FJARD VOL. 38, NO. 4. PP. 664-686(2024)

Fayoum Journal of Agricultural Research and Development
ISSN:1110-7790
ONLINE ISSN:2805-2528

Genetic studies of agronomic and physiological parameters of some bread wheat genotypes under water deficit

Amany N. Sayed*, Yasser A. El-Gabry
Department of Agronomy, Faculty of Agriculture, Ain Shams University, Cairo 11241, Egypt

دراسات وراثية للقياسات الفسيولوجية والمحصولية لبعض التراكيب الوراثية من قمح الخبز تحت ظروف نقص المياه

ABSTRACT

To evaluate the expression of drought tolerance for bread wheat, six parents diverse in their response to drought *i.e*., Giza 171 (P1), Sakha 95 (P2), Bohouth 6 (P3), Cham 8 (P4), Gemmiza 12 (P5) and Masr 3 (P6) and their 15 F_1 crosses at 100% water requirements, and 70% water requirements sown in randomized complete blocks design season 2023/24 to estimate some genetic parameters for day to heading, days to maturity, chlorophyll pigments, superoxide dismutase activity, the activity of ascorbate peroxidase, proline content, number of spikes/plant, number of grains/spike, 100-kernel weight, and grain yield/plant. slightly significant differences were shown for most studied traits across all water regimes. The ratios of general combining ability to specific combining ability exceeded one for the examined traits, with some exceptions, signifying the influence of additive gene effects on the inheritance. The parental genotypes as good combiners, for earliness were P1 under both treatments, as well as P1, P2, and P3 at 70% water requirements, for physiologic and agronomic traits. The crosses P3 × P4 and P4 × P6 were the best combinations across the two treatments depending on physiological response and yield attributes. Most hybrids had significant heterotic values for agronomic and bio-physiological traits. The genotypic and phenotypic coefficients of variation varied from 1.71% for days to maturity to 14.83% for proline content, and from 1.90% for days to maturity to 16.64% for the activity of ascorbate peroxidase under well-watered, respectively; likewise, from 2.03% and 1.80% for days to maturity to 14.69% and 14.05% for chlorophyll a, respectively under water deficit.

Keywords: *Triticum aestivum* L., Drought tolerance, Genetic parameters, heterosis

*Correspoinding author E-mail: Amany87323@agr.asu.edu.eg
Submit date: 04-10-2024
Revise date: 14-10-2024
Accept date: 19-10-2024

1. INTRODUCTION

Water consider the main element in agriculture and achieving food security, especially in light of the increasing population density, food need and with the continuing challenges of water scarcity which considered one of the catastrophic impacts resulted from climate change, which has serious consequences on many countries all over the world, including Egypt. Wheat is a very important cereal crop cultivated worldwide. **(Asseng *et al.*, 2018**; **Giraldo *et al.*, 2019)** and serves as a staple food for people. It can be grown in diverse agro-climatic conditions, but, one of the main obstacles to these nations' output and productivity is the drought **(Sallam *et al.*, 2019)**. It is anticipated that issues with water constraint and drought would grow, which will have an adverse effect on wheat output **(Senapati *et al*., 2019).** In Egypt, wheat is considered as one of the strategic grain crops because of its many uses and high nutritional value as people food and animal feed. Nonetheless, Egypt's annual wheat production is far less than its consumption. The world total acreage of wheat was 220 million hectares in 2023 cropping season; the total production was 796 million tons, China is the first globally in production for wheat then India, Russian federation and United States of America **(FAO, 2023)**. With an average of 6.41 metric ton ha^{-1}, Egypt produced 9.80 million metric tons of grain in 2023 produced from 1.53 million hectares while, consumption was over 18 million tons i.e. gape of 9.2 million ton **(USDA, 2023)**. Therefore, it is imperative that continue to develop high-yielding and drought-stress tolerant varieties of wheat that can be grown in sandy and newly reclaimed lands by wheat breeders; In light of this shifting strategies for increasing wheat output must be developed (**Ray *et al*., 2013; Hunter *et al*., 2017)**.

Moreover, there is a demand to extensively deeply study the physiology further and how this physiology is changed by drought stress **(Verbeke *et al*., 2022).** Therefore, the impact of water deficit on crop growth and productivity requires an understanding of the wheat drought tolerance mechanisms. To boost global food supply, present efforts are concentrated on the creation, assessment, and research of novel crop genotypes with improved resistance to drought **(Abdelkader *et al*., 2022)**. Drought stress have a significant negative impact on the growth, development **(Kumar *et al*., 2011)** and adverse impacts on wheat morphological, physiological, and biochemical characteristics **(Chachar *et al*., 2016).** Tolerance to drought stress is a challenging wheat performance criterion. It is notable that wheat displays morpho-physiological and biochemical changes when it is exposed to water deficiency stress.

Different morphological parameters are impacted by insufficient soil moisture **(Sharma *et al*., 2022).** These measurements are based on biochemical and physiological traits such as, chlorophyll pigments, proline content, superoxide dismutase (SOD) activity and the activity of ascorbate peroxidase (APX). These measurements serve as markers for screening and identifying wheat resistant varieties to drought **(Arjenaki *et al*., 2012; Kadam *et al*., 2017)**.

Furthermore, Breeders may be able to increase the effectiveness of selection in segregating generations by examining the physiological responses among susceptible and drought-tolerant wheat genotypes. Studying these responses may enable the use of appropriate selection criteria for enhancing grain yield and increasing resistance to environmental stresses. Diallel mating design **(Griffing, 1956)** has been used to estimate combining ability effects in crops, i.e. wheat **(Fasahat *et al*., 2016)**. The choice of mating design depends the objectives of the study, time, space, cost and biological measurements **(Semahegn *et al*., 2021)**. Diallel analysis can be used to understand the inheritance of important traits in wheat and its relation to drought tolerance, which can be achieved by unraveling the genetic control through certain genetic parameters such as heterosis, combining ability, heritability. The general combining ability estimate is representative of additive gene, whereas specific combining ability estimates suggestive of non-additive gene action **(Falconer, 1981)**. There are opportunities for early generation selection in wheat due to the preponderance of additive gene effects involved in conditioning agronomic features **(Farshadfar *et al*., 2013)**. On the other hand, it has been reported that non-additive gene action regulating grain yield predominates in advanced generation wheat populations (**Akram *et al*., 2011; Yao *et al*., 2014**).

Thus, the primary goals of this research were to: 1) Estimate the genetic parameters of the studied traits such as heterosis and combining ability as basis of improving bread wheat under water deficit, 2) Identify the traits, which can be used as drought tolerance criteria.

2. MATERIALS AND METHODS

2.1. Genetic material and crossing

For this study, six genotypes of bread wheat were selected based on their tolerance to water deficiency stress and variability in some physiological and agronomic characters. The selected parental genotypes included four local varieties obtained from Agricultural Research Center (ARC), Egypt, in addition to two exotic varieties from Syria. The paternal genotypes' names, origin, and pedigree are presented in Table 1.

Table 1. Name of paternal wheat genotypes, origin, and pedigree used in the present study

Name	Origin	Pedigree	Specific trait
(P1) Giza 171	Egypt	Sakha93/Gemmeiza9 S 6-1GZ-2GZ-2GZ-OS	Tolerant
(P2) Sakha 95	Egypt	SKAUZ*2_SRMA-CMBW91MO2694P-OTOPY-7M-010Y-010M-010Y-5	Tolerant
(P3) Bohouth 6	Syria	Crow's CM 40457	Tolerant
(P4) Cham 8	Syria	JOPATICOCM67458-F-73/BLUEAY/VEE'S'-T-81	Sensitive
(P5) Gemmiza 12	Egypt	OTUS/3/SA/THB//VEE/CMSS97Y00227S-5Y-010M-010Y-010M-2Y-1M-0Y-OGM	Sensitive
(P6) Masr 3	Egypt	ATTILA*2/PBW65*2/KACHU	Tolerant

2.2. Experimental sites and treatments

In 2022/23 growing season, the parents were crossed to form a half diallel set of crosses (excluding reciprocal) so, obtained seeds of 15 F_1 crosses. In 2023/2024 winter growing season, two field trials involved 15 F_1 crosses and their corresponding parents were carried out at the experimental farm of the Giza Agriculture Research Station, ARC, Egypt.

The soil characteristics for location of the study and its properties are presented in **Table 2**. based on **(Soil Survey Staff, 2010)**. Average monthly metrological data of the site obtained from the Central Laboratory for Agricultural Climate, Doki, Giza, Egypt are presented in **Table 3.** The fertigation technique was applied as follow; 36 kg ha^{-1} of calcium superphosphate (P_2O_5 15.5%) added during soil preparation; for the potassium element, it is added at rate of 79.2 kg ha^{-1} potassium sulfate (K_2O 48%), while nitrogen fertilizer was added as ammonium nitrate (N 33.5%) at rate of 7 equal doses so that fertilization ends at flowering with amount 187.5 kg N ha^{-1}. Other recommended cultivation practices were followed.

