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QUANTITATIVE, HETEROSIS AND COMBINING ABILITY ANALYSIS OF MORPHOLOGICAL TRAITS OF WHEAT (*TRITICUM AESTIVUM* L) UNDER WATER STRESS CONDITIONS

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ABSTRACT

Wheat genotypes were evaluated -under water stress conditions to find out drought resistant line in split plot design where stress treatments were main plots and genotypes were subplots. Five genotypes were used to develop ten F_1 hybrids using half diallele mating design. Mean squares of genetic parameters viz. General Combining Ability (GCA), Specific Combining Ability (SCA) and their effects, heterosis and heterobeltiosis showed highly significant differnces (>0.01%) for most of the traits. NIA-sarang, TD-1 and Sarsbz showed highly significant GCA under non-stress and water stress for grain yield main spike^{-1}, seed index plant^{-1} and grain yield plant^{-1}. Highly significant SCA for NIA-sarang x Kiran-95, TD-1 x NIA-sarang, Sarsabz x Kiran-95 and Sarsabz x NIA-sarang for grain yield main spike^{-1} under non-stress. Under both water stress, hybrid TJ-83 x Kiran-95, TD-1 x Kiran-95, Sarsabz x NIA-sarang and NIA-sarang x Kiran-95, TJ-83 x TD-1, TJ-83 x Sarsabz and NIA-sarang x Kiran-95 showed highly significant SCA for grain yield main spike^{-1}. Great seed index plant^{-1} gave TJ-83 x TD-1 and TJ-83 x Kiran-95 under non-stress. Hybrid TJ-83 x Sarsabz, NIA-sarang x Kiran-95, TD-1 x Kiran-95 and TJ-83 x Sarsabz showed highly significant SCAs for seed index plant^{-1} under water stress. For grain yield plant^{-1}, hybrid TJ-83 x TD-1, NIA-sarang x Kiran-95, Sarsabz x Kiran-95showed great SCAs under non-stress and under water stress. Heterobeltiosis under non-stress noted in NIA-sarang x Kiran-95, TD-1 x NIA-sarang, Sarsabz x Kiran-95, Sarsabz x NIA-sarang and Sarsabz x TD-1, under water stress, TJ-83 x Kiran-95, TD-1 x Kiran-95, Sarsabz x NIA-sarang, Hybrid TJ-83 x Sarsabz, TJ-83 x TD-1, Sarsabz x NIA-sarang, Sarsabz x TD-1 and NIA-sarang x Kiran-95 showed heterobeltiosis for grain yield main spike^{-1} and recommended to include future breeding schemes.

Key words: Hybrid, Heterosis, Heterobeltiosis, GCA, SCA, *Triticum aestivum*

INTRODUCTION

Wheat is 2nd staple cereal food grain of World, and its production was 784.91million metric tons in 2023-24. Pakistan is 8th World producer of wheat (Statista 1990-91 to 2023-24). Wheat is great yielder, wide adaptable staple cereal grain food of a large population of the World. Wheat has contributed 20% of total intake food caloric value of living being. Wheat is main source of protein, vitamins, and minerals and is essential in order to maintain health. Wheat yield has been facing severe challenges due to numerous biotic and abiotic stress. Water stress is a big problem limiting wheat production. Combining ability and heterosis are crucial Plant Breeding efforts. Genetic variation is fundamental for effective yield improvement effort. Genotypic ability to pass desired trait to offspring is reffered as combining ability. Pakistan is facing serious food shortage; therefore, it is emmense responsibility of agri-biologists to undertake multi-disciplinary rsearch and overcome poverty and food shortage by sustainable wheat production under climate change. Drought extremely influences wheat germination, growth and developmental stage and crop yield, especially in arid and semi-arid regions of the World (Khan et al. 2021 and Vambol et al. 2023). Wheat yield has been affected by various calamaties; water stress is one of destruction factor (Panhwar et al. 2022). Raised water table, inadequate drain, climate change etc has lowered wheat production (Munns and Gillhen, 2015). Grain yield contributing traits, controlled by polygenes, affected by environment (Panhwar et al., 2021 and 2024), (Ahmed et al. 2007). Grain yield is average genetic effect of additive genes (Panhwar et al. 2022). The genotypic and phenotypic variation in wheat attributed a genetic cause. It is a predictable task to crop breeding and genetics. Combining ability analysis is one of the most effectively used to evaluate crosses. General combining ability is a measure of additive gene action to average performance of genotype in series of hybrid combination, where as SCA is specific cross. GCA is effect of additive genes. SCA is effect of the genes with dominance and epistatic effects (non-additive effects). Breeder faces challenges of selecting parents and crosses both for quantitative and qualitative traits in crop development initiatives. Plant Breeders utilize combining ability to analyze nature of gene action and parental cultivars for usefulness in crosses. Additive portion of total variance includes variance of GCA. Performance of F_1 over mid paraent is relative heterosis and over superior parent is heterobeltiosis that may be allelic or non-allelic interaction under specific environmental factors and are important parameter to develop superior genotypes. The expression of heterosis of hybrid is specific combining ability of parental genes in a cross. Heterosis is effective to study predominant gene effects and additive gene effects. It is effective biometrical methodology to evaluate and select wheat genotypes for high grain yield. Panhwar et al. (2021), Panhwar et al. (2024) and Farzanipour et al. (2013), examined genetic modification for morphological performance under water scarcity tolerance. Yang et al. (2022) studied combining ability parameters and heterosis of wheat genotypes for high grain yield under water stress conditions. Keeping in view of food shortage and poverty elluviation, this research undertaken to evaluate wheat cultivars and hybrids under water stress, to screen out best water stress tolerant wheat cultivar and hybrids, best general combiner, specific combiner, heterosis and heterobeltiosis *in-situ* for morphological traits, which could be utilized in future breeding programmes.

MATERIALS AND METHODS

Split plot design was used used with two factors viz. Treatments as normal water condition (T_0), extreme water stress from tillering to maturity (T_1) and moderate water stress from anthesis to maturity (T_2) were main plots and genotypes were subplots; consisted of five wheat cultivars viz. TJ-83, Sarsbz, TD-1, NIA-sarang and Kiran-95 and their ten F_1 wheat hybrids ; TJ-83 x Sarsbz, TJ-83 x TD-1, TJ-83 x NIA-sarang, TJ-83 x Kiran-95, Sarsbz x TD-1, Sarsbz x NIA-sarang, Sarsbz x Kiran-95, TD-1 x NIA-sarang, TD-1 x Kiran-95 and NIA-sarang x Kiran -95. Crosses were made using Half-diallele mating design according to Griffing's Method-2, Model-1, a numerical approach n (n-1)/n.

Sowing*:* The sowung was done at the experimental field of Plant Breeding and Genetics Division, Nuclear Institute of Agriculture Tandojam, Pakistan during wheat growing season 2010. For this, F_1 wheat hybrids and their parent were sown using dibbler. On maturity, middle rows from each parent and hybrd were used for data collection. The recommended doses of nitrogen (N) in form of Urea applied as 120kg ha^{-1} and Phosphorous (P) in form of DAP (75kg P_2O_5 ha^{-1}) were mixed in the soil before sowing. All common and necessary cultural and management practices were uniformly applied. Four rows of 2.5m length with 15cm and 30cm distance between plants and rows were maintained for investigation.

Traits studied: Following morphological and yield traits were studeied (Table-1).

Table 1. Morphological parameters measured from parents and their hybrids

Character name	Code	Discription of observations
Plant height (cm)	PH	Plant height noted from soil surface to tip of spike at maturity
Number of tillers $plant^{-1}$	NTPP	Number of tillers of randomly selected plant noted at maturity
Main spike length	MSL	Main spike length noted in centimeters of mature random plants
Number of spikelets/ main spike	NSPMS	Number of spikelets/main spike noted in mature randomly selected plants
Number of grains/main spike	NGPMS	Number of grains/main spike noted in mature randomly selected plants
Grain yield/main spike	GYPMS	Grain yield/main spike (weight of total grains of main spike of selected plant
Seed index $plant^{-1}$	SIPP	1000 grain weight in grams taken on top loading balance
Grain yield $plant^{-1}$	GYPP	Grain yield/plant obtained by weighing all grains of randomly selected plant

Replications and Treatments: Three treatments were applied in this research; control (T_0) normal watering maintained, water stress from tillering to maturity (T_1) and water stress from anthesis to maturity (T_2). Three replications were used in the experiment.

Soil Chemical and physical analysis: Before sowing, soil tested by drawing soil samples randomly, from 0 – 6cm depth, 0 – 15cm depth. Soil texture analyzed by Bouyoucos-Hydrometer method (Bouyoucos, 1962). Field capacity measured according to Veihmeyer and Hendrickson (Veihmeyer and Hendrickson, 1994). Soil organic matter was determined by Walkley-Black method (Jackson, 1969), Soil EC and pH measured in 1:5 H_2O (W/V) according to Kwon. (Kwon *et al* 2012). Total nitrogen (TN) detected by Kjeldahl protocol (USEPA Method 351.2). Phosphorous (P) and Potassium (K) determined by NaOH fusion procedure (Olsen SR & Sommer, LE 1982). Soil was sandy loam in texture, field capacity 13% by weight, organic matter 0.97%, EC 2.7mMolS^{-1}, pH 7.4, nitrogen 0.61g kg^{-1}, phosphorous 19.8ppm and potassium 140ppm measured at soil science laboratory, Nuclear Institute of Agriculture Tandojam Sindh Pakistan.

