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Research Article

Evaluation of heterosis and its association among morpho-physiological traits of ten wheat genotypes under water stress

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Abstract

Wheat is a staple food grain ranked that first as consumed globally and occupies a central position in the cereal trade. Grain yield is a polygenic inherited trait and is the product of several attributes which contribute to it direct or indirectly. Wheat production is affected by various calamities, among them; water stress is a destructive factor to the seed yield of wheat. In present study, we investigated the performance of F_1 wheat hybrids for heterosis and the relation between morpho-physiological characters under water stress at field conditions. Split plot design was used consisted of two factors; genotypes and water stress with three replications. Ten F_1 wheat hybrids generated using half-diallel crossing and were evaluated under water stress treatments viz., normal watering (T_0), extreme water stress from tillering to maturity (T_1), and post-flowering water stress from anthesis to maturity (T_2). The obtained results revealed that the F_1 wheat hybrids Sarsabz x Kiran-95 (V7), TD-1 x NIA-Sarang (V8) and NIA-Sarang x Kiran-95 (V10) were found potential wheat hybrids for seed yield under both water stress and normal watering which could be included in the future wheat breeding scheme. Hybrid performance during the wheat breeding scheme can be improved by analyzing genetic potential among wheat genotypes, determining the association between traits and selection with greater genetic diversity and heterosis for water stress tolerance and identification of traits most influenced grain yield. Overall these newly evolved hybrids should be recommended for cultivation under normal field conditions.

Keywords: Correlation; F_1 hybrid; Heterosis; Morpho-physiological traits; *Triticum aestivum* L; Water stress

Introduction

Wheat is an important staple food cereal ranks first among cereals in the world, generally known as the king of cereals for acreage it occupies, high production and major status in trade of international food grain market **[1, 2]**. Rapidly increasing human population has changed climatic conditions and showed concerns to global food security [3]. The current improvement of several important crops is inadequate to meet future food demand [4]. Wheat is an annual, autogamous rabi crop, belongs to the tribe triticeae, and is hexaploid with AA BB DD genome. World production of wheat is being affected by environmental calamities among them water scarcity has been considered a huge problem. Grain yield is a polygenic inherited trait and is the product of several attributes which affect it direct or indirectly [5]. For genetic manipulation, it is necessary to create genetic variability for improving yield and yield-associated attributes [6]. Sufficient genetic variation is necessary for crop improvement schemes, while the presence of variability among wheat genotypes for yield and yield related components was reported by [7, 8].

A successful wheat breeding program needs genetic diversity as a prior condition and of paramount importance in the modern sustainable agriculture. Parents can produce a hybrid with better yield performance. Hence clear information on the nature, pattern and degree of genetic diversity help wheat breeders to choose diverse parents for hybridization [9, 10]. Asifa *et al.* [11] revealed that drought tolerance wheat species are based on morpho-physiological traits. Bernardo *et al.* [12] examined the metabolic responses triggered by arbuscular mycorrhiza increase survival potential to moisture stress in wheat genotypes. Lin *et al.* [13] revealed the heterosis-related genes confer bumper production in super hybrid rice. Moosavi *et al.* [14] investigated the phenological, morphological, physiological, and proteomic traits of *Triticum boeticum* under drought stress conditions. Therefore, this research study aimed to investigate the F_1 wheat hybrids for heterosis and the relation between morpho-physiological characters under three water stress field conditions. It is hypothesized that the morpho-physiological characters of F_1 wheat hybrids for heterosis might be affected under water stress conditions.

Materials and Methods

This research was performed at the field of Division of Plant Breeding and Genetics, Nuclear Institute of Agriculture (NIA) Tandojam, as shown in (Fig. 1) study area. A split plot design was used consisted of two factors; genotypes and water stress with three replications. Genotypes were sub plots; ten F_1 wheat hybrids were included with their five parents. Main plots were treated with three water treatments viz., normal watering (T_0), extreme water stress from tillering to maturity (T_1) and post flowering water stress from anthesis to maturity (T_2). Half diallel design was used followed by Griffing's method-2, model-1 a numerical approach; n(n-1)/n. F_1 wheat hybrids; T J-83 x Sarsabz, T J-83 x TD -1, T J-83 x NIA- Sarang, TJ-83 x Kiran-95, Sarsabz x TD-1, Sarsabz x NIA-Sarang, Sarsabz x Kiran-95, T D-1 x NIA-Sarang, T D-1 x Kiran-95, and NIA-Sarang x Kiran-95. Parents cultivars included TJ-83, Sarsabz, TD-1, Kiran-95 and NIA-Sarang were grown along with their hybrids. Seeds were dibbled. The middle two rows were used to select randomly ten plants of each sub plot. In addition, the recommended dose of nitrogen (N) in the form of urea was applied at 120 kg ha^{-1} and Phosphorus (P) in the form of DAP was incorporated at 75 kg P_2O_5 ha^{-1}. All management practices were uniformly applied. Four rows of 2.5m length with 30cm and 15cm distance between rows and plants respectively were maintained.

Morpho-physiological traits

Days to 50% flowering, days to 90% maturity, plant height, main spike length, tillers $plant^{-1}$, spikelet $spike^{-1}$, grains $spike^{-1}$, 1000 grain weight, grain yield $plant^{-1}$, biological $yield^{-1}$, harvest index, flag leaf area, leaf relative water content, and chlorophyll content. Furthermore, days to 50% flowering were noted from sowing date to date of 50% flowering of individual genotype. Days to 90% maturity were noted from date of sowing to date of visually 90% maturity of individual genotype. Plant height was measured in centimeters from the surface of the soil to the tip of the spike. The main spike length was noted in centimeters from the base of the rachis to the tip of a spike in a field standing crop. The fertile tillers of each genotype were noted at the time of `maturity in the field standing crop. The number of spikelet spike^{-1} of each genotype was noted in the laboratory. The number of grains spike^{-1} was counted after hand threshing the spike in the laboratory. Seed index was noted by weighing 1000 grain. Grain yield plant^{-1} was noted by weighing the total grains of a plant. The biological yield was noted by weighing uprooted plants before threshing. Harvest index was analyzed as grain yield/biological yield x 100. The flag leaf area was measured in the laboratory of the Division of Plant Breeding and Genetics at NIA Tandojam using portable laser leaf area meter AG-51-020, connected with a high speed scanner and scan board/data logger.

