,* 2015; Heiba *et al.,* 2016 a; Ramadan *et al.,* 2016; Eldessouky *et al.,* 2016; Email *et al.,* 2016 and Kishk *et al.,* 2017). By the same token, the superior wheat genotypes in this study were able to preserve the characteristic of short plant height. Because of, this will enable the superior hybrids to carry the largest number of tillers. Thus, this will be reflected in increasing of the yield and its components besides, be suitable for mechanical harvesting. The real resistance to drought was to maintain the total content of chlorophyll and the area of the flag leaf without change under conditions of water stress compared to natural conditions, (Khatab *et al.,* 2017; Khatab *et al.,* 2019; Al-Kordy *et al.,* 2019; El-Mouhamady and Habouh, 2019; Tawfik and El-Mouhamady, 2019 and El-Mouhamady and El-Metwally, 2020 a).

Data obtained in (Table 2) revealed the importance of ANOVA test to make sure that all the genotypes, whether they were from parents or hybrids under studying were highly differentiated between them to a high degree of moral. This fact was the main entrance to Griffing's analysis. In addition, GCA/SCA ratio were less than one in all attributes under testing for the two experiments indicating that the selection process for highly yielding and drought tolerance will be importance and very fruitful in the early segregation generation. Further, also the simple selection will do by bulk method. This genetic progress in plant breeding program would not have occurred unless the parents involved in the crossbreeding method were different from each other in order for a natural exchange to occur between the genes of resistance and sensitivity to water stress. This confirms, of course, that the introduction of imported wheat varieties or lines that tolerate to drought stress, along with Egyptian varieties sensitive to this dangerous environmental factor, is not only correct, but also has some consideration. This is a strong indication of the importance of a good knowledge of the researcher about the quantitative and descriptive traits of all genetic materials used before starting the study including traits that tolerate to salinity, water deficit conditions, resistance to diseases and other traits required for the genetic improvement of crops. (Omar *et al.,* 2010; El-Mouhamady *et al.,* 2011; El-Mouhamady *et al.,* 2013 b; El-Mouhamady *et al.,* 2014 b & c & d; Abedi *et al.,* 2015; Abo-Hamed *et al.,* 2016; Bin, 2012; El-Mouhamady *et al.,* 2017; El-Mouhamady *et al.,* (2019), and Khatab *et al.,* 2019).

The values of heterosis over better-parent viewed in (Table 3) confirmed that dominance variance and their interactions were played a fruitful role for controlling and inheriting all studied traits under both conditions. Besides, increasing the level of water stress tolerance in wheat genotypes under local conditions. Also, heterosis over better-parent is considered one of the important genetic evidence which shows the breeder the feasibility of continuing the breeding to drought tolerance in different wheat lines. The simple selection process based on hybrids that are more tolerant to unfavorable environmental factors, especially water stress, is a natural test for sorting and sifting a large number of genotypes with unknown degree of response to these factors before starting the various plant breeding programs. Therefore, tracing the quantitative traits that have the dominant effect of gene action in this regard will be very fruitful for breeding quantitative traits such as yield and its components and tolerance of water and salt stresses. As well as selection for many other traits such as resistance to various wheat diseases, which also affect the final product. After all this, it is evident that the five promising wheat hybrids which gave positive values in all studied traits had already demonstrated the dominant genetic action to water stress tolerance compared to the rest of genotypes under testing. Therefore, these hybrids are considered as the original nucleus for producing wheat lines that are resistant to water stress and their yield under water deficit conditions was good compared to natural conditions. These results were in agreement with those reported by (El-Keredy *et al.,* 2003 b; Ganapathy and Ganesh, 2008; El-Mouhamady *et al.,* 2013 c; El-Mouhamady *et al.,* 2014 e & f & g; El-Mouhamady *et al.,* 2015; Heiba *et al.,* 2016 b; El-Mouhamady and Habouh, 2019 and Tawfik and El-Mouhamady, 2019).