Heterosis: Heterosis negative (-) / positive (+) to mid parent (comparative heterosis) as well as better parent (heterobeltiosis) computed followed by Fehr (1987).

$$\text{Mid parent heterosis} = \frac{F_1 - MP}{MP} \times 100$$

$$\text{Better parent heterosis} = \frac{F_1 - BP}{BP} \times 100$$

Combining abilities: General combining ability and specific combining ability and their effects were analyzed according to Griffing's method-2, model-1, (Griffing, 1956). Statistical model was adopted as:

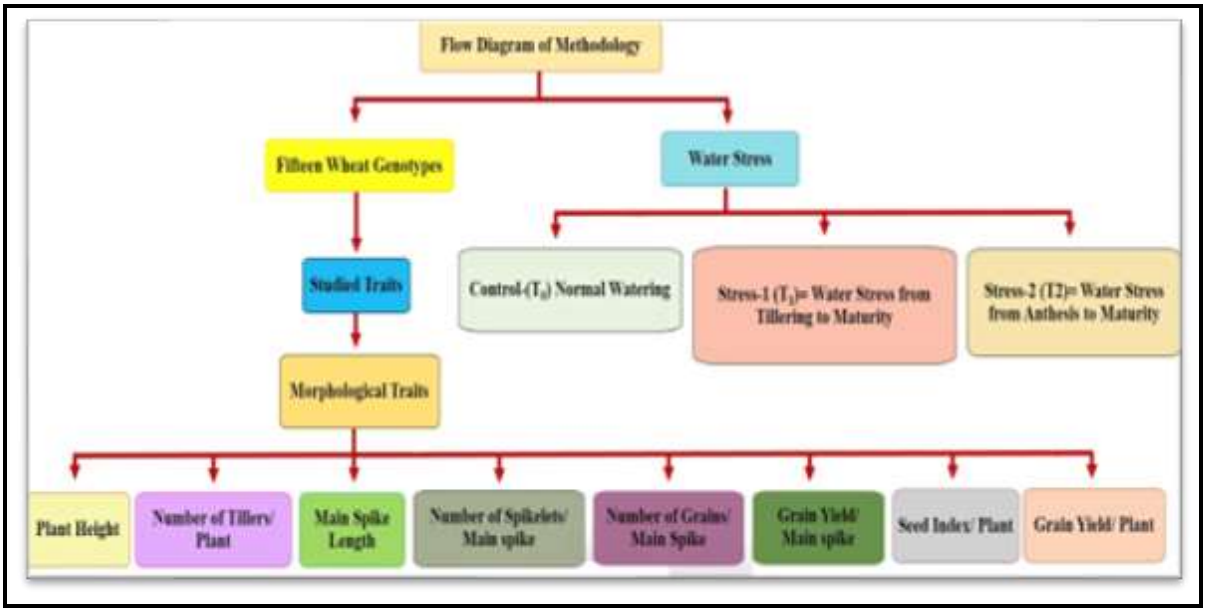
$Y_{ij} = u + g_i + s_{ij} + r_{ij}\ 1/bc\ \Sigma\Sigma e_{ijjk}I$.

Sums of squares of general combining ability and specific combining ability analyzed as:

SS due to general combining ability = $1/n+2\ [\Sigma(Y_i. + Y_{ii})^2 - 4/n\ Y^2..]$

SS due to SCA = $\Sigma\Sigma Y_{ij}^2 - 1/n + 2\ \Sigma\ (Y_i.\ Y_{ii})^2 + 2\ /\ (n + 1)(n +1)\ Y^2 ..$

SS due to error = $\frac{\text{SS Error}}{\mathbf{R}}$



RESULTS AND DISCUSSION

Analysis of variance, table 2, indicates highly significant differences (≥ 0.01) for most of traits except spike length. Treatments, genotypes and interactions were highly significant - which indicated dominant gene effects. Mojarrad *et al*. (2010) indicated quantitative gene action and dominant genetic effects influenced most of characters, Panhwar *et al*. (2024) noted highly significant difference (>0.01) for grain yield plant^{-1} and spike related traits. Short statured cultivar TD-1 (55.7cm), followed by TJ-83 (57.8cm), Sarsabz (60.5cm) and Kiran-95 noted under non-stress and both water stress conditions (Table 3, 4 and 5). Similarly, short-stemmed hybrid noted as TD-I x Kiran-95 (60.5) followed by TD-I x NIA-Sarang (62.7), TJ-83 x TD-I (63.9), TJ-83 x Kiran-95 (64.5), TJ-83 x NIA-sarang and Sarsabz x Kiran-95 (65.4). Similar results were reported by Vambol *et al*. (2023), Panhwar *et al*. (2021), Kerasa *et al*. (2008), Panhwar *et al*. (2022), Khan *et al*. (2003) and Panhwar *et al.* (2024). Result showed that TJ-83 (8.5) and TD-1 (8.4) had great number of tillers plant^{-1} followed by NIA-Sarang (7.1) and Sarsbz (6.5) and also in hybrid TJ-83 x Kiran-95 (9.5), followed by TJ-83 x NIA-Sarang (8.9), TD-I x NIA-Sarang (8.6), TJ-83 x TD-I (8.4) and Sarsabz x NIA-Sarang (7.6). Water stress significantly decreased morphological and physiological traits told Khan *et al*. (2003), Panhwar *et al*. (2021), Azimi *et al.* (2010), Panhwar *et al*, (2022) and Panhwar *et al*. (2024). According to Table 3,4 and5, large main spike was in TJ-83 (10.9) followed by TD-I (9.6) and Sarsabz (8.0. Similarly, large main spike was in hybrids was produced by hybrids TD-I x Kiran-95 (10.0) followed by Sarsabz x NIA-Sarang (9.5) and under normal and both water stress conditions. Panhwar *et al*, (2024) also noted drought effects on morphological traits. Yang *et al*. (2022) similar same drought effects on such traits. Higher number of spikelets main spike^{-1} were noted in Kiran-95 (11.6) followed by NIA-Sarang (10.4) and TD-I (9.5) (Table 3,4 and 5). Among hybrids, TJ-83 x Kiran-95 (12.2) followed by TD-I x NIA-Sarang (10.7) and TJ-83 x Sarsabz (10.3) produced maximum number of spikelets -spike^{-1} under both conditions. Farzanipour *et al*. (2013) and Panhwar *et al*. (2024) also reported great value of wheat spike traits under drought condition. The number of grains- spike^{-1} were higher in NIA-Sarang (25.5) followed by TD-I (22.2) and Sarsabz (21.6). Wheat hybrid NIA-Sarang x Kiran-95 (33.6) followed by TD-I x Kiran-95 (32.3), Sarsabz x NIA-Sarang (31.9) produced maximum number of grains-spike^{-1}. Panhwar *et al.* (2021); Khan *et al.* (2003); Kerasa *et al*. (2008); Panhwar *et al.* (2022) and Drikvand *et al*. (2005) also noted significant influence of water stress on wheat yield traits. Great grain yield main spike^{-1} was higher in TD-I (1.3) followed by Sarsabz (1.2) and NIA-Sarang (1.0) and in hybrids TD-I x Kiran-95 (1.6),TJ-83 x Kiran-95 (1.5) and Sarsabz x NIA-Sarang (1.4) both conditions (Table 3,4 and 5Higher seed index was noted in TJ-83 (13.6) followed by TD-I (12.2) and Kiran-95 (11.5) and among hybrids TJ-83 x Sarsabz (16.2) and Sarsabz x TD-1 (14.5) under both water stress and normal watering. The higher grain yield plant^{-1} was roduced by varieties Kiran-95 (13.2) and NIA-Sarang (12.6). Among the hybrids, maximum grain yield plant^{-1} was noted in hybrid TD-I x NIA-Sarang (26.4) and TD-I x Kiran-95 (24.7). Inamullah *et al.* (2006); Kerasa *et al.* (2008); Panhwar *et al.* (2021); Panhwar *et al.* (2022) and Panhwar *et al.* (2024) also noted similar effects of drought for most of yield and agronomical traits. NIA-Sarang (40.5) showed mazimum grain yield plant^{-1} followed by Kiran-95 (39.7) and TD-I (38.4). Among hybrid, NIA-Sarang x Kiran-95 (55.5), TD-I x NIA-Sarang (52.3) and TJ-83 x TD-I (52.2) remained top ranking for producing higher yield plant -1 under normal watering.