Sowing date was on mid of - November 2023 and the preceding summer crop was maize (*Zea mays*, L.). Each field experiment was designed in a randomized complete blocks design (RCBD) with three replications. Row was 3 m in length and rows spacing and distance among individual seedlings on each row were 20 and 15 cm, respectively. Plants were thinned at one plant per hill after two weeks of planting. Irrigation water levels were 100% (well–watered), and 70% (severe water deficit) of crop water requirements (WR) according to FAO-56 Penman-Monteith equation **(Allen *et al*., 1998)**. Moreover, wheat plants received irrigation water amounts of 6018.32, and 4214.76 m^3 ha^{-1} in the 2023/24 growing season, with irrigation by 100% WR and 70% WR, respectively. Each irrigation treatment had a valve and flow meter to control water application in each treatment and each single irrigation, genotypes were randomly distributed within each irrigation treatment. Sprinkler irrigation was used during all experimental periods; the sprinkler discharge was 750 liters per hour; and the distance between each two sprinkler devices was 8 meters.

Table 2. Soil physical properties and chemical characteristics of the experimental location

Physical properties			**Chemical properties**			
Coarse sand	(%)	10.80	**pH**		7.73	
Fine sand	(%)	30.30	**Organic matter**	(%)	0.72	
Silt	(%)	41.20	**ECe**	(dS/m)	0.60	
Clay	(%)	17.80	**Cations**	(meq/l)	Ca^{+2}	2.4
Texture	Loam				Mg^{+2}	1.69
					Na^{+}	1.63
Field capacity	(%)	16.8			K^{+}	0.3
			Anions	(meq/l)	Cl^{-}	1.35
Wilting point	(%)	7.67			CO_3^{-2}	-
					HCO_3^{-}	1.65
Bulk density	(g/cm^3)	1.24			SO_4^{-2}	3.03

pH and ECe= organic matter and electrical conductivity of the soil saturation extract, respectively

Table 3. Climatic data of the Giza location at 2023/2024 season

Month	Air temperature (°C)		Relative humidity	Solar radiation	Precipitation
	Maximum	Minimum	(%)	(W/m^2)	(mm)
15-Nov	28.2	15.6	62.2	3.4	0.20
30-Nov	24.4	12.7	59	3.5	0.51
15-Dec	24	11.8	59.1	2.9	0.45
30-Dec	22	10.9	71.7	4	0.07
15-Jan	19.3	7.9	66.7	3.4	0.52
30-Jan	18.1	5.8	68.8	3.7	0.02
15-Feb	17.6	5.4	68.9	3.9	0.07
29-Feb	21.2	7.7	66.2	3.4	0.00
15-Mar	23.5	9.1	56	4.2	0.00
30-Mar	23.1	8.6	59	4.3	0.00
15-Apr	29.9	12.8	46.3	4.4	0.00
30-Apr	31.4	14.2	43.8	4.4	0.01
15-May	32	15.7	43.8	4.7	0.00
30-May	35.3	18.3	38.3	4.6	0.02

2.3. Data recorded for measured traits

a) **Earliness and growth traits**

For every genotype, the number of days from the sowing date until the main stem spike entirely emerged from the flag leaf sheath of 50% of the plants/row and 95% of the plants/row reached the dead ripe stage, respectively, was recorded as the days to heading (DTH) and days to maturity (DTM).

b) **Physiological and biochemical traits**

Five guarded plants during anthesis stage from each row in the three replications, from which fresh flag leaf blade samples for measuring physiological traits, then carried immediately to the laboratory to measurements. Chlorophyll pigments (µg g^{-1} FW; fresh weight) i.e. chlorophyll a (Chl. a), chlorophyll b (Chl. b) and total chlorophyll (Total Chl.) were measured by the method of **Arnon (1949)**. Free proline content (PC) (µg g^{-1} FW) was determined according to **Bates *et al.* (1973)**. The enzymes activity (U mg^{-1} protein) **i. e.,** superoxide dismutase (SOD) activity was measured according to **Beyer *et al.* (1987)** and the activity of ascorbate peroxidase (APX) was based on **Nakano and Asada (1981).**

c) Grain yield and its components

Ten guarded plants were randomly selected at harvest from each row in order to assess the number of grains per spike (NGPS), the number of spikes per plant (NSPP), the 100-kernel weight (HKW), and the grain yield per plant (g) (GYPP).

2.4. Statistical Analysis

The TNAUSTAT-Statistical program was used for all statistical analyses (**Manivannan, 2014)**. Combining ability analysis was performed using (**Griffing, 1956)** method 2 model 1. The F_1 mean's deviation from each of the mid-parents' and better parents' values was used to determine heterosis, and the result was reported as a percentage according to **Bhatt (1971)**.

The coefficients of genotypic and phenotypic variation (GCV and PCV) were categorized as **Sivasubramanian and Madhavamenon (1973)**.

3. RESULTS AND DISCUSSION

3.1. Analysis of variance

The analysis of variance (**Tables 4** and **5**) showed that there were slightly significant differences between the genotypes, parents (P), crosses (C) and P vs C for all studied traits under the two water regimes except; P vs C for NGPS, HKW and GYPP under both water regimes and NSPP at 70%WR were not significant; while NSPP was significant under 100%WR. Moreover, chlorophyll pigments (Chl. a, b and total chlorophyll) at 70%WR; APX at 100%WR was significant. Mean squares significance due to the genotypes, parents, crosses and P vs C for the studied traits under both regimes revealed that the genotypes performance differed under the irrigation treatments, demonstrating that there is enough genetic variation between parents and their offspring, reflecting how differently various genotypes responded to different watering regimens.

As shown in this study, the findings showed that, for every attribute under study, the mean squares of GCA and SCA were extremely significant under irrigation regimes, suggesting that the inheritance of these features was influenced by both additive and non-additive genetic effects. The magnitude of GCA was larger than the SCA for all traits under all water regimes, except NSPP overall treatments which SCA magnitude was higher.

In addition, The GCA/SCA ratio was more than unity for all traits except NSSP at 100%WR, suggesting that these traits were mainly controlled by the additive gene effects. **Farshadfar *et al.* (2014)** reported that additive gene effects were more important in the inheritance of their studied traits. These findings are in harmony with many researchers' results like **Abd El-kareem *et al*. (2011), Dorostkar *et al*. (2015), Chaudhary *et al*. (2018)** and **Ozturk *et al*. (2021).** On the other hand, **Adel and Ali (2013)** found the preponderance of non-additive gene action (dominance and epistasis) in the inheritance of most of the studied traits.

3.2. General combining ability effects (GCAs)

The general combining ability effects are presented in **Tables 6 and 7**. Since negative GCA effects would be of interest for earliness traits, the parental Giza 171 (P1) had negative and significant GCA effects for earliness traits under the two water regimes, likewise Sakha 95 (P2) for DTM at 70% WR as well as the introduced genotype Bohouth 6 (P3) for DTH at 100% and DTM at 70% WR are considered to be the best among the parental set as progenitors in hybridization programs towards earliness which proved to be good general combiners for earliness under drought conditions.

On the other hand, the parental genotypes; Giza 171 (P1), Sakha 95 (P2) and Bohouth 6 (P3) showed positive and highly significant GCA effects for all physio-biochemical traits under the two water regimes, except P2 for APX at 100%WR and 70%WR so, they proved to be good combiners for lateness as they attained significant positive GCA effects under these conditions.

In about the same direction, the parental genotypes Giza 171 (P1), Sakha 95 (P2) and Bohouth 6 (P3) showed positive and highly significant GCA effects for yield and its components, except NSPP for the three parental genotypes at 100%WR and P3 at 85% and 70% WR. The best combiner for NSPP was Masr 3 (P6) under the two water treatments while, Gemmiza 12 (P5) under well-water treatment.