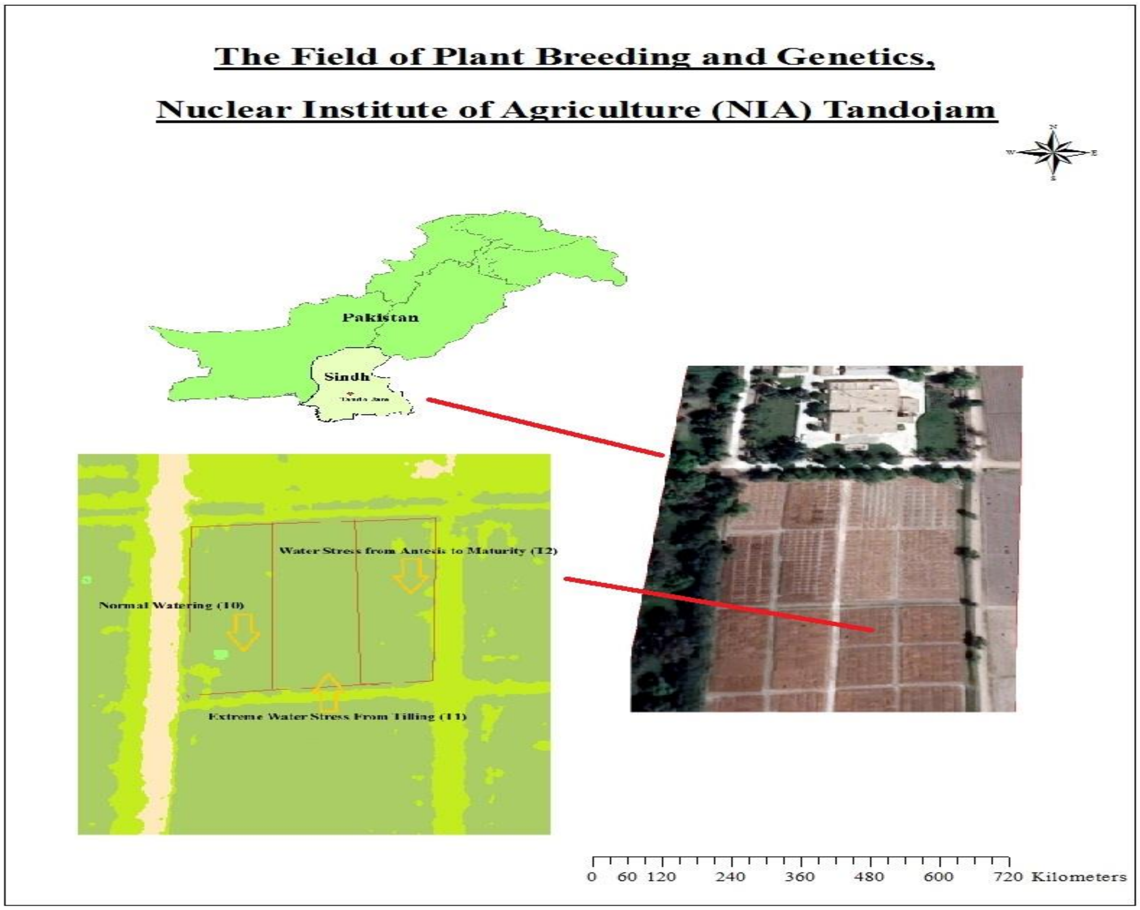

Figure 1. Study Area; The field of division of plant breeding and genetics, Nuclear Institute of Agriculture (NIA) Tandojam

Leaf relative water content

Leaf relative water content was analyzed to cut fully expanded leaf at the second node from the top of canopy to note relative water content in Laboratory where initial weight, turgid weight and dry weight was noted to assess the impact of an increase in the intensity of water stress on physiological parameters. Leaves were cut from adjoining point of leaf lamina and leaf sheath and taken to the laboratory immediately to prevent water loss. Fresh weight was determined on the top loading digital weight balance. This foliage was then separately kept into deionized water in a test tube for 24hr in a cold room for rehydration. Each test tube contained a leaf from a single genotype and replication. After 24 hr, leaves were then used for noting turgid weight. Then carefully placed in a small paper bag and oven dried at 72°C for 24hr to examine the dry weight of leaves. Relative water content was determined followed by Baars and Weatherley [15] as;

Fresh weight- Dry weight/Turgid weight x10

Chlorophyll content

Chlorophyll content was obtained from leaf 2nd of the flag leaf. Three readings were noted with chlorophyll meter M-52 from the base, mid and near the end of leaf lamina. l

Soil physico-chemical analysis

In this study, before planting of wheat soil was tested by drawing soil samples randomly which were collected from 0, 6cm and 15cm at the depth. In addition, soil texture was analyzed by the Bouyoucos Hydrometer method [16]. Soil field capacity was measured according to Veihmeyer and Hendrickson [17]. Soil organic matter was determined by the Walkley-Black method [18]. Soil EC and pH were measured in 1:5 H_2O (W/V) according to Kwon *et al.* [19]. Total nitrogen (TN) was detected via Kjeldahl protocol (USEPA Method 351.2). Total phosphorus (P) and potassium (K) were determined by NaOH fusion procedure [20]. The studied soil was sandy loam in texture, field capacity 13% by weight, organic matter 0.97%, EC 2.7mMolS^{-1}, pH 7.4, nitrogen 0.61 g kg^{-1}, phosphorus 19.8ppm and potassium 140ppm, were measured at the Soil science laboratory of Nuclear Institute of Agriculture Tando Jam.

Heterosis

Heterosis is the performance of F_1 hybrids over their parents. Comparative heterosis was analyzed according to Baloch *et al.* [21]. Increase and decrease ratio over mid and better parent was computed as;

F1–MP /MP x 100 and F1-BP /BP x 10

Pearson correlation coefficient

Coefficient of correlation between some morpho-physiological characters was computed followed by Baloch *et al.* [22] as;

Coefficient of Correlation = Covariance / Geomet-ric mean of covariance.

$$\frac{\sum X\ Y + \Sigma x_i^2 = \Sigma X^2 - (\Sigma X)^2/N = \Sigma y^2 = \Sigma X^2 - (\Sigma X)^2/N}{\sqrt{(\Sigma X)^2 (\Sigma Y)^2}}$$

(Where; X=Independent variable,Y= Dependent variable, N=Number of observations).

Geospatial techniques

Geospatial techniques are remarkable in the field of research for managing, monitoring huge data set easily and efficiently. In this research, high-resolution satellite imaginary data have been extracted from google earth then geo-referencing techniques have been applied for image rectification. For extraction of the area of interest, a mask tool has been used. The editor tool has been used for the digitization of image data.

Statistical analysis

The obtained data were subject to statistical analysis of variance by using Statistics software version 8.1 as suggested by Steel and Torrie [23].

Results and Discussion

As shown in (Table 1) the mean squares indicated that there were highly significant modifications among water treatments. Highly significant differences (≥ 0.01%) between genotypes under water treatments were noted for most of the characters except the flag leaf area. Interaction between genotype and treatment showed highly significant variations for most of the characters except tiller plant^{-1} and flag leaf area. It was noticed from (Table 1) that treatments, genotypes, and their interaction showed differently for the morpho-physiological character. Similarly, Sial *et al.* [10] found significant influences of water deficit on seed production and yield related characters of wheat populations.

Table 1. Mean square of morpho-physiological traits of F_1 wheat hybrids and their parents.