Table 2. Mean square of morphological traits of wheat

Characters	**Mean Squares**					
	Replication D.F=2	**Treatment D.F=2**	**Rep x Treat D.F=4**	**Genotype D.F=14**	**Treat x Genot: D.F=28**	**Error D.F=56**
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**	13.74**	1.88
Main Spike length	0.25	161.5**	0.16	12.93**	2.2*	0.19
Spikelets/M Spike	0.51	167.49**	2.29	4.86**	3.96**	0.55
Grains/main spike	110.18	23.84**	2.09	218.93**	193.89**	17.42
Grain yield/main spike	1.08	12.55**	0.91*	10.52**	20.46**	0.05
Seed index plant^{-1}	1.51	233.07**	3.1	63.43**	70.66**	1.83
Grain yield plant^{-1}	3.46	6102.69**	16.21	104.59**	122.63**	6.55

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

Table 3. Mean performance of wheat cultivars and hybrids under water stress from tillering to maturity

Traits / Genotypes	PH	Till/P	MSL	Spk/MS	Gr/MS	GY/MS	SI	GY/P
TJ-83	57.8	8.5	10.9	7.1	19.6	0.5	13.6	9.8
Sarsbz	60.5	6.5	8.0	8.6	21.6	1.2	9.7	6.9
TD-1	55.7	8.4	9.6	9.5	22.2	1.3	12.2	10.4
NIA-Sarang	65.7	7.1	7.4	10.4	25.5	1.0	10.3	12.6
Kiran-95	65.9	6.4	7.6	11.6	20.4	0.7	11.5	13.2
CV	**5.35**	**10.80**	**9.15**	**4.21**	**6.56**	**19.21**	**4.33**	**6.19**
TJ-83 x Sarsbz	68.3	7.3	6.9	10.3	24.8	1.2	16.2	16.4
TJ-83 x TD-1	63.9	8.4	7.1	9.1	29.4	1.1	13.3	18.2
TJ-83 x NIA-Sarng	73.0	8.9	5.5	8.3	23.8	0.7	12.1	21.5
TJ-83 x Kiran-95	64.5	9.5	6.3	12.2	30.4	1.5	14.1	15.1
Sarsbz x TD-1	70.4	6.8	8.8	4.2	23.8	0.6	14.5	17.6
Sarsbz x NIA-Sarng	70.4	7.6	9.5	7.4	31.9	1.4	10.6	19.6
Sarsbz x Kiran-95	65.4	6.8	7.3	8.1	26.9	0.9	13.3	22.4
TD-1 x NIA-Sarang	62.7	8.6	9.4	10.7	28.8	0.9	13.5	26.4
TD-1 x Kiran-95	60.5	6.8	10.0	9.3	32.3	1.6	12.3	24.7
NIA-Sarang xKran-95	73.1	7.6	8.3	9.4	33.6	1.4	14.3	18.6
CV	**4.04**	**14.98**	**7.25**	**6.84**	**8.25**	**11.85**	**16.41**	**3.53**

Table 4. Mean performance of wheat cultivars and hybrids under water stress from Anthesis to Maturity

Traits / Genotypes	PH	Till/P	MSL	Spk/MS	Gr/MS	GY/MS	SI	GY/P
TJ-83	60.4	9.4	16.5	18.8	40.9	0.8	18.6	20.4
Sarsbz	76.3	6.8	14.5	17.5	37.3	0.7	15.6	18.6
TD-1	63.6	9.7	17.5	14.3	36.6	0.9	18.5	23.0
NIA-Sarang	73.5	6.9	13.4	18.4	41.9	0.9	21.3	25.9
Kiran-95	71.2	7.5	17.5	18.0	39.4	1.0	20.5	26.5
CV	9.95	11.18	4.76	5.52	6.38	9.58	11.17	8.03
TJ-83 x Sarsbz	79.2	8.8	17.9	18.7	40.1	1.9	27.1	28.4
TJ-83 x TD-1	64.9	8.9	18.8	17.4	52.8	1.8	28.8	29.7
TJ-83 x NIA-Sarng	73.5	10.0	18.7	18.1	49.0	1.1	25.1	32.9
TJ-83 x Kiran-95	79.7	7.6	18.3	15.9	45.4	1.1	30.5	32.4
Sarsbz x TD-1	83.3	8.5	18.9	16.1	48.6	1.6	27.6	29.1
Sarsbz x NIA-Sarng	77.6	8.3	18.7	19.3	51.1	1.7	26.5	31.4
Sarsbz x Kiran-95	67.3	8.3	18.8	18.7	43.1	1.6	27.6	34.1
TD-1 x NIA-Sarang	66.3	8.9	18.2	15.0	45.2	1.0	26.5	30.4
TD-1 x Kiran-95	71.8	9.5	18.9	17.9	51.6	1.0	32.5	32.5
NIA-Sarang xKran-95	81.7	7.3	18.7	21.9	54.7	1.7	32.8	35.6
CV	7.96	12.74	4.13	9.91	13.55	16.27	9.13	6.85

Table 5. Mean performance of wheat genotypes for traits under normal watering (T_0)

Traits	**PH**	**Tillers**	**MSL**	**Spklts/ MS**	**Grns/MS**	**GYMS**	**SI**	**GYP**
Varieties								
TJ-83	88.2	11.2	24.7	22.6	65.2	2.8	29.2	35.7
Sarsabz	85.7	10.2	21.5	27.0	60.4	2.0	32.1	31.5
TD-1	78.4	9.8	22.3	25.2	63.3	2.1	28.8	38.4
NIA-Sarang	88.1	13.4	22.8	26.5	61.7	2.2	30.8	40.5
Kiran-95	89.9	14.2	23.6	24.6	62.1	2.5	27.3	39.7
C.V	6.71	3.94	3.41	4.13	2.44	5.24	9.03	6.47
Crosses								
TJ-83 x Sarsabz	86.8	14.4	28.5	29.6	74.4	2.7	51.0	40.4
TJ-83 x TD-1	69.2	15.4	28.1	27.5	71.8	2.8	41.1	52.2
TJ-83 x NIA-Sarang	81.7	12.6	27.8	30.1	76.5	2.8	40.9	37.2
TJ-83 x Kiran-95	91.1	17.2	28.3	25.9	79.0	3.1	41.7	41.9
Sarsabz x TD-1	93.8	14.4	28.6	28.5	68.2	2.8	35.2	48.1
Sarsabz x NIA-Sarang	91.3	11.3	28.4	31.2	65.1	3.1	39.8	48.7
Sarsabz x Kiran-95	95.2	12.3	29.1	33.9	67.4	3.4	37.9	51.9
TD-1 x NIA-Sarang	92.5	15.4	29.5	29.3	70.3	3.3	40.4	52.3
TD-1 x Kiran-95	85.6	14.5	28.4	29.7	76.5	2.5	37.6	49.7
NIA-Sarang x Kiran-95	102.1	10.6	29.3	34.3	74.5	3.7	45.1	55.5
C.V	8.28	7.93	2.84	3.67	3.68	10.99	25.94	5.10

General and Specific combining abilities General combining ability is behavior of parent cultivars in hybrid combination. It is necessary to evaluate parent genotypes for utilization in hybrid production and future selection programmes (Betran et al, 2003). Mean squares of GCAs (Table 6 a and b) showed significant differences for most of traits and most of the treatment combinations used. This suggesting that most of the genotypes used in this study are very useful and can be potentially used in breeding for higher yield under drought stress

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Table 6a. (Mean squares of GCA and SCA of some morphological traits of wheat

Source of variation	D. F	Plant height				Number of tillers plant^{-1}				Main spike length			
		T_1	T_2	T_0	CA	T_1	T_2	T_0	CA	T_1	T_2	T_0	CA
Replication	2	0.8623	22.908	7.566	3.10	0.734	1.850	0.964	0.160	0.4923	0.151	0.758	0.02
Treatments	2	---	---	---	6068.73**	----	-----	----	393.36**	---	---	---	3872.47**
Varieties	4	63.791**	135.74**	61.428**	178.93**	3.112**	5.755**	11.501**	4.659**	6.917**	10.40**	4.611**	13.709**
Crosses	9	58.78**	136.3**	239.47**	268.50**	2.702**	2.011**	12.837**	7.865**	6.814**	0.366**	0.875**	3.63**
Genotype	14	82.418**	148.14**	177.34**	273.513**	2.77**	3.143**	14.501**	8.559**	6.822**	8.428**	24.360**	19.664**
GCA	4	33.728**	55.46**	87.625**	453.401**	1.962**	1.996**	2.398**	13.475**	1.385**	2.157**	3.570	5.612**
SCA	10	24.970**	46.95**	47.707**	201.558**	0.51**	0.668	08**	6.592**	2.629**	3.070**	11.140	25.285**
V x T	1	---	---	---	41.02**	---	---	---	7.85**	---	---	---	4.112**
C x T	1	---	---	---	83.0**	---	---	---	4.843**	---	---	---	2.21**
G x T	1	---	---	---	67.189**	---	---	---	5.927**	---	---	---	9.972**
GCA x T	8	---	---	---	38.512**	---	---	---	2.797**	---	---	---	3.363**
SCA x T	20	---	---	---	78.660**	---	---	---	7.179**	---	---	---	12.616**
Error	84	8.321	26.867	6.306	13.832	1.069	1.051	0.0811	0.077	0.413	0.609	0.798	0.607
Source of variation	**D. F**	**Spikelets main spike^{-1}**				**Number of grains main spike^{-1}**				**Grain yield main spike^{-1}**			
		T_1	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**
Replication	2	2.899	1.623	0.4573	0.32	5.076	180.739	3.769	55.0	0.0234	0.394	0.140	0.054
Treatments	2	---	---	---	4209.54**	---	---	---	2068.75**	---	---	---	39.686**
Varieties	4	9.107**	9.866**	8.847**	9.602**	15.49**	15.104**	9.882**	14.44**	0.332**	0.339**	0.273**	0.087**
Crosses	9	13.955**	11.812**	20.217**	20.10**	38.87**	64.328**	62.731**	78.2**	0.353**	0.405**	0.392**	0.409**
Genotype	14	11.784**	10.598**	32.257**	21.167**	61.384**	102.62**	112.12**	208.552**	0.332**	0.513**	0.677**	0.778**
GCA	4	4.363**	6.196**	9.816**	31.589**	11.48**	12.684**	26.374**	78.984**	0.030**	0.025**	0.094**	0.096**
SCA	10	3.754**	2.467**	11.126**	16.998**	24.053**	42.819**	41.775**	260.380**	0.143**	0.229**	0.278**	1.051**
V x T	1	---	---	---	9.110**	---	---	---	13.02**	---	---	---	0.429**
C x T	1	---	---	---	12.94**	---	---	---	43.9**	---	---	---	0.3707**
G x T	1	---	---	---	16.736**	---	---	---	33.793**	---	---	---	0.372**
GCA x T	8	---	---	---	14.771**	---	---	---	36.318**	---	---	---	0.177**
SCA x T	20	---	---	---	17.522**	---	---	---	32.783**	---	---	---	0.451**
Error	84	0.298	2.320	1.123	1.247	4.417	4.125	5.313	14.618	0.061	0.115	0.078	0.085