Table 4. Analysis of variance under well-water (100% water requirements) for the studied traits in bread wheat genotypes

S.O.V.	D.F.	DTH	DTM	Chl. a ($\mu g\ g^{-1}$ FW)	Chl. b	Total Chl.	SOD (U mg^{-1} protein)
Replicates	2	0.07	0.97	0.0002	0.0008	0.0008	0.35
Genotypes	20	21.43**	26.17**	0.44**	0.11**	0.99**	40.12**
Parents (P)	5	31.45**	40.87**	0.56**	0.19**	1.38**	54.92**
Crosses (C)	14	16.65**	18.73**	0.13**	0.05**	0.35**	15.00**
P vs C	1	38.14**	56.86**	4.18**	0.62**	8.02**	317.91**
Error	40	2.28	1.84	0.01	0.003	0.02	1.05
GCA	5	19.21**	13.17**	0.25**	0.09**	0.63**	24.85**
SCA	15	3.11**	7.23**	0.11**	0.02**	0.23**	9.55**
Error	40	0.76	0.61	0.002	0.001	0.006	0.35
GCA/SCA		6.18	1.82	2.27	4.5	2.74	2.6
S.O.V.	**D.F.**	**APX (U mg^{-1} protein)**	**PC ($\mu g\ g^{-1}$ FW)**	**NSPP**	**NGPS**	**HKW (g)**	**GYPP**
Replicates	2	0.27	17.71	0.1	0.44	0.12	0.14
Genotypes	20	2.97**	2846.97**	14.03**	62.81**	49.18**	60.77**
Parents (P)	5	4.17**	3514.22**	6.86**	120.77**	81.66**	119.40**
Crosses (C)	14	1.79**	893.18**	12.44**	33.32**	36.36**	29.80**
P vs C	1	13.49**	26863.77**	72.21*	185.95	66.17	201.17
Error	40	0.26	5.53	0.51	1.49	1.61	1.67
GCA	5	2.21**	1603.13**	2.39**	61.18**	51.02**	54.37**
SCA	15	0.58**	730.97**	5.44**	7.52**	4.85**	8.89**
Error	40	0.09	1.84	0.17	0.5	0.54	0.56
GCA/SCA		3.81	2.19	0.44	8.14	10.52	6.12

* and ** denote significant at 0.05 and 0.01 levels of probability, respectively. DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

Table 5. Analysis of variance under severe stress (70% water requirements) for the studied traits in bread wheat genotypes

S.O.V.	D.F	DTH	DTM	Chl. a ($\mu g\ g^{-1}$ FW)	Chl. b	Total Chl.	SOD (U mg^{-1} protein)
Replicates	2	0.96	0.13	0.0007	0.0014	0.0038	0.47
Genotypes	20	59.51**	21.97**	0.21**	0.05**	0.46**	38.75**
Parents (P)	5	336.95**	56.58**	0.14**	0.05**	0.34**	54.50**
Crosses (C)	14	60.39**	9.10**	0.13**	0.04**	0.32**	15.49**
P vs C	1	277.31**	29.20**	1.80**	0.16**	3.06**	285.53**
Error	40	5.77	1.81	0.01	0	0.02	0.8
GCA	5	68.89**	18.68**	0.14**	0.04**	0.33**	25.85**
SCA	15	3.48**	3.54**	0.05**	0.01**	0.09**	8.60**
Error	40	1.92	0.60	0.0022	0.001	0.006	0.27
GCA/SCA		19.80	5.28	2.80	4.00	3.67	3.01
S.O.V.	**D.F**	**APX (U mg^{-1} protein)**	**PC ($\mu g\ g^{-1}$ FW)**	**NSPP**	**NGPS**	**HKW (g)**	**GYPP**
Replicates	2	0.04	11.31	0.25	2.77	2.43	0.24
Genotypes	20	2.47**	2919.17**	3.69**	76.54**	28.12**	28.34**
Parents (P)	5	2.86**	3578.67**	7.29**	89.83**	31.45**	29.14**
Crosses (C)	14	0.65**	893.26**	2.00**	60.30**	24.87**	24.75**
P vs C	1	25.92**	27984.40**	9.37	237.43	56.96	74.66
Error	40	0.40	10.55	0.44	1.47	1.56	1.23
GCA	5	1.11**	1629.82**	1.56**	74.96**	28.38**	26.47**
SCA	15	0.73**	754.17**	1.12**	9.03**	3.04**	3.77**
Error	40	0.13	3.52	0.15	0.49	0.52	0.41
GCA/SCA		1.52	2.16	1.39	8.3	9.34	7.02

* and ** denote significant at 0.05 and 0.01 levels of probability, respectively. DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

Table 6. Estimates of general combining ability effects of the parental wheat genotypes evaluated for the studied traits under well-water (100% water requirements)

Parent	DTH	DTM	Chl. a ($\mu g\ g^{-1}$ FW)	Chl. b	Total Chl.	SOD (Unit mg^{-1} protein)
P1	-2.25**	-2.33**	0.17**	0.1**	0.27**	1.65**
P2	-0.46	-0.14	0.13**	0.08**	0.20**	1.33**
P3	-1.06**	-0.09	0.18**	0.11**	0.29**	1.81**
P4	0.5	0.73**	-0.19**	-0.1**	-0.29**	-1.77**
P5	1.64**	1.46**	-0.16**	-0.1**	-0.26**	-1.76**
P6	1.64**	0.37	-0.13**	-0.08**	-0.21**	-1.25**
LSD gi	0.57	0.51	0.02	0.02	0.06	0.38
LSD gi-gj	0.89	0.79	0.04	0.04	0.08	0.61
Parent	**APX (U mg^{-1} protein)**	**PC ($\mu g\ g^{-1}$ FW)**	**NSPP**	**NGPS**	**HKW (g)**	**GYPP**
P1	0.52**	14.05**	-0.83**	3.17**	2.79**	2.58**
P2	0.19	10.69**	0.14	2.21**	2.41**	1.92**
P3	0.63**	13.66**	-0.17	1.31**	1.57**	2.57**
P4	-0.66**	-14.89**	-0.26	-4.05**	-2.82**	-2.75**
P5	-0.43**	-13.41**	0.39**	-2.25**	-1.85**	-2.44**
P6	-0.25*	-10.11**	0.73**	-0.39	-2.11**	-1.88**
LSD gi	0.2	0.89	0.26	0.46	0.49	0.49
LSD gi-gj	0.3	1.37	0.42	0.71	0.75	0.75

* and ** denote significant at 0.05 and 0.01 levels of probability, respectively. P_1, P_2, P_3, P_4, P_5 and P_6 denote Giza 171, Sakha 95, Bohouth 6, Cham 8, Gemmiza 12 and Masr 3, respectively. DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

Table 7. Estimates of general combining ability effects of the parental wheat genotypes evaluated for the studied traits under severe stress (70% water requirements)

Parent	DTH	DTM	Chl. a ($\mu g\ g^{-1}$ FW)	Chl. b	Total Chl.	SOD (U mg^{-1} protein)
P1	-5.78**	-1.76**	0.12**	0.06**	0.18**	1.79**
P2	0.15	-1.28**	0.12**	0.07**	0.19**	1.13**
P3	0.95*	-1.03**	0.12**	0.07**	0.18**	1.9**
P4	1.32**	1.33**	-0.13**	-0.07**	-0.19**	-2.01**
P5	0.89	1.80**	-0.15**	-0.09**	-0.24**	-1.63**
P6	2.49**	0.94**	-0.08**	-0.04**	-0.12**	-1.18**
LSD gi	0.91	0.51	0.04	0.02	0.06	0.34
LSD gi-gj	1.39	0.79	0.04	0.04	0.08	0.53
Parent	**APX (U mg^{-1} protein)**	**PC ($\mu g\ g^{-1}$ FW)**	**NSPP**	**NGPS**	**HKW (g)**	**GYPP**
P1	0.39**	14.12**	0.32*	3.49**	2.23**	1.68**
P2	0.17	10.51**	0.51**	2.7**	2.13**	1.61**
P3	0.4**	14.07**	-0.07	1.66**	0.48*	1.59**
P4	-0.49**	-15.07**	-0.54**	-3.26**	-1.51**	-1.84**
P5	-0.2ns	-13.34**	-0.5**	-3.61**	-1.4**	-2.05**
P6	-0.27*	-10.29**	0.28*	-0.99**	-1.93**	-1.00**
LSD gi	0.24	1.23	0.26	0.46	0.46	0.42
LSD gi-gj	0.36	1.9	0.38	0.71	0.73	0.65

* and ** denote significant at 0.05 and 0.01 levels of probability, respectively. P_1, P_2, P_3, P_4, P_5 and P_6 denote Giza 171, Sakha 95, Bohouth 6, Cham 8, Gemmiza 12 and Masr 3, respectively. DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

3.3. Specific Combining Ability Effects (SCAs)

Tables 8 and **9** displayed the specific combining ability effects (SCA).

a) Earliness traits

The crosses; P1 × P4 for DTH; P4 × P6, P4 × P5 and P5 × P6 for DTM had consistently negative SCA effects across all water regimes. Negative and significant SCA effects were shown in the cross P1 × P3 for DTH and DTM and the cross P4 × P6 for DTM at 100% WR. While, significant and negative effects for DTH at 70%WR were observed by the cross P2 × P3. Moreover, the cross P1 × P2 at 100%WR; the crosses P5 × P6 for DTH, P3 × P4 and P3 × P5 for DTM at 70%WR proved negative and significant SCA effects. The cross P1 × P4 under all treatments; P1 × P5 and P2 × P3 at (100% and 70%WR).

b) Physiological traits

In contrast of physiological and biochemical traits, chlorophyll pigments (Chl. a, Chl. b and total chlorophyll), the cross combinations P1 × P3, P1 × P4, P2 × P3, P3 × P4 and P4 × P5 displayed positive and significant or highly significant SCA effects for chlorophyll pigments under the two water regimes, except P3 × P4 and P4 × P5 for Chl. b at 100%WR, as well as the cross P1 × P2 at 70%WR; P3 × P5 and P4 × P6 at 100%. The crosses P2 × P5, P2 × P6, P3 × P6 and P5 × P6 (at 100% and 70%WR) and the two crosses P1 × P5 and P × P6 at 100%WR showed positive and significant or highly significant effects for Chl. a only, in addition to the two crosses P2 × P6 and P5 × P6 for Chl. b and total chlorophyll at 100%WR and P3 × P6 only for Chl. b at 100%WR.