Characters		Mean squares				
	Replication D.F=2	Treatment D.F=2	Repli x Treat D.F=4	Genotype D.F=14	Treat x Genot D.F=28	Error D.F=56
Days to flower	113.3	35753.5**	13.9	50.1**	52.01**	3.3
Days to maturity	0.67	5281.25**	0.49	34.56**	92.57**	2.08
Plant height	3.51	4657.81**	5.05	210.02**	74.75*	16.4
Tillers plant^{-1}	20.58	87.38**	4.03	10.45*	3.74ns	1.88
Spike length	0.25	161.5**	0.16	2.93**	2.2**	0.19
Spikeletspike^{-1}	0.51	167.49**	2.29	4.86**	3.96**	0.55
Grainsspike^{-1}	110.18	23.84**	2.09	218.93**	193.89**	17.42
Grain yieldmainSpk^{-1}	1.08	12.55**	0.91	0.52**	0.46*	0.05
1000 grain weight	1.51	233.07**	3.1	63.43**	70.66**	1.83
Biol. yield plant^{-1}	63.9	21107.6**	1.2	448.9**	888.9**	5.1
Grain yield plant^{-1}	3.46	6102.69**	16.21	104.59**	122.63**	6.55
Harvest index%	0.1	33920.4**	0.1	46.09**	47.3**	1.0
	Physiological characters					
Flag leaf area(mm)	830619	2.351ns	1.522	1.676ns	1.083ns	3.98574
Relative water content	397.78	841.31**	2.135	260.13**	119.59**	1.6772
Chlorophyll content	9.82	202.37**	1.02	22.96*	29.19**	3.15

*=Significant at 0.5% level of probability, **= significant at 0.1% level of probability, ns=non-significant

Plant height

Heterotic performance of F_1 wheat hybrids for plant height (Table 2) under normal watering (T_0) indicated that TJ-83 x TD-1 (-14.10, -19.00) showed the shortest stature of all the F_1 hybrids against their mid and better parent. Other short statured hybrids were TJ-83 x NIA-Sarang (-6.45, -6.50) and TJ-83 x Sarsabz (-0.15, -1.40) against their mid parent (MP) as well as the better parent (BP). For the selection of short statured wheat genotypes, these hybrids could be included in breeding schemes. The remaining wheat hybrids could be included in the selection scheme for high kernel and biological yield. The (Table 2) revealed that TD-I x Kiran-95 (-0.30, -5.40) showed a reduction in plant height beside both its MP with BP. TD-1 x NIA-Sarang (2.00, -3.00) and Sarsabz x Kiran-95 (2.20,-0.5) showed dwarf plants against their BP. Only wheat hybrid TD-1 x NIA-Sarang (-2.25, -7.20) showed decreased plant height beside both MP with BP under water deficit (T_2). The remaining all hybrids observed an increased plant height besides their both MP and BP under the same water stress. Sial *et al.* [10] also reported significantly reduced plant height under severe water stress.

Main spike length

The data in (Table 2) revealed that all genotypes found an increased main spike length besides both MP and BP under (T_0). The large main spike was observed by F_1 wheat hybrid TD-I x NIA-Sarang (6.95, 6.70) as compared to Sarsabz x TD-I (6.70, 6.30), Sarsabz x Kiran-95 (6.55, 5.50), NIA-Sarang x Kiran-95 (6.50, 6.50), Sarsabz x NIA-Sarang (6.25, 5.60), TD-I x Kiran-95 (5.45, 4.80) and TJ-83 x Sarsabz (5.40, 3.80) respectively against their MP and BP under normal watering (T_0). Water stress from tillering to maturity (T_1) influenced the main spike length of F_1 wheat hybrids. Hybrid Sarsabz x NIA-Sarang (1.80, 1.50), TD-I x Kiran-95 (1.40, 0.40), and NIA-Sarang x Kiran-95 (0.80, 0.70) surpassed their MP, as well as BP concerning the main spike length and rest of hybrids, were reduced in main spike length. The largest spike length of all wheat hybrids was noted in F_1 hybrid Sarsabz x NIA-Sarang (4.75, 4.20) as compared to TJ-83 x NIA-Sarang (3.75, 2.20), NIA-Sarang x Kiran-95 (3.25, 1.20), Sarsabz x TD-I (2.90, 1.40), Sarsabz x Kiran-95 (2.80, 1.30), TD-I x NIA-Sarang (2.75, 0.70) and TJ-83 x Sarsabz (2.40, 1.40) respectively over their MP as well as BP. This material could be utilized for a selection of large main spike wheat genotypes. Sharma [24] reported that in the hybridization system, viz., bi-parental mating and diallel selective mating, which develop both functional and non-functional gene influences, at the same time, could be beneficial in the step-up of spike length in durum wheat.

Table 2. Heterotic effects of F_1 wheat hybrids on plant height and main spike length under water treatments

Genotypes	Plant height						Main spike length					
	T_0 (Control) I/D %		T_1 I/D %		T_2 I/D %		T_0 I/D %		T_1 I/D %		T_2 I/D %	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
V1	-0.15	-1.40	6.08	7.80	10.85	2.90	5.40	3.80	-2.55	-4.00	2.40	1.40
V2	-14.10	-19.00	10.15	8.20	2.90	1.30	4.60	3.40	-3.15	-3.80	1.80	1.30
V3	-6.45	-6.50	14.25	7.30	6.55	0.00	4.05	3.10	-3.65	-5.40	3.75	2.20
V4	2.05	1.20	5.65	-1.40	13.90	8.50	4.15	3.60	-2.95	-4.60	1.30	0.80
V5	11.75	8.10	12.30	9.90	13.35	7.00	6.70	6.30	0.00	-0.80	2.90	1.40
V6	4.40	3.20	7.30	4.70	2.70	1.30	6.25	5.60	1.80	1.50	4.75	4.20
V7	7.40	5.30	2.20	-0.50	13.55	11.00	6.55	5.50	-3.50	-3.70	2.80	1.30
V8	9.25	4.40	2.00	-3.00	-2.25	-7.20	6.95	6.70	0.90	-0.20	2.75	0.70
V9	1.45	-4.30	-0.30	-5.40	4.40	0.60	5.45	4.80	1.40	0.40	1.40	1.40
V10	13.10	12.20	7.30	7.20	14.30	10.50	6.50	6.50	0.80	0.70	3.25	1.20

Note: MP= Mid parent, BP= Better parent, I= Increase, D=Decrease; V1= TJ-83 x Sarsabz, V2= TJ-83 x TD-1, V3=TJ-83 x NIA-Sarang, V=TJ-83 x Kiran-95, V5= Sarsabz x TD-1, V6=Sarsabz x NIA-Sarang, V7=Sarsabz x Kiran-95, V=8 TD-1 x NIA-Sarang, V9 TD-1 x Kiran-95 and V10=NIA-Sarang x Kiran-95

Chlorophyll content

Chlorophyll content is the important physiological character of a plant and generally called the blood of the plant. Chlorophyll plays important role in the manufacture of starch. Water stress directly affects chlorophyll pigmentation which ultimately influences the end product of the plant. According to (Table 3) wheat hybrids transgressed over MP as well as BP concerning chlorophyll concentration under (T_0). Great chlorophyll concentration was noted in hybrid TD-1 x NIA Sarang (11.30, 8.40) over MP and BP as compared to TJ-83 x Kiran-95 (9.10, 8.40), NIA-Sarang x Kiran-95 (8.15, 6.50), Sarsabz x TD-1(7.50, 6.00), Sarsabz x Kiran-95 (4.75, 4.50), TJ-83 x TD-1 (4.35, 3.80), Sarsabz x NIA-Sarang (3.70, 2.30) and TD-1 x Kiran-95 (2.75, 1.50) respectively under normal watering (T_0). According to (Table 3) the F_1 wheat hybrid such as Sarsabz x NIA-Sarang (7.90, 7.40) showed great chlorophyll content over mid as well as a better parent, followed by TJ-83 x TD-1 (5.80, 4.30), TD-1 x Kiran-95 (4.95, 3.80), Sarsabz x TD-1 (4.80, 3.40), and TJ-83 x Sarsabz (1.50, 1.40) were surpassed for chlorophyll content against their mid as well as BP under (T_1). The wheat hybrid such as Sarsabz x NIA-Sarang (6.15, 4.50) surpassed MP as well as BP for chlorophyll content, followed by TD-1 x Kiran-95 (6.80, 3.50), TD-1 x NIA-Sarang (3.50, 3.30), Sarsabz x TD-1 (3.05, 1.20) and TJ-83 x Kiran-95 (2.80, 0.80) respectively surpassed to their MP as well as BP for chlorophyll content.