T_1=Water stress from tillering to maturity, T_2= Water stress from anthesis to maturity, T_0= Normal water condition

Table 6 (b). Mean squares of GCA and SCA for seed index and grain yield plant^{-1}

Source of Variation	D.F	Seed Index plant^{-1}				Grain Yield Plant^{-1}			
		T-1	**T-2**	**T-3**	**CA**	**T-1**	**T-2**	**T-3**	**CA**
Replicat (R)	2	1.434	0.366	80.457	43.55	0.7323	3.330	3.556	5.00
Treatments (T)	2	---	---	---	5530.883**	---	---	---	8457.335**
Varieties (V)	4	6.977**	14.656**	10.418**	3.72**	18.846**	35.062**	40.321**	89.41**
Crosses (C)	9	7.074**	20.614**	207.905**	77.22**	39.713**	15.536**	107.325**	80.13**
Genotypes (G)	14	9.332**	83.668**	180.357**	140.572**	95.198**	74.985**	161.531**	276.055**
GCA	4	2.767**	11.166**	29.972**	61.888**	14.969**	20.099**	39.936**	189.012**
SCA	10	3.248**	34.578**	72.177**	172.046**	38.438**	26.953**	59.406**	310.873**
V x T	1	---	---	---	14.17**	---	---	---	2.41**
C x T	1	---	---	---	79.18**	---	---	---	41.22**
G x T	1	---	---	---	66.392**	---	---	---	27.829**
GCA x T	8	---	---	---	34.915**	---	---	---	18.002**
SCA x T	20	---	---	---	78.983**	---	---	---	31.760**
Error	84	3.211	6.300	6.655	24.388	0.3635	4.024	3.916	2.768

Table 7. General combining ability (GCA) effects for morphological traits in wheat

Varieties	**Plant height**				**Number of tillers plant^{-1}**				**Main spike length**				**Spikelets main spike^{-1}**			
	T_1	**T_1**	**T_1**	**T_1**	**T_1**	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**
TJ-83	-0.84	-0.84	-0.84	-0.84	0.71**	0.52**	0.46**	0.56**	-0.20	0.08	0.26	0.05	-0.07	0.18	-1.70**	-0.53**
Sarsabz	0.61	0.61	0.61	0.61	-0.66**	-0.44*	-0.84**	-0.6**	-0.10	-0.39**	-0.38*	-0.29**	-1.04**	0.21	0.95**	0.04
TD-1	-3.17**	-3.17**	-3.17**	-3.17**	0.19	0.65**	0.07	0.30**	0.79**	0.53**	-0.18	0.38**	-0.32**	-1.64**	-0.70**	-0.89**
NIA-Sarang	2.78**	2.78**	2.78**	2.78**	0.12	-0.33	-0.29*	-0.17	-0.22*	-0.73**	0.02	-0.31**	0.32**	0.67*	1.08**	0.69**
Kiran-95	0.62	0.62	0.62	0.62	-0.37*	-0.40*	0.60**	-0.06	-0.27*	0.51**	0.29*	0.18*	1.10**	0.57*	0.37*	0.68**
S.E (gi)	0.56	0.56	0.56	0.56	**0.20**	**0.20**	**0.18**	**0.11**	**0.12**	**0.15**	**0.17**	**0.09**	**0.11**	**0.30**	**0.21**	**0.13**
Varieties	**Grains main spie^{-1}**				**Grain yield main spike^{-1}**				**Seed Index plant^{-1}**				**Grain yield plant^{-1}**			
	T_1	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**
TJ-83	-1.48**	-0.30	2.52**	0.25	-0.11*	-0.02	0.03	-0.03	0.90**	-0.43	-1.72	-0.42	-1.51**	-1.17**	-3.20**	-1.96**
Sarsabz	-1.06**	-1.94*	-2.68**	-1.89**	0.02	0.10	-0.10*	0.01	-0.38	-1.69**	-2.41	-1.49**	-1.65**	-1.73**	-1.92**	-1.77**
TD-1	0.10	0.05	-0.18	-0.01	0.06	-0.05	-0.14**	-0.04	0.19	0.08	0.39	0.22	0.92**	-0.67*	1.95**	0.73**
NIA-Sarang	1.59**	1.80	-0.68	0.91*	-0.01	-0.02	0.08	0.02	-0.77*	0.23	2.64*	0.70	1.42**	1.38**	1.32**	1.37**
Kiran-95	0.84*	0.38	1.01*	0.74*	0.04	-0.02	0.14**	0.05*	0.06	1.81**	1.10	0.99*	0.83**	2.19**	1.85**	1.62**
S.E (gi)	**0.41**	**1.14**	**0.44**	**0.43**	**0.05**	**0.07**	**0.05**	**0.03**	**0.34**	**0.48**	**1.57**	**0.56**	**0.12**	**0.39**	**0.38**	**0.19**

*, = significant at 5% and **1% respectively.

General Combining Abilities Effects: Under normal watering, Kiran-95 (3.72**), NIA-Sarang (2.27**) and Sarsabz (1.53**) showed highly significant positive GCA effects for plant height (Table 7). Under water stress from tillering to maturity, NIA-Sarang (2.78**) revealed highly significant positive GCA effects, Kiran-95 (0.62) and Sarsabz (0.61) showed positive GCA effects for plant height. Highly significant positive GCA effects observed in Sarsabz (3.42**) and positive GCA effects of NIA-Sarang (1.43) and Kiran-95 (0.96) under water stress from anthesis to maturity (Table 7). Overall, highly positive GCA effects noted in NIA-sarang, Kiran-95 (0.6**) and TJ-83 (0.46**) (Table 7) under normal watering. Under water stress from tillering to maturity, TJ-83 (0.71**) showed highly significant positive GCA effects. Under water stress from anthesis to maturity, TD-I (0.65**) and TJ-83 (0.52**) showed highly significant positive GCA effects (Table 7) for tillers plant^{-1}. TJ-83 and TD-1 were the best. Highly significant positive GCA effects (Table 7) noted for Kiran-95 (0.29**), positive GCA effects of TJ-83 (0.26) and NIA-Sarang (0.02) under normal water. Under water stress from tillering to maturity, TD-I (0.79**) showed highly significant positive GCA effects. Under water stress from anthesis to maturity, TD-I (0.53**) and Kiran-95 (0.51**) showed highly significant positive GCA effects and TJ-83 (0.08) showed positive GCA effects for main spike length (Table 7). Overall results showed that TD-1 and Kiran-95 had great GCA effects. NIA-Sarang (1.08**) and Sarsabz (0.95**) showed highly significant positive GCA effects, Kiran-95 (0.37*) showed significant positive GCA effects under normal watering. Under water stress from tillering to maturity, Kiran-95 (1.1**) and NIA-Sarang (0.32**) showed highly significant positive GCA effects (Table 7) for spikelets main spike^{-1}. Under water stress from anthesis to maturity, NIA-Sarang (0.67**) and Kiran-95 (0.57**) showed highly significant positive GCA effects. Sarsabz (0.21) and TJ-83 (0.18) showed positive GCA effects for spikelets main spike^{-1}. Kiran-95, NIA-sarang and Sarsbz showed great GCA effects (Table 7). TJ-83 (2.52**) showed highly significant positive GCA effects. Kiran-95 (1.01) showed positive GCA effects under normal water for number of grains main spike^{-1}. Under water stress from tillering to maturity, NIA-Sarang (1.59**) showed highly significant positive GCA effects, Kiran-95 (0.84) and TD-I (0.1) showed positive GCA effects. Under water stress from anthesis to maturity, NIA-Sarang (1.8*) showed significant positive GCA effects, Kiran-95 (0.38) and TD-I (0.05) showed postive GCA effects for number of grains main spike^{-1}. TJ-83, NIA-sarang, Kiran-95 and TD-1 noted with great GCA effects. Kiran-95 (0.14**) showed highly significant positive GCA effects. NIA-Sarang (0.08) and TJ-83 (0.03) showed postive GCA effects under normal water level. Under water stress from tillering to maturity (Table 7), TD-1 (0.06), Kiran-95 (0.04) and Sarsabz (0.02) showed positive GCA effects. Under water stress from anthesis to maturity, (T_2) Saarsabz (0.1) showed positive GCA effects for grain yield main spike^{-1}. Overall, Sarsbz, TD-1 and Kiran-95 showed increased highly significant GCA effects for grain yield plant^{-1} under water stress and non-stress conditions.NIA-sarang (2.64*) showed significant positive GCA effects. Kiran-95 (1.1) and TD-I (0.39) shoewed positive GCA effects under normal watering. Under water stress from tillering to maturity, TJ-83 (0.9**), showed great significant positive GCA effects. TD-I (0.19), and Kiran-95 (0.06) showed positive GCA effects. Under water stress from anthesis to maturity, Kiran-95 (1.81**) showed highly significant positive GCA effects (Table 7), NIA-Sarang (0.23) and TD-I (0.08) showed positive GCA effects for seed index plant^{-1}. Overall results revealed that TJ-83, TD-1, iran-95 and NIA-sarang showed significant GCA effects under normal watering and water stress for seed index plant^{-1}. TD-I (1.95**), Kiran-95 (1.85**) and NIA-Sarang (1.32**) showed highly significant positive GCA effects under normal watering for grain yield plant^{-1}. Under water stress from tillering to maturity, NIA-Sarang (1.42**), TD-I (0.92**) and Kiran-95 (0.83**) showed highly significant positive GCA effects. Under water stress from anthesis to maturity, Kiran-95 (2.19**) and NIA-Sarang (1.38**) showed highly significant positive GCA effects for grain yield plant^{-1}. Overall GCA effects were highly significant positive of NIA-sarang, TD-1 and Kiran-95 (Table 7) under water stress and non-stress. Chowdhary *et al*. (2007), Seboka *et al*. (2009), Hussain *et al*. (2006) and Griffings (1956) reported positive GCA effects.