In respect of SOD, 9 out of 15 crosses i.e., P1 × P3, P1 × P4, P2 × P3, P3 × P4, P3 × P5, P3 × P6, P4 × P5, P4 × P6 and P5 × P6 displayed positive and slightly significant SCA effects under both water treatments.

The three crosses P3 × P5, P3 × P6 and P5 × P6 under the two water treatments; P1 × P4 and P4 × 6 (at 100% and 70%WR); P2 × P3 at 70%WR; P1 × P3 and P1 × P5 (at 100%WR) showed positive and significant or highly significant SCA effects for the APX trait. Moreover, for proline content all crosses exhibited positive and highly significant SCA effects under all treatments except P1 × P6.

c) Yield traits

For grain yield traits, P2 × P3, P4 × P6 and P5 × P6 at 100%WR had positive and highly significant specific combining ability effects. In respect of NSPP, NGPS, HKW and GYPP, the two crosses P1 × P3 and P3 × P4 were revealed at 100%WR; P1 × P2, P1 × P3 and P2 × P3 at 70 %WR for NGPS, HKW and GYPP.

The crosses; P1 × P4 and P2 × P4 at 100%; P1 × P5, P4 × P5 and P5 × P6 at 70%WR; P2 × P6 and P3 × P5 at 100%WR for NSPP possessed slightly significant and positive SCA effects; likewise, NGPS, P2 × P5 P3 × P4 and P4 × P5 at 100%WR; P2 × P6 and P4 × P5 at 70%WR. Also, the cross P1 × P4 at the three treatments; P3 × P6 at 100%WR; P4 × P6 at 70%WR exhibited positive and highly significant SCA effects for HKW. Nevertheless, P1 × P4, P4 × P5 under the two water regimes; P3 × P5 and P3 × P6 at 100% and P3 × P4 at 70%WR exposed good specific combiners for GYPP.

It is possible, therefore, to note that these hybrids appeared to be good F1-cross combinations for earliness and it could be advised that wheat breeding programs could be involving the parents of the previous crosses to improve these traits (**El-Hosary *et al*. 2012; Ibrahim *et al*. 2014; Kumar and Prasad 2017; El-Gammaal *et al*. 2018; El-Fahdawy *et al*. 2019; Kamara *et al*. 2022).**

Table 7. Estimates of specific combining ability effects of 15 F1crosses of bread wheat evaluated for the studied traits under well-water (100% water requirements)

Cross	DTH	DTM	Chl. a ($\mu g\ g^{-1}$ FW)	Chl. b	Total Chl.	SOD (U mg^{-1} protein)
P1 × P2	0.05	-2.92**	0.08*	0.03	0.11	0.29
P1 × P3	-2.15**	-2.06**	0.2**	0.06*	0.26**	2.09**
P1 × P4	-1.75**	1.92**	0.18**	0.07**	0.25**	1.00*
P1 × P5	0.27	-0.06	0.08*	0.02	0.1	0.78
P1 × P6	-0.28	2.32**	-0.08*	-0.11**	-0.19**	-0.53
P2 × P3	-1.56*	1.70**	0.17**	0.09**	0.25**	2.34**
P2 × P4	2.53**	-0.08	0.06	0.02	0.08	0.01
P2 × P5	-0.02	1.76**	0.07*	0	0.07	0.28
P2 × P6	-0.35	-0.12	0.14**	0.05*	0.19**	0.68
P3 × P4	0.12	0.25	0.19**	0.05	0.23**	1.64**
P3 × P5	-0.42	-0.08	0.20**	0.09**	0.29**	1.33**
P3 × P6	1.8**	-0.06	0.36**	0.22**	0.57**	3.30**
P4 × P5	-1.17	-2.47**	0.20**	0.06*	0.26**	1.69**
P4 × P6	-3.39**	-6.32**	0.40**	0.21**	0.61**	4.61**
P5 × P6	-1.08	-2.78**	0.21**	0.09**	0.30**	1.80**
LSD sij	0.75	0.67	0.04	0.02	0.06	0.51
LSD sij-ik	2.32	2.08	0.12	0.08	0.20	1.58
LSDsij-kl	2.16	1.94	0.10	0.08	0.18	1.46

Cross	APX (U mg^{-1} protein)	PC ($\mu g\ g^{-1}$ FW)	NSPP	NGPS	HKW (g)	GYPP
P1 × P2	-0.01	6.82**	-0.52	0.98	0.12	0.01
P1 × P3	0.49*	16.82**	1.64**	1.63**	2.04**	1.73**
P1 × P4	0.60**	14.26**	2.67**	-1.35*	1.11*	1.37*
P1 × P5	0.51*	6.54**	-0.13	-0.61	-0.65	-0.09
P1 × P6	-0.96**	-7.05**	-1.3**	-1.38*	0.29	-2.52**
P2 × P3	0.19	16.45**	2.37**	2.24**	2.28**	1.71**
P2 × P4	0.4	3.81**	1.03**	0.1	0.41	-0.49
P2 × P5	-0.04	5.16**	-2.72**	3.73**	-0.17	-0.29
P2 × P6	-0.04	9.20**	0.97**	1.03	0.02	0.49
P3 × P4	0.31	14.54**	-0.49	2.17**	1.91**	1.36*
P3 × P5	0.47*	14.68**	2.79**	0.45	-2.69**	1.34*
P3 × P6	1.12**	28.97**	-2.65**	-0.06	2.25**	4**
P4 × P5	-0.13	15.00**	0.49	1.69**	-1.88**	1.51**
P4 × P6	0.85**	33.20**	2.94**	1.86**	2.13**	4.87**
P5 × P6	0.65**	17.49**	3.06**	3.83**	2.56**	1.96**
LSD sij	0.26	1.15	0.34	0.61	0.63	0.65
LSD sij-ik	0.81	3.62	1.11	1.90	1.96	2.00
LSDsij-kl	0.75	3.35	1.01	1.76	1.82	1.86

* and ** denote significant at 0.05 and 0.01 levels of probability, respectively. P_1, P_2, P_3, P_4, P_5 and P_6 denote Giza 171, Sakha 95, Bohouth 6, Cham 8, Gemmiza 12 and Masr 3, respectively. DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

Table 8. Estimates of specific combining ability effects of 15 F1crosses of bread wheat evaluated for the studied traits under severe stress (70% water requirements)

Cross	DTH	DTM	Chl. a ($\mu g\ g^{-1}$ FW)	Chl. b	Total Chl.	SOD ($U\ mg^{-1}$ protein)
P1 × P2	-0.85	-0.51	0.18**	0.06*	0.24**	0.49
P1 × P3	-1.36	-0.93	0.29**	0.15**	0.43**	1.84**
P1 × P4	-2.73**	-0.19	0.17**	0.05*	0.23**	1.77**
P1 × P5	-1.65	-0.47	0.02	-0.01	0.01	0.97*
P1 × P6	1.01	2.29**	-0.02	-0.03	-0.05	-1.71**
P2 × P3	-2.70*	0.83	0.23**	0.12**	0.35**	1.53**
P2 × P4	1.1	1.78**	0.01	-0.06*	-0.05	0.65
P2 × P5	0.57	-0.5	0.07*	0.01	0.08	0.32
P2 × P6	1.96	1.01	0.08*	0	0.08	0.7
P3 × P4	1.41	-1.63**	0.12**	0.06*	0.18**	1.47**
P3 × P5	1.25	-1.83**	-0.03	-0.05*	-0.08	1.63**
P3 × P6	-0.95	-0.13	0.10**	0.02	0.12*	3.58**
P4 × P5	-0.51	-1.22*	0.20**	0.09**	0.28**	1.10**
P4 × P6	2.16*	-3.55**	0.10**	0.06**	0.16**	3.75**
P5 × P6	-2.04*	-1.4*	0.09*	0.02	0.11	2.11**
LSD sij	1.19	0.67	0.04	0.02	0.06	0.44
LSD sij-ik	3.70	2.06	0.12	0.08	0.20	1.39
LSDsij-kl	3.44	1.92	0.12	0.08	0.18	1.29
Cross	**APX ($U\ mg^{-1}$ protein)**	**PC ($\mu g\ g^{-1}$ FW)**	**NSPP**	**NGPS**	**HKW (g)**	**GYPP**
P1 × P2	0.05	7.21**	0.23	2.21**	3.28**	1.83**
P1 × P3	0.35	16.62**	2.00**	2.84**	1.24*	3.10**
P1 × P4	0.77**	14.64**	0.19	-3.35**	1.90**	1.96**
P1 × P5	-0.16	6.67**	0.99**	2.72**	-0.14	-0.59
P1 × P6	0.14	-6.67**	0.5	1.50**	0.32	-1.5**
P2 × P3	0.56*	16.49**	-0.15	3.41**	1.54**	2.16**
P2 × P4	-0.09	4.44**	0.35	-0.58	-1.01	-1.12*
P2 × P5	0.52	5.54**	0.16	0.71	0.02	0.43
P2 × P6	0.1	9.82**	-1.16**	2.56**	-0.69	0.3
P3 × P4	0.46	14.59**	-0.05	2.38**	-0.48	1.22*
P3 × P5	0.70*	14.48**	0.34	1.50**	-0.49	-1.05*
P3 × P6	0.59*	29.02**	-0.82**	-1.56**	0.41	0.49
P4 × P5	0.42	15.39**	0.93**	1.09*	0.09	1.97**
P4 × P6	1.04**	33.83**	-0.59*	2.85**	2.37**	0.63
P5 × P6	0.64*	17.87**	0.75*	0.13	0.66	0.51
LSD sij	0.30	1.60	0.32	0.61	0.61	0.55
LSD sij-ik	0.97	5.01	1.03	1.88	1.92	1.72
LSDsij-kl	0.89	4.65	0.95	1.74	1.78	1.58