Flag leaf area

Flag leaf adds food manufacturing in plants up to maturity and is an important source to sink. The larger area of flag leaf would capture more solar light as compared to smaller. Results in (Table 3) revealed that hybrids showed increased flag leaf area against their MP as well as BP under normal watering (T_0). The large flag leaf of all hybrids was attained by F_1 wheat hybrid TD-I x NIA-Sarang (117.10, 69.90) as compared to Sarsabz x NIA-Sarang (76.90, 60.40), NIA-Sarang x Kiran-95 (73.90, 55.3), Sarsabz x Kiran-95 (50.70, 15.06), Sarsabz x TD-1 (37.80, 7.10), TJ-83 x Sarsabz (36.75, 8.30) and TJ-83 x Kiran-95 (19.45, 12.8) which surpassed to their MP as well as BP. However, F_1 wheat hybrid TD-I x NIA-Sarang (120.65, 81.8) showed the largest flag leaf area of all hybrids, as well as MP and BP, followed by NIA-Sarang x Kiran-95 (88.95, 80.60), Sarsabz x NIA-Sarang (82.40, 59.30), Sarsabz x TD-1 (81.45, 74.00), TD-1 x Kiran-95 (52.3, 21.8) and Sarsabz x Kiran-95 (45.45, 21.70) which also showed increased flag leaf area against their MP and BP under same water stress. The wheat F_1 hybrid TD-1 x NIA-Sarang (116.80, 35.90) was noted with the highest flag leaf area overall hybrids and its MP as well as BP. TD-1 x Kiran-95(89.65, 36.30), Sarsabz x TD-1 (76.20, 7.8), TJ-83 x Sarsabz (65.40, 53.60), Sarsabz x Kiran-95 (28.95, 13.9) and Sarsabz x NIA-Sarang (17.50, 5.00) showed increased flag leaf area over their MP and BP under (T_2). Elshafei *et al.* **[25]** observed the changes in the chlorophyll content and flag leaf senescence of wheat genotypes under water stress conditions.

Table3. Heterosis of F_1 wheat hybrids on leaf chlorophyll content and flag leaf area under water stress treatments

Genotypes	Leaf chlorophyll content						Flag leaf area					
	T_0 (Control) I/D %		T_1 I/D %		T_2 I/D %		T_0 I/D %		T_1 I/D %		T_2 I/D %	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
V1	0.35	-0.60	1.50	1.40	-0.45	-1.00	36.75	8.30	19.30	-41.30	65.40	53.60
V2	4.35	3.80	5.80	4.30	-2.40	-3.70	-44.45	-103.6	33.15	-34.20	45.20	-35.0
V3	-3.35	-5.70	-0.20	-0.80	0.00	-1.10	-51.15	-63.10	-115.10	-143.60	-68.10	-68.80
V4	9.10	8.40	2.35	-0.30	2.80	0.80	19.45	12.8	-90.75	-127.60	-39.45	-66.30
V5	7.50	6.00	4.80	3.40	3.05	1.20	37.80	7.10	81.45	74.00	76.20	7.80
V6	3.70	2.30	7.90	7.40	6.15	4.50	76.90	60.40	82.4	59.30	17.50	5.00
V7	4.75	4.50	-1.55	-4.10	-3.15	4.60	50.70	15.60	45.45	21.70	28.95	13.90
V8	11.30	8.40	1.80	0.90	3.50	3.30	117.10	69.90	120.65	81.80	116.80	35.90
V9	2.75	1.50	4.95	3.80	6.80	3.50	59.40	-6.40	52.3	21.80	89.65	36.30
V10	8.15	6.50	-1.25	-3.30	3.00	-0.10	73.00	55.30	88.95	80.60	26.15	-1.40

Grain filling period

As shown in (Table 4) under normal watering (T_0) except F_1 wheat hybrid Sarsabz x Kiran-95 (8.60, 7.90), all the wheat hybrids revealed a decreased grain filling period. Shortest grain filling period was noted in TJ-83 x

Kiran-95 (-11.65, -13.00) as compared to TD-1 xKiran-95 (-10.85, -11.40), NIA-Sarang x Kiran-95 (-7.90, -10.40), T-83 x NIA-Sarang (-6.65, -7.80), TJ-83 x TD-1 (-6.50, -8.4), TD-1 x NIA-Sarang (-4.15, -7.20), T-83 x Sarsabz (-4.45, -5.10) and Sarsabz x NIA-Sarang (-0.80, -2.60). In addition, except wheat hybrid NIA-Sarang x Kiran-95 (9.15, 6.90) and TJ-83 x Sarsabz (0.30, 0.20), all the hybrids showed decreased grain filling period (T_1). Shortest grain filling period against all hybrids was noted in Sarsabz x NIA-Sarang (-9.45, -11.80) followed by Sarsabz x TD-1 and TD-1 x NIA-Sarang (-8.75,-10.3), TJ-83 x NIA-Sarang (-6.75, -9.00), Sarsabz x Kiran-95 (-3.80, -4.50), TD-1 x Kiran-95 (-3.65, -5.90), TJ-83 x TD-I (-2.75, -4.20) and TJ-83 x Kiran-95 (-1.00, -1.80). According to results of (Table 4), all of wheat hybrids showed decreased performance over MP as well as BP under water stress from anthesis to maturity (T_2). The greatest decline in grain filling period was noted in F_1 wheat hybrid TJ-83 x Kiran-95 (-17.45, -25.60) as compared to NIA-Sarang x Kiran-95 (-12.90, -21.20), TJ-83 x NIA-Sarang (-11.15, -11.30), TJ-83 x Sarsabz (-10.55, -10.70), TD-I x Kiran-95 (-8.70, -16.40), TJ-83 x TD-I (-7.75, -8.20), TD-1 x NIA-Sarang (-5.90, -6.50), Sarsabz x NIA-Sarang (-3.10, -3.40),Sarsabz x Kiran-95 (-3.00, -11.00) and Sarsabz x TD-I (-1.30, -1.60) (T_2). Farooq *et al.* **[26]** revealed that drought obstructs wheat performance at all growing stages; it is more serious at the time of flowering and grain-filling periods which may possibly low yield.