Specific Combining Abilities Effects: Specific combining abilities are performance of hybrid, well or poor under particular combination. SCA is necessary to evaluate hybrids (Betran et al, 2003). Wheat cultivars including hybrids evaluated under partial diallele analysis. Mean squares significantly differed for characters under non-stress and water stress conditions at >0.01% probability (Table 8). Significant SCAs for most of traits under normal water and water stress were noted. Specific combining abilities for most of the traits under normal and water stress were highly significant different. Quantitative gene action and dominant genetic effects influenced most of the characters. Mojarrad *et al*. (2010), Kamaluddin *et al*. (2007), Iqbal and Khan (2006) and Farooqi *et al*. (2006) indicated highly significant (>0.1) SCAs under drought conditions. Hybrid TJ-83 x TD-1 (-3.53**), Sarsabz x Kiran-95 (-2.93**) showed negative significant SCA effects, TD-1 x Kiran-95(-0.85) and TD-1 x NIA-sarang (-0.06) showed negative SCA effects. Wheat hybrid Sarsabz x TD-I (8.6**), NIA-Sarang x Kiran-95 (8.14**) and TD-I x NIA-Sarang (6.5**) showed highly significant positive SCA effects for plant height. TJ-83 x Kiran-95 (2.62*) showed significant positive SCA effects. Sarsabz x Kiran-95 (1.98) and TJ-83 x Sarsabz (0.54) showed positive SCA effects for plant height under normal watering (Table 8). Under water stress from tillering to maturity, hybrid Sarsabz x TD-I (7.78**), TJ-83 x NIA-Sarang (5.83**) and NIA-Sarang x Kiran-95 (4.55**) showed highly significant positive SCAs, TJ-83 x Sarsabz (3.3*) and TJ-83 x TD-I (2.72*) showed significant positive SCA effects. Sarsabz x NIA-Sarang (1.79) showed positive SCA effects for plant height. Under water stress from anthesis to maturity, wheat hybrid Sarsabz x TD-I (10.45**), TJ-83 x Kiran-95 (8.6**), NIA-Sarang x Kiran-95 (6.62**) and TJ-83 x Sarsabz (5.68**) showed highly significant positive SCA effects, TJ-83 x NIA-Sarang (1.97), TD-I x Kiran-95 (1.34) and Sarsabz x NIA-Sarang (0.1) revealed positive SCA effects for plant height. Iqbal (2004), Hussain *et al*. (2006) and Farooqi *et al*. (2006) told dominant gene control for plant height and tillers plant^{-1}. Hybrids TJ-83 x Kiran-95 (3.01**), TD-I x NIA-Sarang (2.52**), Sarsabz x TD-I (2.07**), TJ-83 x TD-I (1.73**) and TJ-83 x Sarsabz (1.65**) showed highly significant positive SCA effects. TD-I x Kiran-95 (0.7) showed positive SCA effects under normal watering for number of tillers plant^{-1}. Under water stress from tillering to maturity, hybrid TJ-83 x Kiran-95 (1.45**) showed highly significant positive SCA effects. TD-I x NIA-Sarang (0.57), Sarsabz x NIA-Sarang (0.46), TJ-83 x NIA-Sarang (0.36), NIA-Sarang x Kiran-95 (0.2) and Sarsabz x Kiran-95 (0.15) showed positive SCA effects for number of tillers plant^{-1}. Under water stress from anthesis to maturity, TJ-83 x NIA-Sarang (1.42**) showed highly significant positive SCA effects. TD-I x Kiran-95 (0.86*) showed significant positive SCA effects. Sarsabz x Kiran-95 (0.67), Sarsabz x NIA-Sarang (0.61), TJ-83 x Sarsabz (0.33) and TD-I x NIA-Sarang (0.13) showed positive SCA effects for number of tillers plant^{-1}. Tillers plant^{-1} of wheat is essential component of seed yield and is under control of additive genes Iqbal (2004), Hussain *et al*. (2006) and Farooqi *et al*. (2006) and Chowdhry *et al.* 2005a. Wheat hybrids TD-I x NIA-sarang (2.9**), Sarsabz x TD-I (2.47**), NIA-Sarang x Kiran-95 (2.27**), Sarsabz x NIA-Sarang (2**) and TJ-83 x Sarsabz (1.9**) showed highly significant positive SCA effects. Hybrid TJ-83 x NIA-Sarang (0.8*) revealed significant positive SCA effects under normal watering for -spike length (Table 8). Under water stress from tillering to maturity, Sarsabz x NIA-Sarang (1.64**) and TD-I x Kiran-95 (1.31**) showed highly significant positive SCA effects. NIA-sarang x Kiran-95 (0.65*) and TD-I x NIA-Sarang (0.62*) showed positive significant SCA effects for main spike length. Under water stress from anthesis to maturity, hybrid Sarsabz x NIA-Sarang (2.13**), TJ-83 x NIA-Sarang (1.66**), NIA-Sarang x Kiran-95 (1.26**), Sarsabz x Kiran-95 (1.02**) and TD-I x NIA-Sarang (0.68**) showed highly significant positive SCA effects. TJ-83 x Sarsabz (0.53) and TJ-83 x TD-I (0.51) showed positive SCA effects for - spike length. Hybrids NIA-Sarang x Kiran-95 (4.48**), Sarsabz x Kiran-95 (4.14**), TJ-83 x NIA-Sarang (2.36**), TJ-83 x Sarsabz (1.95**), TD-I x Kiran-95 (1.66**) and TJ-83 x TD-I (1.54**) showed highly significant positive SCA effects. Hybrid Sarsabz x NIA-Sarang (0.73) and TD-I x NIA-Sarang (0.55) showed positive SCA effects under normal watering, for number of spikelets spike^{-1} (Table 8). Under water stress from tillering to maturity, wheat hybrid TJ-83 x Sarsabz (2.35**), TJ-83 x Kiran-95 (2.07**) and TD-I x NIA-Sarang (1.64**) showed highly significant positive SCA effects. TJ-83 x TD-I (0.36) showed positive SCA effects for spikelets main spike^{-1} (Table 8). Under water stress from anthesis to maturity, Hybrids NIA-Sarang x Kiran-95 (2.92**) and TD-I x Kiran-95 (1.26**) showed highly significant positive SCA effects, while hybrid TJ-83 x TD-I (1.11), Sarsabz x NIA-Sarang (0.68), TJ-83 x Sarsabz (0.6) and Sarsabz x Kiran-95 (0.21) showed positive SCA effects for spikelets main spike^{-1}. Under normal watering, TD-I x Kiran-95 (6.59**), TJ-83 x Kiran-95 (6.39**), TJ-83 x NIA-Sarang (5.58**), TJ-83 x Sarsabz (5.48**) and NIA-Sarang x Kiran-95 (5.07**) showed highly significant positive SCA effects. Hybrid TD-I x NIA-Sarang (2.05*) showed significant positive SCA effects. Hybrid Sarsabz x TD-I (1.95) and TJ-83 x TD-I (0.38) showed positively SCA effects for number of grains -spike^{-1} (Table 8). Under water stress from tillering to maturity, hybrid Sarsabz x NIA-Sarang (5.04**), TD-I x Kiran-95 (5**), NIA-Sarang x Kiran-95 (4.8**), TJ-83 x TD-I (4.49**) and TJ-83 x Kiran-95 (4.08**) showed highly significant positive SCA effects. Positive SCA effects noted in hybrid TJ-83 x Sarsabz (0.98), TD-I x NIA-Sarang (0.78) and sarsabz x Kiran-95 (0.75) for number of grains main spike^{-1}. Under water stress from anthesis to maturity, hybrid TJ-83 x TD-I (7.87**) and NIA-Sarang x Kiran-95 (7.38**) showed highly positive SCA effects. Hybrid Sarsabz x NIA-Sarang (6.03*), TD-I x Kiran-95 (5.96*) and Sarsabz x TD-I (5.31*) showed positive significant SCA effects. Hybrid TJ-83 x NIA-Sarang (2.29) and TJ-83 x Kiran-95 (0.14) showed positive SCA effects of number of grains main spike^{-1}. Wheat hybrid NIA-Sarang x Kiran-95 (0.7**), TD-I x NIA-Sarang (0.57**), Sarsabz x Kiran-95 (0.55**) and Sarsabz x NIA-Sarang (0.34**) showed highly significant positive SCA effects. Sarsabz x TD-I (0.29*) showed positive significant SCA effects. TJ-83 x TD-I (0.16) and TJ-83 x Kiran-95 (0.12) showed positive SCA effects for grain yield main spike^{-1} under normal watering. Under water stress from tillering to maturity, TJ-83 x Kiran-95 (0.49**), TD-I x Kiran-95 (0.42**) and Sarsabz x NIA-Sarang (0.31**) showed highly significant positive SCA effects. Hybrid NIA-Sarang x Kiran-95 (0.25*) showed positive significant SCA effects. TJ-83 x Sarsabz (0.24) and TJ-83 x TD-I (0.13) showed positive SCA effects for grain yield main spike^{-1} (Table 8). Under water stress from anthesis to maturity, TJ-83 x TD-I (0.58**), TJ-83 x Sarsabz (0.56**) and NIA-Sarang x Kiran-95 (0.52**) showed highly positive significant SCA effects (Table 8). Hybrid Sarsbz x NIA-Sarang (0.37*), Sarsabz x TD-I (0.3*) and Sarsabz x Kiran-95 (0.29*) showed positive significant SCA effects to grain yield main spike^{-1}. Hybrid TJ-83 x TD-I (7.56*) and TJ-83 x Kiran-95 (7.48*) showed significant positive SCA effects. Hybrid, NIA-Sarang x Kiran-95 (6.48), TJ-83 x NIA-Sarang (5.07), Sarsabz x NIA-Sarang (4.73), Sarsabz x Kiran-95 (4.37) and TD-I x Kiran-95 (1.21) showed positive SCA effects for seed index under normal watering. Under water stress from tillering to maturity, hybrid TJ-83 x Sarsabz (2.88**) and NIA-Sarang x Kiran-95 (2.28**) showed highly significant positive SCA effects. Hybrid Sarsabz x T D -I (1.89), T D -I x NIA-Sarang (1.35), Sarsabz x Kiran-95 (0.89) and TJ-83 x Kiran-95 (0.41) showed positive SCA effects for seed index. Under water stress from anthesis to maturity, hybrid NIA-Sarang x Kiran-95 (5.49**), TD-I x Kiran-95 (5.28**), TJ-83 x Sarsabz (3.96**), TJ-83 x TD-I (3.89**) and TJ-83 x Kiran-95 (3.86**) showed highly significant positive SCA effects, while hybrid Sarsabz x NIA-Sarang (2.62*) and Sarsabz x Kiran-95 (2.21*) showed positive significant SCA effects for seed index plant^{-1} (Table 8). Hybrid TJ-83 x TD-I (9.24**), NIA-Sarang x Kiran-95 (8.06**), Sarsabz x Kiran-95 (7.76**), Sarsabz x NIA-Sarang (5.02**), TD-I x NIA-Sarang (4.76**) and Saesabz x TD-I (3.83**) had highly significant positive SCA effects. Hybrid TD-I x Kiran-95 (1.7*) showed positive significant SCA effects and TJ-83 x Sarsabz (1.27) showed positive SCA effects for grain yield plant^{-1} (Table 8), under normal watering. Under water stress from tillering to maturity, hybrid TD-I x NIA-Sarang (7.2**), Sarsabz x Kiran-95 (6.31**), TD-I x Kiran-95 (6.08**), TJ-83 x NIA-Sarang (4.66**), Sarsabz x NIA-Sarang (2.93**), TJ-83 x Sarsabz (2.69**), TJ-83 x T D-I (1.93**) and Sarsabz x T D-I (1.47**) had highly significant positive SCA effects for grain yield plant^{-1}. Under water stress from anthesis to maturity, hybrid Sarsabz x Kiran-95 (4.91**), TJ-83 x NIA-Sarang (3.93**), NIA-Sarang x Kiran-95 (3.27**), Sarsabz x NIA-Sarang (3.06**), TJ-83 x TD-I (2.77**), Sarsabz x TD-I (2.77**), TJ-83 x Kiran-95 (2.68**), TJ-83 x Sarsabz (2.6**) and TD-I x Kiran-95 (2.28**) showed highly significant positive SCA effects and TD-I x NIA-Sarang (0.96) showed positive SCA effect for grain yield plant^{-1} (Table 8). Khan *et al*. (2003) reported overdominant genes in grains spike^{-1} and seed yield plant^{-1}. Akbar *et al*. (2007) estimated heterobeltiosis for wheat grain yield and reported significant mid parent heterosis and heterobeltiosis for seed yield, number of spikes per plant, Plant biomass and weight of 1000 seeds. Hussain *et al.* (2007) estimated mid parent heterosis and heterobeltiosis for seed yield, number of tillers per plant, grains spike^{-1} and weight of 1000 seeds.