* and ** denote significant at 0.05 and 0.01 levels of probability, respectively. P_1, P_2, P_3, P_4, P_5 and P_6 denote Giza 171, Sakha 95, Bohouth 6, Cham 8, Gemmiza 12 and Masr 3, respectively. DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

3.4. Heterosis (MP) relative to mid-parents and relative to better-parent (BP) as heterobeltiosis

It is generally acknowledged that manipulating heterosis is a safe way to get around obstacles to wheat output and that it is an essential technique for increasing the yield potential of wheat **(Noorka *et al*. 2013)**. The heterotic effects relative to mid-parents in **(Tables 9 and 10)** and better parent in **(Tables 11 and 12)** has been explained.

a) Earliness traits

The earliest cross in heading relative to MP was recorded by P1 × P4 under all water treatments, followed by the cross P4 × P6 at 100%. The cross P1 × P3 had negative and significant heterotic effect relative to MP and BP at 100%WR. The two crosses P4 × P5 and P5 × P6 at 100%WR revealed negative and significant heterotic effects relative to MP. Only the cross P1 × P5 had negative and significant heterotic effect relative to mid parents at severe stress (70%WR). In respect of days to maturity, the two cross combinations P4 × P5 and P4 × P6 under all treatments and P5 × P6 at 100%WR) displayed negative and highly significant heterotic effects relative to MP and BP. However, the cross combinations P1 × P2 and P1 × P3 at 100%WR as well as P5 × P6, P3 × P4 and P3 × 5 at 70%WR recorded heterotic effects toward earliness.

b) Physiological traits

In respect of physiological and biochemical traits; there are positive and slightly significant heterotic effects relative to better parent by the crosses P4 × P5, P2 × P4, P3 × P6, P4 × P6 and P5 × P6 at 100%WR; as well as the two crosses P1 × P3 and P1 × P4 at 70%WR. All cross combinations relative to mid parents had positive and highly significant heterotic effects for SOD trait over all treatments, except the cross P1 × P6 which was not significant.

Nevertheless, 8 out of 15 cross i.e., P1 × P3, P2 × P3, P3 × P4, P3 × P5, P3 × P6, P4 × P5, P4 × P6 and P5 × P6 expressed positive and highly significant heterotic effects at the two water regimes; and the cross P1 × P2 at 100% exhibited positive and significant heterotic effects relative to BP.

For APX trait, 9 out of 15 cross i.e., P1 × P3, P1 × P4, P2 × P3, P × P4, P3 × P6, P4 × P5, P4 × P6 and P5 × P6 at all water regimes; the two crosses P1 × P5 and P2 × P at 100%WR; and the three crosses P1 × P6, P2 × P5 and P2 × P6 at 70%WR had positive and significant or highly significant heterotic effects relative to MP. Moreover, positive and significant or highly significant heterotic effects relative to BP by the three crosses P3 × P6, P4 × P6 and P5 × P6 under all treatments; the two crosses P3 × P5 and P4 × P5 at 70%WR; the cross P2 × P3 (at 100% and 70%WR); and the cross P1 × P3 at 100%WR.

All cross combinations relative to MP had positive and highly significant heterotic effects for proline content at the two water regimes. Likewise, 10 out of 15 crosses i.e., P1 × P2, P1 × P3, P2 × P3, P2 × P6, P3 × P4, P3 × P5, P3 × P6, P4 × P5, P4 × P6 and P5 × P6 at 100% and 70%WR exhibited positive and highly significant heterotic effects relative to BP; while the cross P1 × P4 had positive and significant heterosis at 100%WR.

In respect of chlorophyll pigments relative to MP (Chl. a, Chl. b and total chlorophyll), all crosses exhibited positive and highly significant heterotic effects at 100%WR, except the two crosses P1 × P2 and P1 × P5 had positive and significant heterotic effects and the cross P1×P6 was non-significant for Chl. b. At 70%WR the all cross combinations for Chl. b; P1 × P3 and P1 × P4 for Chl. a and total chlorophyll; P1 × P2, P2 × P3, P3 × P4, P3 × P6, P4 × P5 and P4 × P6 for total chlorophyll. The heterotic effects relative to BP showed positive and highly significant effects for all pigments by the crosses P1 × P3, P2 × P3, P3 × P5, P3 × P6, P4 × P5, P4 × P6 and P5 × P6; while by the crosses P1 × P2 and P3 × P4 for Chl. a and total chlorophyll; and the cross P2 × P6 for Chl. a. at 100%WR. Moreover, the crosses P1 × P2, P1 × P3, P2 × P3, P3 × P4 and P4 × P6 for chlorophyll pigments; the three crosses P3 × P5, P3 × P6 and P4 × P5 for Chl. a and total chlorophyll and the cross P × P6 for Chl. a. In addition to the four crosses P1 ×P2, P1 × P3, P2 × P3 and P4 × P5 for the three pigments; also, the four crosses P1 × P4, P3 × P4, P3 × P6 and P4 × 6 for Chl. a and total chlorophyll; the two crosses P2 × P6 and P5 × P6 for Chl. a at 70%WR.

c) Yield traits

For yield and its attributes, the best cross combinations for NSPP were assigned by P1 × P4, P1 × P3 and P4 × P5 under the two water treatments relative to MP and BP. The crosses; P2 × P3, P2 × P4, P4 × P6, P5 × P6, P2 × P6, P3 × P4 and P3 × P5 at 100%WR; P1 × P5 at 70%WR; relative to MP and BP. Relative to MP only, P1 × P5, P5 × P6, P3 × P5 and P1 × P2 at 100%WR and P1 × P6 at 70%WR exhibited positive and highly significant heterosis.

For the NGPS, the two crosses P2 × P3 and P2 × P6 under the two water treatments; P4 × P5, P5 × P6 and P2 × P5 at 100%WR; P1 × P2 and P1 × P3 at sever stress were the best combinations relative to MP and BP as well as P2×P4, P3 × P4, P3 × P5 and P3 × P6 under all treatments; P1 × P2 and P1 × P3 at 100%; P5 × P6, P1 × P5, P1 × P6 as well as P2 × P5 and P4 × P5 at 70%WR were the best combinations relative to MP only.

For HKW, P1 × P3 and P4 × P6 under all water regimes; P2 × P3 at 100% and P1×P2 at 70%WR were the highest crosses for MP and BP heterosis; while, P1 × P6 and P1 × P4 under the all treatments; P2 × P4, P2 × P6, P3 × P4, P3 × P6 and P5 × P6 at 100%WR; P3×P5 and P2×P3 at 70%WR had positive and significant heterotic effects relative to MP.

With reference to GYPP, the two cross combinations P2 × P3 and P4 × P5 under the two water regimes; P3 × P6, P4 × P6 and P5 × P6 under well-watered; P1 × P2 and P1 × P3 under severe stress showed positive and highly significant heterotic effects relative to MP and BP. Moreover, the cross P1 × P4, P3 × P4 and P3 × P6 under all treatments; P3 × P5 at 100% and P3 × P6 at 70%WR, respectively as well as P1 × P3, P2 × P4 and P2 × P6 under well water and P4 × P6 and P2 × P5 under severe stress had positive and highly significant heterotic effects relative to MP.