Tillers plant^{-1}

According to (Table 4) the data revealed that six F_1 wheat hybrids evidently enhanced tillers plant^{-1} against their MP and BP as compared to other wheat hybrids. Great number of tillers plant^{-1} was noted in TJ-83 x TD-I (4.90, 4.20) followed by TJ-83 x Kiran-95 (4.50 x 3.00), Sarsabz and TD-I (4.40, 4.20), TD-1 x NIA-Sarang (3.80, 2.00), TJ-83 x Sarsabz (3.70, 3.20) and TD-1 x Kiran-95 (2.50, 0.30) under normal watering (T_0). Underwater stress from tillering to maturity (T_1), F_1 wheat hybrid TJ-83 x Kiran-95 (2.05, 1.00) was noted as a great tillering hybrid followed by Sarsabz x NIA-Sarang (1.80, 0.50), NIA-Sarang x Kiran-95 (1.2, 1.2), TJ-83 x NIA-Sarang (1.1, 0.4), TD-1 x NIA-Sarang (0.85, 0.20) and Sarsabz x Kiran-95 (0.35, 0.30) over their MP and BP. The results revealed that the maximum tillers plant^{-1} showed by F_1 hybrid TD-1 x Kiran-95 (2.30, 2.20) followed by TD-1 x NIA-Sarang (2.00, 2.00), TJ-83 x NIA-Sarang (1.85, 0.40), Sarsabz x NIA-Sarang (1.45, 1.40) and Sarsabz x Kiran (1.20, 0.80) under (T_2). Destro *et al.* **[27]** revealed that tiller grain yield contributed little to the total wheat yield under water stress conditions.

Harvest index

The **(**Table 5) revealed that harvest index under normal watering (T_0) was noted increased inF_1wheat hybrids over MP as well as BP.Greatly increased harvest index was noted in TJ-83 x Sarsabz (9.50, 8.00) as compared to TD-I x NIA-Sarang (8.00, 7.00), Sarsabz x TD-I (7.00, 5.00), TJ-83 x TD-I and NIA-Sarang x Kiran-95 (6.50, 6.00), Sarsabz x NIA-Sarang (6.00, 5.00), TJ-83 x Kiran-95 (4.00, 4.00), TJ-83 x NIA-Sarang and TD-I x Kiran-95 (2.50, 2.00) over MP as well as BP. The F_1 wheat hybrids evidently increased MP as well as BP under (T_1) for harvest index. TD-I x NIA-Sarang (0.13, 0.13), showed great increase in harvest index, followed by TD-1 x Kiran-95 (0.13, 0.12), TJ-83 x NIA-Sarang (0.12, 0.11) and Sarsabzx Kiran-95 (0.12, 0.08). The greatest harvest index was noted in TJ-83 x TD-I (0.13, 0.11) as compared to TJ-83 x NIA-Sarang (0.11, 0.10) and Sarsabz x Kiran-95 (0.10, 0.07) respectively over their MP as well as BP. Erice *et al.* **[28]** revealed that the under optimal water availability conditions only the wheat plants with higher harvest index correlated to enhanced CO2 which may resulting enhanced plant growth under water stress conditions.

Table 4. Heterosis of F_1 wheat hybrids on grain filling period and tillers plant^{-1} under water treatments

Genotypes	Grain filling period						Tillers plant^{-1}					
	T_0 (Control) I/D %		T_1 I/D %		T_2 I/D %		T_0 I/D %		T_1 I/D %		T_2 I/D %	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
V1	-4.45	-5.1	0.3	0.2	-10.55	-10.7	3.7	3.2	-0.2	-1.2	0.7	-0.6
V2	-6.5	-8.4	-2.75	-4.2	-7.75	-8.2	4.9	4.2	-0.05	-0.1	-0.65	-0.8
V3	-6.65	-7.8	-6.75	-9.0	-11.15	-11.3	0.3	-0.8	1.1	0.4	1.85	0.4
V4	-11.7	-13	-1.0	-1.8	-17.45	-25.6	4.5	3.0	2.05	1.0	-0.85	-1.8
V5	0.45	-0.8	-8.75	-10.3	-1.3	-1.6	4.4	4.2	-0.65	-1.6	0.25	-1.2
V6	-0.8	-2.6	-9.45	-11.8	-3.1	-3.4	-0.5	-2.1	1.8	0.5	1.45	1.4
V7	8.6	7.9	-3.8	-4.5	-3.0	-11.0	0.1	-1.9	0.35	0.3	1.2	0.8
V8	-4.15	-7.2	-8.75	-10.3	-5.9	-6.5	3.8	2.0	0.85	0.2	2.0	2.0
V9	-10.9	-11.4	-3.65	-5.9	-8.7	-16.4	2.5	0.3	-0.6	-1.6	2.3	2.0
V10	-7.9	-10.4	9.15	6.9	-12.9	-21.2	-3.2	-3.6	1.2	1.2	-3.2	-3.2

Biological yield plant^{-1}

The data in (Table 5) revealed that the four wheat hybrids were significantly increased over MP as well as BP for biological yield plant^{-1} under (T_0). The maximum increased biological yield was noted in F_1 wheat hybrid TJ-83 x Sarsabz (31.20, 27.06) followed by TD-I x Kiran-95 (27.80, 22.40), Sarsabz x Kiran-95 (19.70, 16.90), and TJ-83 x TD-I (13.70, 12.70) to their mid and better parent respectively. The wheat hybrid including TD-I x NIA-Sarang (9.60, 1.50) and Sarsabz x Kiran-95 (4.60, 2.30) showed increased biological yield over MP and BP under (T_1). Furthermore, five wheat hybrids over performed to both MP and BP for biological yield under (T_2). The greatest biological yield was noted in NIA-Sarang x Kiran-95 (29.05, 11.80) as compared to Sarsabz x NIA-Sarang (28.15, 23.00), TD-I x Kiran-95 (17.05, 7.60), Sarsabz x TD-I (13.35, 10.70), and TD-I x NIA-Sarang (9.80, 2.00) over MP and BP. F_1 wheat hybridTJ-83 x NIA-Sarang (3.90, -12.10) and Sarsabz x Kiran-95 (2.80, -9.30) were showed great biological yield over MP only under the same water stress. The rest of the F1 wheat hybrids were noted as decreased biological yield against their MP as well as BP under (T_2). Johari-Pireivatlou [29] stated that seed and straw yield significantly reduced about 25% under water stress conditions.