Heterosis: Hybrid TJ-83 x TD-1 (-14.1,-19.0), TJ-83 x NIA-Sarang (-6.45,-6.5) and TJ-83 x Sarsabz (-0.15, -1.4) showed negative heterobeltiosis for plant height under water stress from tillering to maturity. Hybrid TD-I x Kiran-95 (-0.3,-5.4) showed negative heterobeltiosis. Hybrid TD-1 x NIA-Sarang (-3.0), TJ-83 x Kiran-95 (-1.4) and Sarasabz x Kiran-95 (-0.5) showed negative heterosis. Rest of the hybrids surpassed both parents under water stress from anthesis to maturity (Table 9). Hybrid TD-1 x NIA-Sarang (-2.25, -7.2) showed negative heterobeltiosis for plant height under control conditions. Hybrid TJ-83 x TD-I (4.9, 4.2), Sarsabz x TD-I (4.4, 4.2), TJ-83 x Kiran-95 (4.5, 3.0), TD-I x NIA-Sarang (3.8, 2.0), TJ-83 x Sarsabz (3.7, 3.2) and TD-I x Kiran-95 (2.5, 0.3) showed heterobeltiosis and four hybrids showed negative heterobeltiosis under control conditions for number of tillers plant^{-1} (Table 9). Hybrid TJ-83 x Kiran-95 (2.05, 1.0), Sarsabz x NIA-Sarang (1.8, 0.5), NIA-Sarang x Kiran-95 (1.2, 1.2), TJ-83 x NIA-Sarang (1.1, 0.0), TD-I x NIA-Saramng (0.85, 0.2) and Sarsabz x Kiran-95 (0.35, 0.3) showed heterobeltiosis and rest of hybrids showed negative heterobeltiosis for number of tillers plant^{-1} under water stress from tillering to maturity (Table 9). Hybrid TD-I x Kiran-95 (2.3, 2.0), TD-I x NIA-Sarang (2.0, 2.0) and TJ-83 x NIA-Sarang (1.85, 0.40) showed heterobeltiosis, rest of wheat hybrids showed negative heterobeltiosis for number of tillers plant^{-1} under water stress from anthesis to maturity. Fida *et al.* (2007) noted heterosis of mid parent and heterobeltiosis for seed yield, number of tillers per plant, seeds spike^{-1} and weight of 1000 seeds. Akbar *et al*. (2007) estimated heterobeltiosis for wheat grain yield, number of spikes – plant^{-1}, Plant biomass and weight of 1000 seeds. Hussain *et al.* (2007) estimated mid parent heterosis and heterobeltiosis for seed yield, number of tillers per plant, grains spike^{-1} and weight of 1000 seeds. Superior hybrid of - spike length was Sarsabz x NIA-Sarang (1.8, 1.5) followed by TD-I x Kiran-95 (1.4, 0.4). Higher Heterobeltiosis for number of spikelets - spike^{-1} noted in hybrid, NIA-Sarang x Kiran-95 (8.75, 7.8), and Sarsabz x Kiran-95 (8.1, 6.9) under control. Three wheat hybrids TJ-83 x Sarsabz (2.45, 1.7), TJ-83 x Kiran-95 (2.85, 0.6) and TD-I x NIA-Sarang (0.75, 0.3) had better heterobeltiosis for number of spikelets -spike^{-1} under water stress from tillering to maturity. Hybrid TJ-83 x Kiran-95 (-2.5, -2.9), TD-I x NIA-Sarang (-1.35, -3.4) and TJ-83 x NIA-Sarang (-0.5, -0.7) showed negative heterosis under water stress from anthesis to maturity. Akbar *et al*. (2007) also estimated heterobeltiosis for wheat grain yield and reported significant mid parent heterosis and heterobeltiosis for seed yield, number of spikes –plant^{-1}, Plant biomass and weight of 1000 seeds. Hussain *et al.* (2007) reported mid parent heterosis and heterobeltiosis for seed yield, number of tillers per plant, grains spike^{-1} and weight of 1000 seeds. Heterobeltiosis for number of grains - spike^{-1} noted in hybrid NIA-Sarang x Kiran-95 (16.7, 15.3), TJ-83 x Sarsabz (14.05, 11.9), TD-I x Kiran-95 (13.6, 12.2), Sarsabz x TD-I (11.65, 11.3), Sarsabz x NIA-Sarang (11.5, 9.2), TJ-83 x NIA-Sarang (7.6, 7.1), TD-I x NIA-Srang (5.95, 3.3), Sarsabz x Kiran-95 (4.75, 3.7) under water stress from anthesis to maturity (Table 9). Fida *et al.* (2007) noted heterosis of mid parent and heterobeltiosis for seed yield, number of tillers plant^{-1}, seeds spike^{-1} and weight of 1000 seeds. Heterobeltiosis noted in hybrid NIA-Sarang x Kiran-95 (1.35, 1.2), TD-I x NIA-Sarang (1.15, 1.1), sarsabz x Kiran-95 (1.15, 0.9), Sarsabz x NIA-Sarang (1.0, 0.9), Sarsabz x TD-I (0.75, 0.7) for grain yield - spkie^{-1} under control conditions. Hybrid TJ-83 x Kiran-95 (0.9, 0.8), TD-I x Kiran-95 (0.6, 0.3) and Sarsabz x NIA-sarang (0.3, 0.2) showed heterobeltiosis under water stress from tillering to maturity. The higher Heterobeltiosis for grain yield main spike^{-1} noted in hybrid TJ-83 x Sarsabz (1.15, 1.1) under water stress from anthesis to maturity. Hybrid TJ-83 x Sarsabz (26.35, 24.9) and NIA-Sarang x TD-I (15.95, 14.3) had better heterobeltiosis than other hybrids for seed index under control conditions (Table 9). Heterobeltiosis for seed index plant^{-1} noted in hybrid TD-I x Kiran-95 (13, 12), NIA-Sarang x Kiran-95 (11.9, 11.5), TJ-83 x Kiran-95 (10.95, 10.0), Sarsabz x TD-I (10.55, 9.1), TJ-83 x TD-I (10.25, 10.2), Sarsabz x Kiran-95 (9.55, 7.1), Sarsabz x NIA-Sarang (8.05, 5.2), TD-I x NIA-Sarang (6.6, 5.2) and TJ-83 x NIA-Sarang (5.15, 3.8) under water stress from anthesis to maturity (Table 9). Akbar *et al*. (2007) estimated heterobeltiosis for wheat grain yield and reported significant mid parent heterosis and heterobeltiosis for seed yield, number of spikes plant^{-1}, Plant biomass and weight of 1000 seeds. Hussain *et al.* (2007) estimated mid parent heterosis and heterobeltiosis for seed yield, number of tillers plant^{-1}, grains spike^{-1} and weight of 1000 seeds. Fida *et al.* (2007) noted heterosis of mid parent and heterobeltiosis for seed yield, number of tillers plant^{-1}, seeds spike^{-1} and seed index plant^{-1}. Akbar *et al*. (2007), reported significant mid parent heterosis and heterobeltiosis for seed yield, number of spikes plant^{-1}, and seed index. Hussain *et al.* (2007) estimated mid parent heterosis and heterobeltiosis for seed yield, number of tillers plant^{-1}, grains spike^{-1} and seed index. Heterobeltiosis showed in hybrid Sarsabz x Kiran-95 (16.3, 12.2), NIA x Kiran-95 (15.4, 15.0), TJ-83 x TD-I (15.5, 13.8), Sarsabz x TD-I (13.15, 9.7), TD-I x NIA-Sarang (12.85, 11.8), Sarsabz x NIA-Sarang (12.7, 8.2), TD-I x Kiran-95 (10.65, 10), TJ-83 x Sarsabz (6.8, 4.7) and TJ-83 x Kiran-95 (4.2, 2.2) under control (Table 9) for grain yield plant^{-1}. Under water stress from tillering to maturity, hybrid TD-I x NIA-Sarang (14.9, 13.8), TD-I x Kiran-95 (12.9, 11.5), Sarsabz x Kiran-95 (12.35, 9.2), TJ-83 x NIA-Sarang (10.3, 8.9), Sarsabz x NIA-Sarang (9.85 x 7.0), Sarsabz x TD-1 (8.95, 7.2), TJ-83 x TD-I (8.1, 7.8), TJ-83 x Sarsabz (8.05, 6.6), NIA-Sarang x Kiran-95 (5.7, 5.4) and TJ-83 x Kiran-95 (3.6, 1.9) showed heterobeltiosis for grain yield plant^{-1}. Heterobeltiosis for grain yield plant^{-1} noted in hybrid NIA-Sarang x Kiran-95 (35.3, 9.1), Sarsabz x Kiran-95 (11.55, 7.6), TJ-83 x NIA-Sarang (9.75, 7.0), Sarsabz x NIA-Sarang (9.15, 5.5), TJ-83 x Kiran-95 (8.95, 5.9), TJ-83 x Sarsabz (8.9, 8.0), Sarsabz x TD-I (8.3, 6.1), TJ-83 x TD-I (8.0, 6.7), TD-I x Kiran-95 (7.75, 6.0) and TD-I x NIA-Sarang (5.95, 4.5) under water stress from anthesis to maturity. Fida *et al.* (2007) noted heterosis of mid parent and heterobeltiosis for seed yield, number of tillers, seeds spike^{-1} and 1000 seed weight. Akbar *et al*. (2007) estimated heterobeltiosis for wheat grain yield and reported significant mid parent heterosis and heterobeltiosis for seed yield, number of spikes, Plant biomass and 1000 seed weight. Hussain *et al.* (2007) estimated mid parent heterosis and heterobeltiosis for seed yield, number of tillers plant^{-1}, grains spike^{-1} and 1000 seed weight. Tahara *et al*. (1990) estimated high seed yield selection, maintained significantly great relative water content of leaf than low yielded selections. Hussain et al. (2007), Panhwar *et al*. (2022), Fida et al. (2007) and Cifci (2021) also noted heterobeltiosis under water stress conditions.