Therefore, it could be concluded that these crosses are considered as the best F_1-cross combinations in this respect. The negative values of heterosis for the earliness traits (heading anthesis and maturity dates) are considered useful heterosis. Because more stress-responsive genes may have expressed under stressful conditions, increasing the heterotic impacts of the hybrids, there may be a variation in the amount of heterosis between water stress and non-stress situations **(Jatoi *et al*., 2014)**. Also, some of these results are in harmony with **Noorka *et al*. (2013), Ibrahim *et al*. (2014), and Gomaa *et al*. (2014).**

Table 9. Percentages of heterosis over the mid- parents for the studied traits in 15 F_1 crosses of bread wheat under well-water (100% water requirements)

Cross	DTH	DTM	Chl. a ($\mu g\ g^{-1}$ FW)	Chl. b	Total Chl.	SOD (U mg^{-1} protein)
P1 × P2	-0.82	-1.86**	11.9**	6.06*	9.77**	8.17**
P1 × P3	-4.03**	-1.42*	23.05**	13.39**	19.51**	23.21**
P1 × P4	-3.91**	0.03	24.48**	14.83**	20.92**	19.5**
P1 × P5	-1.39	-0.71	16.87**	7.27*	13.34**	14.32**
P1 × P6	-2.21	0.23	12.75**	1.52	8.65**	13.16**
P2 × P3	-2.13	1.03	22.53**	18.06**	20.91**	24.52**
P2 × P4	1.9	-0.99	20.24**	13.6**	17.82**	15.04**
P2 × P5	-0.49	0.55	17.33**	8.34**	14.06**	12.16**
P2 × P6	-1.06	-1.06	23.25**	16.89**	20.95**	19.00**
P3 × P4	-1.43	-0.88	34.4**	22.71**	30.13**	33.34**
P3 × P5	-1.67	-0.63	30.63**	21.97**	27.47**	26.78**
P3 × P6	0.46	-1.11	41.37**	37.81**	40.08**	42.26**
P4 × P5	-2.80*	-2.96**	35.64**	21.19**	30.33**	31.19**
P4 × P6	-5.31**	-5.7**	50.6**	42.21**	47.55**	55.39**
P5 × P6	-2.57*	-3.18**	34.69**	24.96**	31.15**	32.59**
Mean	-1.83	-1.24	26.65	18.05	23.51	24.71
Cross	**APX (U mg^{-1} protein)**	**PC ($\mu g\ g^{-1}$ FW)**	**NSPP**	**NGPS**	**HKW (g)**	**GYPP**
P1 × P2	3.83	12.48**	2.6	3.61**	3.01	1.29
P1 × P3	18.91**	24.16**	24.82**	3.93**	8.69**	12.01**
P1 × P4	22.05**	24.74**	41.53**	-0.57	6.18**	11.54**
P1 × P5	17.08**	16.63**	10.02*	2.02	-1.34	3.48
P1 × P6	-6.56	12.52**	0.38	-0.31	6.36**	-0.61
P2 × P3	14.61*	25.01**	25.54**	7.87**	9.11**	12.89**
P2 × P4	18.99**	19.9**	22.61**	4.65**	4.5*	6.56*
P2 × P5	7.87	16.83**	-10.75**	11.42**	-0.45	3.64
P2 × P6	8.22	22.57**	13.34**	5.99**	5.65**	9.64**
P3 × P4	27.38**	35.31**	17.12**	7.07**	10.01**	20.7**
P3 × P5	26.08**	30.72**	33.54**	6.2**	-4.32*	16.29**
P3 × P6	37.21**	43.1**	-6.93	3.95**	12.96**	29.06**
P4 × P5	16.25*	34.61**	23.56**	7.83**	-4.04	18.59**
P4 × P6	37.47**	52.08**	40.43**	6.35**	12.58**	36.76**
P5 × P6	28.07**	35.39**	31.86**	10.86**	8.88**	19.89**
Mean	18.5	27.07	17.98	5.39	5.19	13.45

* and ** denote significant at 0.05 and 0.01 levels of probability, respectively. P_1, P_2, P_3, P_4, P_5 and P_6 denote Giza 171, Sakha 95, Bohouth 6, Cham 8, Gemmiza 12 and Masr 3, respectively. DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

Table 10. Percentages of heterosis over the mid- parents for the studied traits in 15 F_1 crosses of bread wheat under severe water (70% water requirements)

Cross	DTH	DTM	Chl. a ($\mu g\ g^{-1}$ FW)	Chl. b	Total Chl.	SOD (U mg^{-1} protein)
P1 × P2	-3.03	0.13	26.57**	14.06**	21.96**	6.26**
P1 × P3	-4.47	-1.27	35.85**	26.68**	32.41**	14.8**
P1 × P4	-5.09*	-0.93	31.33**	17.78**	26.19**	15.19**
P1 × P5	-4.87*	-1.22	16.82**	6.35	13.13**	10.26**
P1 × P6	0.2	1.32	13.83**	4.15	10.41**	3.82
P2 × P3	-4.12	0.4	30.35**	21.09**	27.21**	14.43**
P2 × P4	1.87	0.85	18.82**	2.7	12.71**	12.2**
P2 × P5	0	-0.83	18.43**	6.36	13.99**	8.70**
P2 × P6	3.16	0.85	18.38**	5.23	13.52**	11.75**
P3 × P4	1.46	-2.57**	29.28**	20.08**	26.05**	20.58**
P3 × P5	0.08	-2.80**	14.68**	3.68	10.81**	18.31**
P3 × P6	-1.23	-1.04	21.86**	11.73**	18.3**	26.56**
P4 × P5	-0.93	-2.53**	31.87**	19.24**	26.89**	17.57**
P4 × P6	3.8	-3.52**	23.26**	16.00**	20.26**	29.44**
P5 × P6	-2.59	-2.16**	17.74**	5.68	13.47**	20.28**
Mean	-1.05	-1.02	23.27	12.05	19.15	15.34
Cross	**APX (U mg^{-1} protein)**	**Proline ($\mu g\ g^{-1}$ FW)**	**NSPP**	**NGPS**	**HKW (g)**	**GYPP**
P1 × P2	5.64	7.40**	9.45*	8.08**	14.05**	15.15**
P1 × P3	12.06**	13.4**	32.23**	9.2**	8.78**	22.84**
P1 × P4	17.2**	13.27**	13.88**	-1.9	11.51**	19.48**
P1 × P5	6.31	9.03**	29.47**	8.75**	4.1	4.02
P1 × P6	10.36*	6.96**	10.17*	6.36**	7.49**	-0.82
P2 × P3	14.16**	13.90**	0.27	11.07**	7.19**	17.81**
P2 × P4	8.63	10.79**	3.66	3.19*	1.28	4.21
P2 × P5	13.03**	9.20**	7.56	6.72**	2.17	7.14*
P2 × P6	10.11*	12.31**	-12.98**	8.95**	2.32	5.37
P3 × P4	18.48**	17.84**	4.81	7.94**	2.17	17.74**
P3 × P5	18.84**	15.69**	15.13**	8.21**	0.28	3.32
P3 × P6	19.16**	22.05**	-7.17	2.96*	4.83	8.77*
P4 × P5	17.48**	16.69**	20.83**	5.4**	2.42	17.86**
P4 × P6	25.9**	24.91**	-6.36	7.69**	11.43**	9.24*
P5 × P6	19.07**	17.33**	11.36*	4.95**	4.25	4.37
Mean	14.43	14.05	8.82	6.5	5.62	10.43

* and ** denote significant at 0.05 and 0.01 levels of probability, respectively. P_1, P_2, P_3, P_4, P_5 and P_6 denote Giza 171, Sakha 95, Bohouth 6, Cham 8, Gemmiza 12 and Masr 3, respectively. DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

Table 11. Heterobeltiosis for the studied traits in 15 F1 crosses of bread wheat under well-water (100% water requirements)

Cross	DTH	DTM	Chl. a ($\mu g\ g^{-1}$ FW)	Chl. b	Total Chl.	SOD ($U\ mg^{-1}$ protein)
P1 × P2	-0.1	-0.7	9.78**	2.51	7.1**	6.85*
P1 × P3	-3.2*	-0.14	16.5**	6.28*	12.73**	15.58**
P1 × P4	-1.03	2.83**	1.96	-6.07*	-1	-2.32
P1 × P5	2.48	2.05**	-0.49	-9.00**	-3.63	-3.12
P1 × P6	1.85	2.85**	-5.38*	-16.11**	-9.34**	-6.22
P2 × P3	-2	1.15	18.17**	14.35**	16.79**	18.18**
P2 × P4	4.17**	0.57	0	-4.48	-1.62	-5.05
P2 × P5	2.64	2.12**	1.52	-5.38	-0.97	-3.98
P2 × P6	2.28	0.34	5.08*	-0.67	3	-0.41
P3 × P4	0.63	0.57	15.18**	5.98	11.84**	14.98**
P3 × P5	1.29	0.8	16.69**	9.57**	14.10**	13.66**
P3 × P6	3.71**	0.17	24.35**	20.33**	22.89**	24.51**
P4 × P5	-1.95	-2.93**	29.39**	15.92**	24.45**	25.52**
P4 × P6	-4.26**	-5.54**	46.13**	40.38**	44.06**	52.72**
P5 × P6	-2.36	-3.04**	32.35**	21.02**	28.19**	29.02**
Mean	-3.82	-2.51	14.08	6.31	11.24	11.99