Relative water content

Relative water content is an important physiological character to determine drought tolerance in wheat genotypes. The data in (Table 6), revealed that except TJ-83 x TD-I, rest of the hybrids showeds an increase to their MP and BPs for leaf relative water content under (T_0). The greater water content was noted in F_1 wheat hybrid Sarsabz x NIA-Sarang (10.55, 10.00), followed by Sarsabz x Kiran-95 (8.00, 7.00),TJ-83 x Sarsabz (7.95, 6.60), TD-I x Kiran-95 (7.50, 6.00), Sarsabz x TD-1 (6.5, 6.00), NIA-Sarang x Kiran-95 (6.45, 5.00), TJ-83 x NIA-Sarang (2.40, 0.50) and TD-I x NIA-Sarang (2.35, 1.30) which surpassed over MP and BP under normal watering (To). The maximum leaf relative water content was noted in Sarsabz x NIA-Sarang (10.25, 10.20) followed by TJ-83 x NIA-Sarang (10.20, 9.30), NIA-Sarang x Kiran-95 (9.15, 6.10), TD-I x Kiran-95 (8.50, 7.80), TJ-83 x Kiran-95 (8.25, 6.40), Sarsabz x Kiran-95 (6.60, 3.80), Sarsabz x TD-I (5.30, 3.20), TJ-83 x TD-I (5.05, 3.90), TD-I x NIA-Sarang (4.25, 2.20) and TJ-83 x Sarsabz (2.25, 1.30) over MP and BP respectively. Meanwhile, all the F_1wheat hybrids showed increased leaf relative water content over their mid as well as a better parent under water stress from anthesis to mature (T_2). The maximum leaf relative water content showed by hybrid TD-I x NIA-Sarang (8.90, 6.20), followed by TJ-83 x Kiran-95 (8.85, 8.00), Sarsabz x NIA-Sarang (8.15, 7.40), TJ-83 x Sarsabz (7.40, 6.70), Sarsabz x TD-1 (7.25, 5.30), TJ-83 x NIA-Sarang (4.55, 3.10), TJ-83 x TD-1 (3.55, 2.30) and TD-1 x Kiran-95 (1.60, 1.20) respectively. Wheat hybrid NIA-Sarang x Kiran-95 (2.00, -0.30) and Sarsabz x Kiran-95 (0.85, -0.70) were noted as increased over their mid parent and decreased relative water content over their BP under water stress from anthesis to maturwate (T_2), respectively. Akram [30] found that the water scarcity caused lessening in leaf relative water concentrations.

Table 5. Heterotic performance of F_1 wheat hybrids on harvest index and biological yield plant^{-1}under water treatments

Genotypes	Harvest index						Biological yield plant^{-1}					
	T_0 (Control) I/D %		T_1 I/D %		T_2 I/D %		T_0 I/D %		T_1 I/D %		T_2 I/D %	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
V1	9.5	8.0	0.095	0.08	0.085	0.08	31.2	27.6	-15.4	-17.8	-3.95	-14.8
V2	6.5	6.0	0.06	0.05	0.13	0.11	13.7	12.7	7.8	-1.5	-28.7	-36.9
V3	2.5	2.0	0.12	0.11	0.11	0.1	-30.05	-47.5	-13.4	-14.6	3.9	-12.1
V4	4.0	4.0	0.04	0.02	0.07	0.05	-4.0	-10.4	-7.7	-11.4	-4.05	-5.3
V5	7.0	5.0	0.095	0.07	0.055	0.03	-8.1	-10.7	-5.2	-12.1	13.35	10.7
V6	6.0	5.0	0.105	0.08	0.075	0.06	1.25	-12.6	0.5	-6.4	28.15	23
V7	6.5	5.0	0.115	0.08	0.095	0.07	19.7	16.9	4.6	2.3	2.8	-9.3
V8	8.0	7.0	0.13	0.13	0.07	0.06	-9.35	-25.8	9.6	1.5	9.8	2.0
V9	2.5	2.0	0.13	0.12	0.03	0.03	27.8	22.4	0.0	-5.6	17.05	7.6
V10	6.5	6.0	0.05	0.04	0.05	0.04	5.35	-5.7	1.7	-0.8	29.05	11.8

Leaf proline content

The results in (Table 6) revealed that in normal watering (T_0), wheat hybrid TJ-83 x TD-I showed high proline concentration (0.40, 0.30) over MP and BP as compared with TJ-83 x NIA-Sarang (0.35, 0.20) and TJ-83 x Kiran-95 (0.25, 0.00), respectively. Increased proline content over the MP was attained by F_1hybrid Sarsabz x Kiran-95 (0.15, -0.20) only. However, the rest of the wheat hybrids showed a decrease in leaf proline against MP and BP under the same watering (T_0). Great proline content was noted in Sarsabz x Kiran-95 (0.80, 0.70) as compared to Sarsabz x NIA-Sarang (0.70, 0.40), Sarsabz x TD-I (0.60, 0.20), NIA-Sarang x Kiran-95 (0.50, 0.30), TJ-83 x Kiran-95 (0.45, 0.20), TD-I x Kiran-95 (0.40, 0.10), TJ-83 x TD-I (0.35, 0.20), TJ-83 x Sarsabz (0.35, 0.00) and TD-1 x NIA-Sarang (0.30, 0.20) respectively against MP and BP under water stress from tillering to maturity (T_1). Only a single wheat hybrid TJ-83 x NIA-Sarang showed decreased proline content (-0.35, -0.40) under the same water stress. It was observed that the F_1 wheat hybrids revealed increased proline content over their MP and BP (T_2). The greater proline content was observed in wheat hybrid TJ-83 x TD-I (0.85, 0.80) against TJ-83 x NIA-Sarang (0.80, 0.60), Sarsabz x TD-I andSarsabz x NIA-Sarang (0.70, 0.50), TJ-83 x Sarsabz (0.45, 0.20), TD-I x Kiran-95 (0.40, 0.40), TD-I x NIA-Sarang (0.25,0.10), Sarsabz x Kiran-95 (0.20, 0.10) and NIA-Sarang x Kiran-95 (0.05, 0.00) respectively over both MP as well as BP under (T_2). Johari-Pireivatlou [29] found an increase of proline content in four wheat lines under water stress conditions.

Table 6. Heterosis of F_1 wheat hybrids for relative water content and leaf proline content under water treatments

Genotype	Relative water content						Leaf proline content					
	T_0 (Control) I/D %		T_1 I/D %		T_2 I/D %		T_0 I/D %		T_1 I/D %		T_2 I/D %	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	M P	BP
V1	7.95	6.6	2.25	1.3	7.4	6.7	-0.5	-0.6	0.35	0.0	0.45	0.20
V2	-0.75	-1.6	5.05	3.9	3.55	2.3	0.4	0.3	0.25	0.2	0.85	0.80
V3	2.4	0.5	.10.2	9.3	4.55	3.1	0.35	0.2	-0.35	-0.4	0.80	0.60
V4	5.65	3.3	8.25	6.4	8.85	8.0	0.25	0.0	0.45	0.2	0.55	0.40
V5	6.5	6.0	5.3	3.2	7.25	5.3	-0.1	-0.3	0.6	0.2	0.70	0.50
V6	10.55	10.0	10.25	10.2	8.15	7.4	-0.25	-0.5	0.7	0.4	0.70	0.50
V7	8.0	7.0	6.6	3.8	0.85	-0.7	0.15	-0.2	0.8	0.7	0.20	0.10
V8	2.35	1.3	4.25	2.2	8.9	6.2	0.05	0.0	0.3	0.2	0.25	0.10
V9	7.5	6.0	8.5	7.8	1.6	1.2	-0.15	-0.3	0.4	0.1	0.40	0.40
V10	6.45	5.0	9.15	6.1	2.0	-0.3	-0.2	-0.3	0.5	0.3	0.05	0.0

Days to 50 % flowering

The (Table 7) showed that for days to 50% flowering, F_1wheat hybrid TD-1 x NIA-Sarang attained minimum days to 50% flowering under normal watering as compared to TJ-83 x Kiran-95 (-1.95, -4.30), Sarsabz x Kiran-95 (-1.05, -5.2) and NIA-Sarang x Kiran-95 (-0.65, -4.2) over their MP and BPs under (T_0). The F_1 wheat hybrid NIA-Sarang x Kiran-95 (-3.75, -6.00), followed by TJ-83 x Sarsabz (-2.85, -4.50), Sarsabz x Kiran-95 (-1.60, -2.60) which showed early flowering against their MP and BP under Extreme water stress (T_1). F_1 wheat hybrid TJ-83 x Kiran-95 (-3.70, -5.20), TJ-83 x Sarsabz (-2.5 x -5.5) and Sarsabz x Kiran-95 (-2.50, -4.00) showed early 50% flowering followed by their MP and BP under (T_2).