Results presented in (Table 4) and related to general combining ability effects confirmed that additive gene action and its interactions were very fruitful for enhansing water deficit resistance in wheat. While, dominance gene action and their interactions were refelected the importance role of specific combining ability effects and contributed for increasing the ability of drought tolerance in wheat genotypes (Table 5), respectively. If we look closely to results of general and specific combining

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ability effects, we find that all parents used in this study were genetically similar to a large extent in their biological growth characteristics. In addition, the physiological changes associated with water stress were the greatest evidence that these parents were indeed tolerant of drought stress that affects critical plant growth stages. Especially, the number of days to flowering and the stages of mitotic division responsible for the final output. These physiological changes are closely related to additive gene action and its various interactions in showing the trait of tolerance to drought, among which is the ability of plants to genetically control osmotic pressure. This is done by controlling the entry and exit water amount necessary for growth and completion of the rest vital processes. Besides, reaching to the ideal pressure to save the life of plant, which is the modified osmotic pressure or osmotic adjustment. As well as, the genetic control responsible for opening and closing the stomata, especially the upper ones. In order to prevent the loss of a large amount of water during the process of transpiration and maintain a reasonable water amount needed for photosynthesis and production of dry matter.This really did agree and also agreed with each of (Khakwani *et al.,* 2011; Hassan *et al.,* 2012; Abdel Sattar and El-Mouhamady, 2012; El-Mouhamady *et al.,* 2012 a; El-Mouhamady *et al.,* 2012 b; El-Mouhamady *et al.,* 2013 d; El-Mouhamady and El-Seidy, 2014 a; El-Mouhamady and El-Seidy, 2014 b; Yogameenakshi and Vivekanandan, 2015; Tawfik and El-Mouhamady, 2019 and El-Mouhamady *et al.,* 2020).

After all the reviewed results for the drought tolerance indices evidence in (Table 6) and relation to grain yield/plant in wheat. It can briefly explain the most important genetic achievements obtained in this investigation is screening of all genotypes under studying for water stress tolerance. Because of the previous promising wheat accessions were not only tolerant for water deficit conditions but it were also able to reduce the losing rate of the final output under the drought stress compared to natural conditions. This indicates the extent of physiological and biochemical changes in metabolism and growth processes and the foremost of it is the speed of early maturity that ultimately extinguished the trait of endurance and resistance to water deficit conditions. These results were in agreement with those reported by (El-Keredy *et al.,* 2003 c; El-Mouhamady *et al.,* 2012 c; El-Mouhamady *et al.,* 2012 d; El-Seidy *et al.,* 2013; El-Demardash *et al.,* 2017; El-Mouhamady and Habouh, 2019; Tawfik and El-Mouhamady, 2019 and El-Mouhamady and Ibrahim, 2020 b).

There is no doubt that the current study has succeeded well in knowing and understanding the genetic behavior that controls and is responsible for bearing water stress in some wheat genotypes. Simply, because it dealt with some length of study of an important set of genetic constants in this regard. On top of it is heterosis over better-parent and general and specific combining ability effects. As well as, the investigation of an important group of agro-morphological traits of these genotypes under water stress conditions compared to the standard experiment. In addition, the use of some drought tolerance indices, which were successful in testing and sorting all wheat genotypes for its ability to water deficit tolerance. This very briefly referred to the additive gene effect and its various interactions, which had the largest role in tracking and identifying the mechanism of drought tolerance in this regard. Therefore, it can be said that the process of genetic improvement for water stress resistance in wheat of this investigation had paid off, (Khatab *et al.,* 2021 a & b; El-Mouhamady *et al.,* 2021a & b & c & d and Khatab *et al.,* 2022).

Conclusions

The present investigation was carried out using five wheat entries and their first hybrid population obtained from half diallel analysis. Yield and its attributes components were the most importance traits were estimating under normal and water stress conditions.The final results confirmed that the genotypes; Sakha 94 and PGH-OR 12, Sakha 94 X Shandweel1, PGH-OR12 X Chah "s"/6/Maya/vul//Cmh 74 a. 630 /4*sxs.16342 and PGH-OR 12 X PFSW 343*2/Tukuru were the most desirable entries for water stress tolerance and recorded highly values of yield traits in this regard. Also, heterosis over better-parent, general and specific combining ability effects parameters for the previous wheat entries were gave significant and highly significant positive values for all attributes tested under frought stress treatment compared to the control experiment. While, the other wheat accessions showed low to medium tolerance for water deficit conditions and its yield were coming in the second rank in this regard. Data of drought tolerance indices recorded positice results in the five promising wheat hybrids compared to the rest genotypes under evaluating. Therefore, the process of genetic improvement of wheat's tolerance to water stress in these hybrids will be very fruitful and may give new wheat accessions with high yield and resistance to water stress in the coming years.

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