Cross	APX ($U\ mg^{-1}$ protein)	PC ($\mu g\ g^{-1}$ FW)	NSPP	NGPS	HKW (g)	GYPP
P1 × P2	-0.51	10.22**	-6.21	-0.43	2.36	-1.02
P1 × P3	12.70*	16.2**	21.61**	-0.73	4.51*	5.06
P1 × P4	-3.74	1.86*	35.8**	-10.99**	-6.03**	-9.51**
P1 × P5	-1.71	-1.02	2.74	-7.87**	-7.62**	-12.44**
P1 × P6	-19.72**	-5.77**	-8.88*	-6.53**	-6.26**	-17.26**
P2 × P3	13.31*	19.29**	17.57**	7.18**	5.55*	8.25**
P2 × P4	-3.02	-0.5	7.97*	-2.83*	-7.00**	-11.97**
P2 × P5	-6.1	0.86	-12.77**	4.41**	-6.23**	-10.58**
P2 × P6	-3.48	4.38**	12.47**	3.30*	-6.37**	-6.98*
P3 × P4	4.74	16.78**	9.62*	0.03	0.89	3.24
P3 × P5	10.83	17.64**	27.84**	0.13	-6.93**	4.11
P3 × P6	23.62**	26.94**	-13.46**	1.95	3.15	13.52**
P4 × P5	7.55	28.41**	11.04**	6.78**	-9.68**	12.60**
P4 × P6	23.99**	47.36**	22.85**	1.19	12.05**	32.39**
P5 × P6	24.57**	33.22**	27.9**	6.48**	2.02	17.52**
Mean	5.54	14.39	10.41	0.14	-1.71	1.8

* and ** denote significant at 0.05 and 0.01 levels of probability, respectively. P_1, P_2, P_3, P_4, P_5 and P_6 denote Giza 171, Sakha 95, Bohouth 6, Cham 8, Gemmiza 12 and Masr 3, respectively. DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

Table 12. Heterobeltiosis for the studied traits in 15 F1 crosses of bread wheat under severe stress (70% water requirements)

Cros	DTH	DTM	Chl. a (µg g^{-1} FW)	Chl. b	Total Chl.	SOD (U mg^{-1} protein)
P1 × P2	3.33	0.21	24.95**	11.42**	19.93**	4.12*
P1 × P3	3.75	-0.07	34.58**	25.24**	30.92**	9.89**
P1 × P4	2.28	2.14**	14.39**	2.91	10.19**	-0.97
P1 × P5	3.24	2.28**	4.49	-5.18	1.07	-2.09
P1 × P6	9.43**	3.64**	6.17	-2.59	3.08	-8.16**
P2 × P3	-2.39	1.70**	27.5**	16.98**	23.71**	11.74**
P2 × P4	2.97	4.07**	2.37	-12.04**	-2.98	-1.85
P2 × P5	1.73	2.77**	4.74	-7.1	0.34	-1.7
P2 × P6	5.59**	3.24**	9.11*	-3.7	4.35	0.66
P3 × P4	2.2	-0.77	13.52**	5.96	11.15**	7.72**
P3 × P5	0.15	-0.59	3.43	-6.62	0	9.34**
P3 × P6	-0.72	0	14.67**	5.63	11.64**	16.51**
P4 × P5	-0.28*	-2.12**	27.96**	16.53**	23.64**	13.29**
P4 × P6	5.09**	-2.77**	14.47**	7.81	11.89**	25.24**
P5 × P6	-2.02	-0.98	12.53**	0.37	8.2	19.77**
Mean	-4	-2.8	14.33	3.71	10.48	6.9

Cross	APX (U mg^{-1} protein)	PC (µg g^{-1} FW)	NSPP	NGPS	HKW (g)	GYPP
P1 × P2	3.6	6.02**	-1.93	6.02**	11.93**	14.15**
P1 × P3	8.35	9.44**	28.89**	5.46**	6.97**	21.04**
P1 × P4	4.16	1.24	12.89*	-9.8**	3.65	3.23
P1 × P5	-1.58	-0.41	21.34**	-1.94	-1.18	-7.52*
P1 × P6	0.53	-3.12**	-0.99	-0.03	-1.36	-7
P2 × P3	12.52*	11.32**	-8.04	9.33**	3.49	15.08**
P2 × P4	-1.76	0.17	-7.83	-3.41*	-7.47**	-10.62**
P2 × P5	6.58	0.93	-8.97*	-2.06	-4.72	-5.47
P2 × P6	2.13	2.92**	-13.28**	4.31**	-7.7**	-1.99
P3 × P4	8.56	8.81**	1.3	2.57	-3.53	3.02
P3 × P5	13.62**	9.27**	5.36	0.77	-3.26	-6.93
P3 × P6	12.03*	14.25**	-14.6**	0.11	-2.3	3.44
P4 × P5	12.35*	13.92**	14.17*	3.17	0.17	14.07**
P4 × P6	22.49**	23.07**	-16.49**	5.19**	9.89**	0.04
P5 × P6	16.99**	16.23**	-5.49	0.4	0.58	-1.44
Mean	8.04	7.6	0.42	1.34	0.34	2.21

* and ** denote significant at 0.05 and 0.01 levels of probability, respectively. P_1, P_2, P_3, P_4, P_5 and P_6 denote Giza 171, Sakha 95, Bohouth 6, Cham 8, Gemmiza 12 and Masr 3, respectively. DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

3.5. Phenotypic (PCV) and genotypic (GCV) variability

The variability was assessed via genotypic (GCV) and phenotypic (PCV) coefficients of variation of wheat genotypes are presented in **Table 13.** Despite the low magnitude difference between phenotypic and genotypic coefficients of variation for all traits studied, the phenotypic coefficient of variation was clearly higher than the corresponding genotypic coefficient of variation for all studied traits. According to **Deshmukh *et al.* (1986)**, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values are classified as low (10%), medium (10-20%), and high (>20%). In this study, all genotypes demonstrated low to moderate levels of both PCV and GCV for all studied traits. The genotypic and phenotypic coefficients of variation varied from 1.71% for DTM to 14.83% for proline content, and from 1.90% for DTM to 16.64% for APX under well-watered (100%WR), respectively. Earliness traits had low PCV and GCV values under all water regimes; moderate PCV and GCV values were exhibited for physiological and biochemical traits under the two water regimes except, APX and proline at 70%WR. For grain yield and its attributes, moderate values were showed by NSPP, GYPP under all treatments except GCV value for NSPP at 70%WR was low, while the trait NGPS and HKW exhibited low values under all treatments except PCV value for GPC at 70%WR was moderate.

Table 13. Phenotypic (PCV) and genotypic (GCV) variability for the studied traits under well-water (100% water requirements) and severe stress (70% water requirements)

Parameter	**PCV (%)**		**GCV (%)**	
Treatment	**100% WR**	**70% WR**	**100% WR**	**70% WR**
DTH	3.18	6.27	2.73	5.45
DTM	1.9	2.03	1.71	1.8
Chl. a (µg g^{-1} FW)	14.81	14.69	14.48	14.05
Chl. b (µg g^{-1} FW)	14	13.52	13.46	12.4
Total Chl. (µg g^{-1} FW)	14.42	14.06	14.04	13.32
SOD (U mg^{-1} protein)	15.28	10.54	14.7	10.22
APX (U mg^{-1} protein)	16.64	9.49	14.63	7.54
PC (µg g^{-1} FW)	14.88	8.46	14.83	8.41
NSPP	14.73	10.93	13.96	9.21
NGPS	6.28	7.48	6.07	7.27
HKW (g)	9.02	8.34	8.6	7.69
GYPP (g)	13.56	12.98	13.02	12.17

WR: Water requirements, DTH: Day to heading, DTM: Days to maturity, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Chl. content: Chlorophyll content, SOD: Superoxide dismutase activity, APX: The activity of ascorbate peroxidase, PC: Proline content, NSPP: No. of spikes/plant, NGPS: No. of grains/spike, HKW: 100-kernel weight, GYPP: Grain yield/plant.

REFERENCES

Abd El-Kareem, T. H. A. and El-Saidy, A. E. A. 2011. Evaluation of yield and grain quality of some bread wheat genotypes under normal irrigation and drought stress conditions in calcareous soils. J. Biol. Sci., 11(2):156-164.

Abdelkader, M. A., El-Gabry, Y. A., Sayed, A. N., Shahin, M. G., Darwish, H. A., Aboukota, M. E., Hashem, F. A. E. and Abd-Elrahman, S. H. 2022. Evaluation of physio-biochemical criteria in maize inbred lines and their F1 hybrids grown under water-deficit conditions. Ann. Agric. Sci., 67:220–231.

Adel, M. M. and Ali, E. A. 2013. Gene action and combining ability in a six parent diallel cross of wheat. Asian J. Crop Sci., 5(1): 14-23.

Akram Z., Ajmal, S., Khan, K. and Qureshi, R. 2011. Combining ability estimates of some yield and quality related traits in spring wheat (*Triticum aestivum*, L.). Pak. J. Bot., 43:221–231.

Allen, R. G., Pereira, L. S., Raes, D. and Smith, M. 1998. Crop evapotranspiration-guidelines for computing crop water requirements. FAO Irrigation and Drainage, Paper 56. D05109. FAO, Rome, p. 300.

Arjenaki, F. G., Jabbari, R. and Morshedi, A. 2012. Evaluation of drought stress on relative water content, chlorophyll content and mineral elements of wheat (*Triticum aestivum*, L.) varieties. Int. J. Agric. Crop Sci., (4):726–729.