Days to 90% maturity

According to result in (Table 7), F_1 wheat hybrid TJ-83 x Kiran-95 (-13.60, -14.60) was noted as earliest maturing as compared to other F1 wheat hybrids against their mid and better parent under normal watering (T_0) followed by NIA-Sarang x Kiran-95 (-8.55, -9.60), TD-1 x NIA-Sarang (-6.35 -7.30), TD-1 x Kiran-95 (-4.5, -6.5), TJ-83 x TD-1 (-3.60, -2.60) and TJ-83 x Sarsabz (-0.20, -2.60) which revealed reduced days to 90% maturity against their MP and BPs under (T_0). The maximum decreased days to 90 % maturity was noted in Sarsabz x TD-1 (-8.10,-9.10), Sarsabz x Kiran-95 (-5.40, -7.10), Sarsabz x NIA-Sarang (-4.40, -5.30), TJ-83 xSarsabz (-2.55, -4.10), TD-1 x NIA-Sarang (-1.20, -1.30) and TJ-83 x TD-1 (-0.85,-1.40) respectively under normal watering (T_1). The genotypes TJ-83 x Kiran-95 (-21.00, -27.60) was earliest maturing wheat hybrid followed by TJ-83 x Sarsabz (-12.95, -15.80), TJ-83 x NIA-Sarang (-9.50, -13.20), TJ-83 x TD-I (-5.75, -7.30) Sarsabz x Kiran-95 (-5.45, -14.90),TD-I x Kiran-95 (-5.05, -13.20), TD-I x NIA-Sarang (-3.15 x -5.30), Sarsabz x NIA-Sarang (-0.65, -1.50) for days to 90% maturity against their MP as well as BP under parent under water stress from anthesis to maturity (T_2). Panhwar *et al.* [31] also noted remarkable variations in days to 50 % flowering and days to 90% maturity among four wheat genotypes.

Table 7. Heterosis of F_1 wheat hybrids for days to 50% flowering and days to 90% maturity under water treatments

Genotypes	Days to 50% flowering						Days to 90% maturity					
	T_0 (Control) I/D %		T_1 I/D %		T_2 I/D %		T_0 I/D %		T_1 I/D %		T_2 I/D %	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
V1	4.3	2.5	-2.85	-4.5	-2.5	-5.5	-0.2	-2.6	-2.55	-4.1	-12.95	-15.8
V2	3.75	2.8	1.90	1.0	1.95	0.0	-2.6	-3.6	-0.85	-1.4	-5.75	-7.3
V3	8.2	7.0	7.0	5.4	1.65	-1.9	1.45	1.4	0.35	-0.3	-9.5	-13.2
V4	-1.95	-4.3	1.45	0.8	-3.7	-5.2	-13.6	-14.6	0.45	0.3	-21	-27.6
V5	2.35	-0.4	0.65	-1.9	5.95	4.9	2.8	1.4	-8.1	-9.1	4.7	3.4
V6	7.5	6.9	5.05	1.8	2.45	1.9	6.65	4.3	-4.4	-5.3	-0.65	-1.5
V7	-1.05	-5.2	-1.6	-2.6	-2.5	-4.0	7.5	4.1	-5.4	-7.1	-5.45	-14.9
V8	-2.25	-4.4	9.9	9.2	2.7	1.1	-6.35	-7.3	-1.2	-1.3	-3.15	-5.3
V9	6.3	4.9	6.45	4.9	3.45	3.0	-4.5	-6.5	2.8	2.1	-5.05	-13.2
V10	-0.65	-4.2	-3.75	-6.0	3.95	1.9	-8.55	-9.6	4.6	3.8	-11.05	-19.2

Grain yield plant^{-1}

Grain yield can be considered an important trait that may possibly be contributed by many morphological traits. Therefore, grain yield is a polygenic character. According to (Table 8), F_1 wheat hybrids showed increased grain yield over MP and BP. Hybrid NIA-Sarang x Kiran-95 (15.40, 15-00) showed increased grain yield plant^{-1} against MP and BP followed by Sarsabz x Kiran-95 (16.30, 12.20), TJ-83 x TD-I (15.15, 13.80), Sarsabz x TD-I (13.15, 9.70), TD-I x NIA-Sarang (12.85, 11.80), Sarsabz x TD-1 (13.15, 9.70), Sarsabz x NIA-Sarang (12.70, 8.20) and TD-1 x Kiran-95 (10.65, 10.00) respectively under normal watering (T_0). Meles *et al.* [7] found increased heterosis over both the parents for grain yield. Wheat hybrids surpassed grain yield over MP and BP under extreme water stress (T_1). Hybrid TD-I x NIA-Sarang (14.90, 13.80) showed great increased grain yield as compared to TD-I x Kiran-95 (12.90, 11.50), Sarsabz x Kiran-95 (13.35, 9.20), TJ-83 x NIA-Sarang (10.30, 8.90), Sarsabz x NIA-Sarang (9.85, 7.00), Sarsabz x TD-1 (8.95, 7.20), TJ-83 x TD-I (8.10, 7.80), TJ-83 x Sarsabz (8.05, 6.60). Underwater stress from anthesis to maturity (T_2), NIA-Sarang x Kiran-95 (35.30, 9.10), Sarsabz x Kiran-95 (11.55, 7.60), TJ-83 x NIA-Sarang (9.75, 7.00), and TJ-83 x Sarsabz (8.90, 8.00) showed increased grain yield over MP and BP. Çifci [32] observed that the heterosis for grain yield and positive correlations with grain yield by agronomical traits.

1000 grain weight

The data in (Table 8) highlighted that all wheat hybrids found an increased 1000 grain weight over their mid and better parent. While, the maximum increase of 1000 grain weight was noted in TJ-83 x Sarsabz (26.35, 24.90) as compared to NIA-Sarang x Kiran-95 (15.95, 14.30), TJ-83 x Kiran-95 (13.35, 12.50), TJ-83 x TD-I (12.10, 11.90), TJ-83 x NIA-Sarang (10.90, 10.10) and TD-I x NIA-Sarang (10.60, 9.60) respectively over MP and BP, under normal watering (T_0). As a result, all F_1 wheat hybrids showed increased 1000grain weight against their MP as well as BP under (T_1). However, the greatest increase of 1000 grain weight was noted in Sarsabz x TD-I (3.55, 2.30) followed by NIA-Sarnag x Kiran-95 (3.40, 2.80), TD-I x NIA-Sarang (2.25, 1.30), TJ-83 x Kiran-95 (1.55, 0.50), Sarsabz x NIA-Sarang (0.60, 0.30) and TD-I x Kiran-95 (0.45, 0.10) over MP as well as BP respectively under (T_2). Wheat hybrid T-83 x Sarsabz (4.35, -1.00), TJ-83 x TD-1 (0.40, -0.30) and TJ-83 x NIA-Sarang (0.15, -1.5) showed as increased 1000 grain weight over their MP only under same water stress. Johari-Pireivatlou [29] observed that the maximum high seed yield, straw yield, harvest index, and 1000 kernel weight were observed under control conditions (Non-stress).