Table 8. Specific Combining Ability (SCA) effects for morphological traits in wheat

Hybrids	**Plant height**				**Number of tillers plant^{-1}**				**Main spike length**				**Spikelets main spike^{-1}**			
	T_1	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**
TJ-83 x Sarsabz	3.30*	5.68*	0.54	3.18**	-0.43	0.33	1.65**	0.51*	**-1.01****	**0.53**	**1.90****	**0.47****	2.35**	0.60	1.95**	1.63**
TJ-83 x TD-1	2.72*	-2.01	-11.29**	-3.53**	-0.18	-0.72	1.73**	0.28	**-1.63****	**0.51**	**-1.30****	**0.06**	0.36	1.11	1.54**	1.00**
TJ-83 x NIA-Sarang	5.83**	1.97	-5.32**	0.83	0.36	1.42**	-0.73	0.35	**-2.23****	**1.66****	**0.80***	**0.08**	-1.01**	-0.46	2.36**	0.30
TJ-83 x Kiran-95	-0.50	8.60**	2.62*	3.57**	1.5**	-0.98*	3.01**	1.16**	**-1.44****	**-0.01**	**-1.03***	**-0.14**	2.07**	-2.63**	-1.13*	-0.56*
Sarsabz x TD-1	7.78**	10.45**	8.60**	8.94**	-0.38	-0.17	2.07**	0.51*	**-0.07**	**-1.07****	**2.47****	**1.16****	-3.54**	-0.21	-0.15	-1.30**
Sarsabz x NIA-Sarang	1.79	0.10	-0.44	0.48	0.46	0.61	-0.70	0.12	**1.64****	**2.13****	**2.00****	**1.92****	-0.94**	0.68	0.73	0.16
Sarsabz x Kiran-95	-0.98	-9.80**	1.98	-2.93**	0.15	0.67	-0.59	0.08	**-0.54****	**1.02****	**-2.50****	**0.99****	-1.03**	0.21	4.14**	1.11**
TD-1 x NIA-Sarang	-2.13	-4.56*	6.50**	-0.06	0.57	0.13	2.52**	1.07**	**0.62***	**0.68***	**2.90****	**1.40****	1.64**	-1.77*	0.55	0.14
TD-1 x Kiran-95	-2.10	1.34	-1.79	-0.85	-0.70	0.86*	0.70	0.29	**1.31****	**-0.17**	**-1.53****	**1.00****	-0.61**	1.26*	1.66**	0.77**
NIA-Sarang x Kiran-95	4.55**	6.62**	8.14**	6.44**	0.20	-0.36	-2.9**	-1.0**	**0.65***	**1.26****	**2.27****	**1.39****	-1.11**	2.92**	4.48**	2.10**
S.E (si)	**1.46**	**2.58**	**1.27**	**0.86**	**0.52**	**0.52**	**0.46**	**0.23**	**0.32**	**0.38**	**0.44**	**0.18**	**0.28**	**0.77**	**0.54**	**0.26**

Hybrids	**Grains main spike^{-1}**				**Grain yield main spike^{-1}**				**Seed Index plant^{-1}**				**Grain yield plant^{-1}**			
	T_1	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**	**T_1**	**T_2**	**T_0**	**CA**
TJ-83 x Sarsabz	0.98	-2.87	5.48**	1.20	0.24*	0.56**	-0.01	0.26**	2.88**	3.96**	-15.71**	-2.96**	2.69**	2.60**	1.27	2.19**
TJ-83 x TD-1	4.49**	7.87**	0.38	4.25**	0.13	0.58**	0.16	0.29**	-0.52	3.89**	7.56*	3.64**	1.93**	2.77**	9.24**	4.65**
TJ-83 x NIA-Sarang	-2.60**	2.29	5.58**	1.76*	-0.27*	-0.15	-0.12	-0.18**	-0.79	-0.03	5.07	1.44	4.66**	3.93**	-5.16**	1.14**
TJ-83 x Kiran-95	4.68**	0.14	6.39**	3.74**	0.49**	-0.15	0.12	0.15*	0.41	3.86**	7.48*	3.92**	-1.13**	2.68**	-0.99	0.19
Sarsabz x TD-1	-1.60	5.31*	1.95	1.89*	-0.53**	0.30*	0.29*	0.02	1.89*	-3.91**	-2.36	2.72**	1.47**	2.77**	3.83**	2.69**
Sarsabz x NIA-Sarang	5.04**	6.03*	-0.68	3.46**	0.31**	0.37*	0.34**	0.34**	-1.05	2.62*	4.73	2.10*	2.93**	3.06**	5.02**	3.67**
Sarsabz x Kiran-95	0.75	-0.48	-0.07	0.07	-0.24*	0.29*	0.55**	0.20**	0.89	2.21*	4.37	2.49*	6.31**	4.91**	7.76**	6.33**
TD-1 x NIA-Sarang	0.78	-1.86	2.05*	0.32	-0.23*	-0.18	0.57**	0.05	1.35	-0.85	-2.50	1.57	7.20**	0.96	4.76**	4.31**
TD-1 x Kiran-95	5.00**	5.96*	6.59**	5.85**	0.42**	-0.22	-0.25*	-0.02	-0.75	5.28**	1.21	1.91*	6.08**	2.28*	1.70*	3.35**
NIA-Sarang x Kiran-95	4.80**	7.38**	5.07**	5.75**	0.25*	0.52**	0.70**	0.49**	2.28**	5.49**	6.48	4.75**	-0.52*	3.27**	8.06**	3.60**
S.E (si)	**1.06**	**2.94**	**1.14**	**0.88**	**0.12**	**0.17**	**0.14**	**0.07**	**0.89**	**1.25**	**4.05**	**1.14**	**0.30**	**1.01**	**0.98**	**0.38**

*, = significant at 5% and **1% respectively.