Arnon, D. I. 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. Plant Physiol., 24:1–15.

Asseng, S., Kheir, A. M. S., Kassie, B. T., Hoogenboom, G., Abdelaal, A. I. N., Haman, D. Z. and Ruane, A. C. 2018. Can Egypt become self-sufficient in wheat? Environ. Res. Lett., (13):094012.

Bates, L. S., Waldren, R. P. and Teare, I. D. 1973. Rapid determination of free proline for water-stress studies. Plant Soil, 39:205-207.

Beyer, F. W. and Fridovich, Jr. I. 1987. Assaying for superoxide dismutase activity: Some large consequences of minor changes in conditions. Anal. Biochem., (161):559–566.

Bhatt, G. M. 1971. Heterotic performance and combining ability in a diallel cross among spring wheat (*Triticum aestivum* L.). Aust. J. Agric. Res., (22):356-369.

Chachar, M. H., Chachar, N. A., Chachar, Q., Mujtaba, S. M., Chachar, S. and Chachar, Z. 2016. Physiological characterization of six wheat genotypes for drought tolerance. Int. J. Res. Granthaalayah (4):184–196.

Chaudhary, N., Dey, T., Bharti, R. and Sandhu, R. 2018. Heterosis studies for grain yield and other morpho-physiological traits in bread wheat (*Triticum aestivum*, L.) for drought tolerance. Multilogic in Science**,** (8):333-342.

Deshmukh, S. N. N., Basu, M. S. and Reddy, P. S. 1986. Genetic variability, character association and path coefficients of quantitative traits in Virginia bunch varieties of groundnut. Indian J. Agric. Sci., (56):816-821.

Dorostkar, S., Dadkhodaie, A., and Heridari, B. 2015. Evaluation of grain yield indices in hexaploid wheat genotypes in response to drought stress. **Arch. Agron. Soil Sci.**, 61 (3,4):397-413.

El-Fahdawy, A., El-Hosary, A. A., El-Badawy, M. El. M., Mehasen, S. A. S and El-Hosary, A. A. A. 2019. Utilization of diallel crosses to determine combining ability and heterosis in wheat grown under drought and normal irrigation treatments. Egypt. J. Plant Breed., 23(3):212 -292.

El-Gammaal, A. A. 2018. Combining ability analysis of drought tolerance screening techniques among wheat genotypes (*Triticum aestivum*, L). J. Plant Prod., Mansoura Univ. 9 (11):875 – 885.

EL-Hosary, A. A., EL-Badawy, M. E. M., Mustafa, A. K. and EL-Shal, M. H. 2012. Evaluation of diallel wheat crosses under drought tolerance. Egypt. J. Plant Breed., 16(1):19-40.

Falconer, D. S. 1981. Introduction to quantitative genetics. New York: The Ronald.

FAO, 2024. Food and Agriculture Organization of the United Nations. Statistical Year Book. World Food and Agriculture, 2023.

Farshadfar, E., Ghaderi, A. and Yaghotipoor, A. 2014. Diallel analysis of physiologic indicators of drought tolerance in bread wheat (*Triticum aestivum*, L.). Agriculture Communications, 2(1):1-7.

Farshadfar, E., Rafiee, F. and Hasheminasab, H. 2013. Evaluation of genetic parameters of agronomic and morpho-physiological indicators of drought tolerance in bread wheat (*Triticum aestivum*, L.) using diallel mating design. Australian J. Crop Sci., 7:268–275.

Fasahat, P., Rajabi, A., Rad, J. M. and Derera, J. 2016. Principles and utilization of combining ability in plant breeding. Biom. Biostat. Int. J., (4):1–22.

Giraldo, P., Benavente, E., Manzano-Agugliaro, F. and Gimenez, E. 2019. Worldwide research trends on wheat and barley: A bibliometric comparative analysis. Agronomy, (9):352.

Gomaa, M. A., El-Banna, M. N. M., Gadalla, A. M., Kandil, E. E. and Ibrahim, A. R. H. 2014. Heterosis, combining ability and drought susceptibility index in some crosses of bread wheat (*Triticum aestivum*, L.) under water stress conditions. Middle-East J. Agric. Res., 3(2):338-345.

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci., (9):463-493.

Hunter, M., Smith, R., Schipanski, M. and Atwood, L. 2017. Agriculture in 2050: recalibrating targets for sustainable intensification. Bioscience, 67:385–390.

Ibrahim, H. S., Mohamed, A. A., Ibrahim, K. I. M. and Sayed, A. N. 2014. Heterosis and combining ability for some agronomic and physiological traits in bread wheat crosses under water stress condition. Egypt. J. Plant Breed., 18(3):551-583.

Jatoi, W., Baloch, M., Khan, N., Munir, M., Khakwani, A., Vessar, N., Panhwar, S. and Gul, S. 2014. Heterosis for yield and physiological traits in wheat under water stress conditions. J. Anim. Plant Sci., 24: 252–261.

Kadam, S., Shukla, Y., Subhash, N., Singh, C. and Suthar, K. 2017. Screening of wheat genotypes (*Triticum durum*, L.) in response to drought stress by some physiological and biochemical indices. Int. J. Pure App. Biosci., (5):969–977.

Kamara, M. M., Rehan, M., Mohamed, A. M., El Mantawy, R. F., Kheir, A. M. S., Abd El-Moneim, D., Safhi, F. A., ALshamrani, S. M., Hafez, E. M. and Behiry, S. I. 2022. Genetic potential and inheritance patterns of physiological, agronomic and quality traits in bread wheat under normal and water deficit conditions. Plants, 11, 952.

Kumar, P., Yadava, R., Gollen, B., Kumar, S., Verma, R. K. and Yadav, S. 2011. Nutritional contents and medicinal properties of wheat: A review. Life Sci. Med. Res. 22:1–10.

Kumar, T. A. and Prasad, B. 2017. Study of combining ability and nature of gene action for yield and its contributing traits in bread wheat (*Triticum aestivum*, L. em Thell). Int. J. Curr. Microbiol. App. Sci., 6(10):3562- 3573.

Manivannan, N. 2014. TNAUSTAT-Statistical package. https://sites.google.com/site/tnaustat.

Nakano, Y. and Asada, K. 1981. Hydrogen peroxide is scavenged by ascorbate-specific peroxidase in spinach chloroplasts. Plant Cell Physiol., (22):867–880.

Noorka, I. R., Batool, A., Rauf, S., Teixeira da Silva, J. A. and Ashraf, E. 2013. Estimation of heterosis in wheat (*Triticum aestivum*, L.) under contrasting water regimes. Int. J. Plant Breed., 7(1):55-60.

Ozturk, A., Erdem, E., Aydin, M. and Karaoglu, M. M. 2021. The effects of drought after anthesis on the grain quality of bread wheat depend on drought severity and drought resistance of the variety. Cereal Res. Commun., (1):105–116.

Ray, D., Muellr, N., West, P. and Foley, J. 2013. Yield trends are insufficient to double global crop production by 2050. Plos One. 8:e006428.

Sallam, A., Alqudah, A. M., Dawood, M. F. A., Baenziger, P. S. and Börner, A. 2019. Drought stress tolerance in wheat and barley: advances in physiology, breeding and genetics research. Int. J. Mol. Sci., (20):3137.

Semahegn, Y., Shimelis, H., Mark, L. and Mathew, I. 2021. Combining ability of bread wheat genotypes for yield and yield-related traits under drought stressed and non-stressed conditions. S. Afr. J. Plant Soil, 38(2):171–179.

Senapati, N., Stratonovitch, P., Paul, M. J. and Semenov, M. A. 2019. Drought tolerance during reproductive development is important for increasing wheat yield potential under climate change in Europe. J. Exp. Bot., (70):2549–2560.

Sharma, V., Kumar, A., Chaudhary, A., Mishra, A., Rawat, S., Basavaraj, Y.B., Shami, V. and Kaushik, P. 2022. Response of wheat genotypes to drought stress stimulated by PEG. Stresses, (2):26–51.

Sivasubramanian, S. and Madhavamenon, P. 1973. Genotypic and phenotypic variability in rice. Madras Agri. J., 60:1093-1096.

Soil Survey Staff. 2010. Keys to Soil Taxonomy. 11th ed. U.S. Department of Agriculture, Natural Resources Conservation Service, U.S. Government Printing Office, Washington, DC, USA.

USDA, 2023. United States Department of Agriculture Reports.

Verbeke, S., Padilla-Díaz, C. M., Haesaert, G. and Steppe, K. 2022.

Osmotic adjustment in wheat (*Triticum aestivum*, L.) during pre- and post-anthesis drought. Front. Plant Sci., (13):775652.

Yao, J., Ma, H., Yang, X., Yao, G. and Zhou, M. 2014. Inheritance of grain yield and its correlation with yield components in bread wheat (*Triticum aestivum*, L.). Afr. J. Biotechnol., (13):1379-1385.