Table 8. Heterosis of F_1 wheat hybrids on grain yield plant^{-1} and 1000 grain weight under water treatments

Genotypes	Grain yield plant^{-1}						1000 grain weight					
	T_0 (Control) I/D %		T_1 I/D %		T_2 I/D %		T_0 I/D %		T_1 I/D %		T_2 I/D %	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
V1	6.8	4.7	8.05	6.6	8.9	8.0	26.35	24.9	4.35	-1	10	8.5
V2	15.15	13.8	8.1	7.8	8.0	6.7	12.1	11.9	0.4	-0.3	10.25	10.2
V3	-0.9	-3.3	10.3	8.9	9.75	7.0	10.9	10.1	0.15	-1.5	5.15	3.8
V4	4.2	2.2	3.6	1.9	8.95	5.9	13.35	12.5	1.55	0.5	10.95	10.0
V5	13.15	9.7	8.95	7.2	8.3	6.1	4.75	3.1	3.55	2.3	10.55	9.1
V6	12.7	8.2	9.85	7	9.15	5.5	8.35	7.7	0.6	0.3	8.05	5.2
V7	16.3	12.2	12.35	9.2	11.55	7.6	8.1	5.8	2.7	1.8	9.55	7.1
V8	12.85	11.8	14.9	13.8	5.95	4.5	10.6	9.6	2.25	1.3	6.6	5.2
V9	10.65	10.0	12.9	11.5	7.75	6	9.45	8.8	0.45	0.1	13	12.0
V10	15.4	15	5.7	5.4	35.3	9.1	15.95	14.3	3.4	2.8	11.9	11.5

Pearson correlation coefficient

Correlation studies are a useful tool for plant breeders to understand the relationship between yield and its related components. Correlation helps for the improvement of drought tolerant cultivars in the sense that physiological parameters might be used as indirect choice criteria to enhance grain yield under water stress environment. Results in (Table 9) indicated that highly positive significant association with grain yield was observed in biological yield plant^{-1} (0.745), days to 90% maturity (0.727), grain yield main spike^{-1} (0.590), harvest index (0.747), main spike length (0.714), plant height (0.705) and tillers plant^{-1} (0.584). While chlorophyll content (0.228), grains spike^{-1}(0.202), nodes tiller^{-1} (0.288), spikelet spike^{-1} (0.400) were medium positively correlated with grain yield plant^{-1}. Highly negative correlations (-0.669) were noted between grain yield and days to 50% flowering, a medium negative correlation was noted between grain yield and 1000grain weight (-0.366). A low positive correlation (0.011) was noted between grain yield and proline content. A low negative correlation coefficient (-0.071) was noticed in between flag leaf area and grain yield plant^{1}. Zerga *et al.* [33] observed the positive association among growth and yield related traits in bread wheat. Also, Meles *et al.* [7] reported such positive correlations of grain yield with other agronomical traits.

Table 9. Pearson correlation coefficient among some morpho-physiological traits of wheat genotypes

Traits	BY	CL	Ds50%	Ds90%	FLA	GYP	GYS	GPS	HI	MPL	NPT	PH	PC	RWC	1000G	SPS	TPP
BY	1																
CL	-0.024	1															
Ds50%	-0.393	-0.464	1														
Ds90%	0.624	0.305	-0.685	1													
FLA	0.152	-0.294	0.134	-0.070	1												
GYP	0.745	0.228	-0.669	0.727	-0.070	1											
GYS	0.522	0.016	-0.305	0.555	0.038	0.590	1										
GPS	0.116	-0.073	0.012	0.131	0.045	0.202	0.425	1									
HI	0.667	0.184	-0.457	0.748	0.116	0.747	0.658	0.089	1								
MPL	0.504	0.375	-0.786	0.722	-0.002	0.714	0.462	0.300	0.610	1							
NPT	0.424	-0.165	0.104	0.224	-0.132	0.288	0.261	0.131	0.349	0.054	1						
PH	0.658	0.028	-0.473	0.685	-0.074	0.705	0.610	0.324	0.711	0.652	0.400	1					
PC	-0.219	0.330	-0.502	0.026	-0.260	0.011	-0.343	-0.143	0.102	0.010	-0.051	-0.028	1				
RWC	-0.169	-0.234	-0.403	-0.116	0.344	-0.341	-0.111	-0.356	0.028	0.693	0.251	-0.623	-0.752	1			
1000G	0.093	0.759	0.494	-0.144	0.246	-0.366	0.118	-0.249	0.026	-0.084	0.089	0.300	0.611	0.132	1		
SPS	0.349	0.054	0.324	0.072	0.652	0.400	0.007	-0.46	0.234	-0.387	-0.202	-0.083	-0.179	-0.020	-0.171	1	
TPP	-0.092	0.190	0.040	-0.205	-0.331	0.584	-0.207	-0.157	0.045	0.185	0.713	0.739	0.192	0.698	0.016	-0.014	1

BY= Biological yield, CL=chlorophyll content, Ds50%= Days to 50% flowering, Ds90%= Days to 90% maturity, FLA=Flag leaf area, GYP= Grain yield per plant, GYS= Grain yield per main spike, GMnS=Grains/main spike HI=Harvest index, MSL= Main spike length, NPT= Nods/main tiller, PH= plant height, PC=Prolin content, RWC= Relative water content, 1000G= 1000 grain weight, SPS= Spikelet/spike, and TPP=Tillers per plant

Conclusion
It is concluded that the results of the present research work had confirmed that the importance of heterosis and association of characters are as efficient criteria for the evaluation of wheat genotypes. F_1 wheat hybrids showed large genetic variation under water treatments, indicating increased heterosis. It is suggested that F_1 wheat hybrid NIA-Sarang x Kiran-95, TD-1 x NIA-Sarang and Sarsabz x Kiran-5 were observed superior with high heterosis for water stress tolerance and grain yield, therefore could be considered for breeding water stress tolerant genotypes. Farmers need to grow wheat genotypes with high grain yield and straw yield. Therefore wheat hybrids TJ-83 x Sarsabz, Sarsabz x Kiran-95, TD-1 xNIA-Sarang, NIA-Sarang x Kiran-95, and Sarsabz x NIA-Sarang showed greater performance in biological yield and production under water stress conditions.

Authors' contributions
Conceived and designed the experiments: NA Panhwar, GM Baloch & ZA Soomro, Performed the experiments: NA Panhwar & MA Sial, Analyzed the data: NA Panhwar, GM Baloch & ZA Soomro, Contributed materials/ analysis/ tools: NA Panhwar, SA Panhwar & A Afzal, Wrote the paper: NA Panhwar & AH Lahori.

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