Table 9. Heterosis for grain yield and its contributing characters

Hybrids	PLant height						Tillers plant^{-1}						Main spike length						Spikelets main spike^{-1}					
	Control		T_1		T_2		Control		T_1		T_2		Control		T_1		T_2		Control		T_1		T_2	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
TJ-83 x Sarsabz	-0.15	-1.4	6.075	7.8	10.85	2.9	3.7	3.2	-0.2	-1.2	0.7	-0.6	5.4	3.8	2.55	-4.0	2.4	1.4	2.4	2.6	2.45	1.7	0.55	-0.1
TJ-83 x TD-1	-14.1	-19	10.15	8.2	2.9	1.3	4.9	4.2	-0.05	-0.1	-0.65	-0.8	4.6	3.4	-.15	-3.8	1.8	1.3	3.6	2.3	0.8	-0.4	0.85	-1.4
TJ-83 x NIA-Sarang	-6.45	-6.5	14.25	7.3	6.55	0	0.3	-0.8	1.1	0.4	1.85	0.4	4.05	3.1	-3.65	-5.4	3.75	2.2	5.55	3.6	-0.45	-2.1	-0.5	-0.7
TJ-83 x Kiran-95	2.05	1.2	5.65	-1.4	13.9	8.5	4.5	3.0	2.05	1.0	-0.85	-1.8	4.15	3.6	-2.95	-4.6	1.3	0.8	2.3	1.3	2.85	0.6	-2.5	-2.9
Sarsabz x TD-1	11.75	8.1	12.3	9.9	13.35	7	4.4	4.2	-0.65	-1.6	0.25	-1.2	6.7	6.3	0.0	-0.8	2.9	1.4	2.4	1.5	-4.85	-5.3	0.2	-1.4
Sarsabz x NIA-Sarang	4.4	3.2	7.3	4.7	2.7	1.3	-0.5	-2.1	1.8	0.5	1.45	1.4	6.25	5.6	1.8	1.5	4.75	4.2	4.45	4.2	-2.1	-3.0	1.35	0.9
Sarsabz x Kiran-95	7.4	5.3	2.2	-0.5	13.55	11	0.1	-1.9	0.35	0.3	1.2	0.8	6.55	5.5	-3.5	-3.7	2.8	1.3	8.1	6.9	-2.0	-3.5	0.95	0.7
TD-1 x NIA-Sarang	9.25	4.4	2	-3	-2.25	-7.2	3.8	2.0	0.85	0.2	2.0	2.0	6.95	6.7	0.9	-0.2	2.75	0.7	3.45	2.8	0.75	0.3	-1.35	-3.4
TD-1 x Kiran-95	1.45	-4.3	-0.3	-5.4	4.4	0.6	2.5	0.3	-0.6	-1.6	2.3	2.0	5.45	4.8	1.4	0.4	1.4	1.4	4.8	4.5	-1.25	-2.3	1.75	-0.1
NIA-Sarang x Kiran-95	13.1	12.2	7.3	7.2	14.3	10.5	-3.2	-3.6	1.2	1.2	-3.2	-3.2	6.5	6.5	0.8	0.7	3.25	1.2	8.75	7.8	-1.6	-2.2	5.75	3.9
S.E (si)	-0.15	-1.4	6.08	7.8	10.85	2.9	3.7	3.2	-0.2	-1.2	0.7	-0.6	5.4	3.8	-2.55	-4.0	2.4	1.4	2.4	2.6	2.45	1.7	0.55	-0.1

Hybrids	Grains main spike^{-1}						Grain yield main spike^{-1}						Seed index plant^{-1}						Grain yield plant^{-1}					
	Control		T_1		T_2		Control		T_1		T_2		Control		T_1		T_2		Control		T_1		T_2	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
TJ-83 x Sarsabz	5.8	4.6	4.2	3.2	1.00	-0.8	0.3	-0.1	0.35	0.0	1.15	1.1	26.35	24.9	4.35	-1	10	8.5	6.8	4.7	8.05	6.6	8.9	8.0
TJ-83 x TD-1	7.55	6.6	8.5	7.2	14.05	11.9	0.35	0.0	0.2	-0.2	0.95	0.9	12.1	11.9	0.4	-0.3	10.25	10.2	15.15	13.8	8.1	7.8	8.0	6.7
TJ-83 x NIA-Sarang	13.05	11.3	1.25	-1.7	7.6	7.1	0.3	0.0	-0.05	-0.3	0.25	0.2	10.9	10.1	0.15	-1.5	5.15	3.8	-0.9	-3.3	10.3	8.9	9.75	7.0
TJ-83 x Kiran-95	15.35	13.8	10.4	10	5.25	4.5	0.45	0.3	0.9	0.8	0.2	0.1	13.35	12.5	1.55	0.5	10.95	10.0	4.2	2.2	3.6	1.9	8.95	5.9
Sarsabz x TD-1	6.35	4.9	1.9	1.6	11.65	11.3	0.75	0.7	-0.65	-0.7	0.8	0.7	4.75	3.1	3.55	2.3	10.55	9.1	13.15	9.7	8.95	7.2	8.3	6.1
Sarsabz x NIA-Sarang	4.01	3.4	8.35	6.4	11.5	9.2	1.0	0.9	0.3	0.2	0.9	0.8	8.35	7.7	0.6	0.3	8.05	5.2	12.7	8.2	9.85	7	9.15	5.5
Sarsabz x Kiran-95	6.15	5.3	5.9	5.3	4.75	3.7	1.15	0.9	-0.05	-0.3	0.75	0.6	8.1	5.8	2.7	1.8	9.55	7.1	16.3	12.2	12.4	9.2	11.6	7.6
TD-1 x NIA-Sarang	7.8	7	4.95	3.3	5.95	3.3	1.15	1.1	-0.35	-0.4	0.1	0.1	10.6	9.6	2.25	1.3	6.6	5.2	12.85	11.8	14.9	13.8	5.95	4.5
TD-1 x Kiran-95	13.8	13.2	11	10.1	13.6	12.2	0.2	0.0	0.6	0.3	0.05	0.0	9.45	8.8	0.45	0.1	13	12.0	10.65	10.0	12.9	11.5	7.75	6
NIA-Sarang x Kiran-95	12.6	12.4	13.2	13.2	16.7	15.3	1.35	1.2	0.4	0.1	0.75	0.7	15.95	14.3	3.4	2.8	11.9	11.5	15.4	15	5.7	5.4	35.3	9.1

CONCLUSION

Highly significant difference (≥ 0.01) for traits noted under treatments, genotype, treatment x genotype, Combined analysis (CA) of treatments, CA of varieties, varieties x treatments, crosses x treatments, CA of crosses and treatments, genotypes x treatments, GCA x treatments, SCA x treatments under normal watering and water stress conditions for grain yield spike^{-1} and grain yield plant^{-1}. Kiran-95, NIA-Sarang and TJ-83 showed postive GCAs under normal watering and water stress from tillering to maturity and from anthesis to maturity for grain yield spike^{-1} and grain yield plant^{-1}. For seed index plant^{-1}, NIA-sarang showed significant positive and Kiran-95 and TD-I showed positive GCA effects under non-stress conditions. Under water stress from tillering to maturity and from anthesis to maturity, TJ-83, TD-1, Kiran-95 and NIA-sarang showed positive GCAs for seed index plant^{-1}. TD-I, Kiran-95 and NIA-Sarang, showed highly significant positive GCA effects under non-stress and both water stress conditions for grain yield plant^{-1}. SCA mean squares showed highly significant difference (0.01%) for characters under non-stress and water stress conditions. NIA-Sarang x Kiran-95, TD-I x NIA-Sarang, Sarsabz x Kiran-95 and Sarsabz x NIA-Sarang showed highly significant positive SCA effects for grain yield main spike^{-1} under normal watering and water stress from tillering to maturity and from anthesis to maturity. Heterobeltiosis under water stress from tillering to maturity and anthesis to maturity noted for grain yield spike^{-1} in hybrid TJ-83 x Kiran-95, TD-I x Kiran-95 and Sarsabz x NIA-sarang, TJ-83 x Sarsabz, TJ-83 x TD-I, Sarsabz x NIA-Sarang, Sarsabz x TD-I, and NIA-Sarang x Kiran-95. For seed index plant^{-1} under non-stress, hybrid NIA-Sarnag x Kiran-95, Sarsabz x TD-I, Sarsabz x Kiran-95, TD-I x NIA-Sarang and TJ-83 x Sarsabz showed heterobeltiosis for seed index plant^{-1} under water stress from tillering to maturity and from anthesis to maturity. Overall, NIA-Sarang, TJ-83, TD-1 performed well in terms of higher yield, good general and specific combining abilities and they also exhibited better heterosis responses when crossed with other varieties or eachother. Hence these varieties are confidently suggested for higher yield under drought stress breeding programs.

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