Research Article

Estimation of genetic variability and heritability in F₂ populations of wheat (*Triticum aestivum* L.) genotypes under drought stress conditions

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Abstract

Drought is a serious problem in many parts of the world because of quick changes in climatic conditions especially for rain-fed agriculture. Among predominant abiotic stresses, it is the most important and severe factor limiting the plant growth and production. Two irrigation regimes *i.e.*, non-stress and water stress at anthesis considered as main plots and genotypes as sub-plots. The mean squares from analysis of variance showed that treatments, genotypes and their relations were significant for most of the traits. Water deficit caused significant influence on yield and its contributing although cultivars like TD-1, Benazir, TJ-83 and Kiran declined minimum for most of the traits. In F₂ progenies, Benazir × Kiran, TJ-83 × SKD-1, TJ-83 × Kiran and SKD-1 × Kiran executed well under stressed environments. The proportion of genetic characters such as genetic coefficient of variability, genetic variance, heritability and genetic advance were higher in non-stress as compared to water stress conditions which indicated that F₂ progenies were more influenced by water stress. Among the F₂ populations, TJ-83 × Kiran recorded maximum genetic variability (43.42), heritability (18.85%) and genetic advance (22.30) for days to 75% heading, (GCV = 63.71, h^2 = 40.70% and GA = 48.21) for harvest index, TD-1 × TJ-83 (GCV = 50.98, h^2 = 26.35% and GA = 57.57) for days to 75% maturity, TD-1 × SKD-1 (GCV = 68.60, h^2 = 47.06% and GA = 66.56) for plant height, Benazir × SKD-1 (GCV = 38.49, h^2 = 14.86% and GA = 1.90) for tillers plant⁻¹, SKD-1 × Kiran (GCV = 45.49, h^2 = 20.72% and GA = 3.12) for spike length, (GCV = 74.18, h^2 = 55.03% and GA = 35.38) for seed index (g), TJ-83 × SKD-1 (GCV = 48.97,

$h^2 = 24.00\%$ and $GA = 6.70$) for spikelets spike⁻¹, ($GCV = 41.12$, $h^2 = 16.91\%$ and $GA = 14.08$) for grains spike⁻¹, Benazir $\times$ Kiran ($GCV = 42.38$, $h^2 = 17.97\%$ and $GA = 5.05$) for grain yield plant⁻¹, ($GCV = 27.15$, $h^2 = 7.37\%$ and $GA = 3.68$) for biological yield plant⁻¹. Different characters such as Days to 75% heading, plant height (cm), tillers plant⁻¹, spike length (cm), spikelets spike⁻¹, grains spike⁻¹, seed index (100 grain weight, g), grain yield plant⁻¹ (g), biological yield plant⁻¹ (g), harvest index (%) showed positive and significant correlation with grain yield plant⁻¹ (g).

Keywords: Genetic advances; Heritability; Variability; Water stress and Wheat genotypes

Introduction

Wheat (*Triticum aestivum* L.) is broadly adapted crop in the world, providing 1/3 of the universal with approximately partial of their nutrimental values. In temperate countries wheat is the leading crop and shows vital role in the nutritional safety of Pakistan, wheat is basic food grown in ten major wheat-producing countries of the world Pakistan counts, in area under wheat cultivation yield per hectare and total production [1]. The hexaploid wheat family named Poaceae. The crop has many species, but the most dynamic one is hexaploid, because this is grown all over the world for the human consumption in a wide range of forms [2]. Wheat is one of the valuable crops of the world. It is virtually said that this crop was the first crop which was domesticated by the human being on the earth. The wheat has about 14% protein higher than any other the grain crop. It is round about accounts for 20% of nutritional sources of the people all over the world [3]. Wheat accounts for 8.7% to value adding in agriculture and 24.946 million tons production percent increase than last year's production of 24.349 million tons. The area under cultivation increase percent to 8,825 thousand hectares than last year's area (8,678 thousand hectares) production enlarged due to increase in cultivated area, healthy grain emergence and superior crop yield [4].

Drought deficit can be defined as the deficiency of rainfall for a period enough to deplete soil humidity and injure plants [5]. he also well-defined drought tolerance as the capability of a variety to keep on relatively stronger and more productive over others

under water shortage conditions. He defined that the best genotype for water deficit conditions must together a sensible high yield capability with specific plant characters, which may buffer yield compare severe moisture stress. Unfortunately, with current distribution of pure line cultivars, improved high yielding in whole world's wheat growing areas, selection from well-known cultivars may isolate a new genotype hardly [6]. Drought leads to stomata closing, decrease of water content, and turgor loss. Sometimes it may cause to death of plant by disturbing metabolism [7].

Water deficit upsets the physiological characters of wheat crop. Efforts have been made to expand the yield of wheat crop under water deficit condition by improving the characters which are affected by drought stress. Drought not only affects the physiological characters but also affects the morphological traits. Harshness of drought depends on growth stage, cultivar, duration and attention of stress. Different stages differently respond to drought stress; some stages can survive with the stress by maintaining its water turgor force or effective utilization of water. Water deficit can decrease the biomass, grain size, tillering ability etc. Photosynthesis and many factors that pay to photosynthesis like relative water content, chlorophyll content and different pigments is affected by stress. Water deficit causes leaf senescence in several genotypes of wheat, thus causing the chlorophyll degeneracy. Proline is an amino acid, which gather during several stresses as an osmoregulatory protein. Genotypes that collect more proline maintaining the plant water

potential by displays tolerance against stress. Therefore, literature concerning physiological traits affected by water stress in wheat genotypes is very partial. Hence, the current experiment was collected in physiological characters to assess the changes in wheat genotypes under water deficit condition.

Drought is one of the biggest abiotic stress factors foremost to reduced crop production, so high-yielding crops even in environmentally stressful conditions are vital. The increasing existence and importance of drought in link to crop production has equipped it as a major emphasis of research for some decades. However, studying drought response is dared by the quantitative nature of the trait and complex. Drought tolerance is multifaceted with environmental interchange. Water stress response, the mode, timing, and harshness of the dehydration stress in the analysis of a plants and its phenomenon with other biotic and abiotic stress features are famous. Although progress of higher-yielding crops under water deficit environments is the most practical solution to stabilize and expand wheat production under present climatic conditions, it is drought response challenged by the nature as a complex genomic constitution and trait of the wheat. Genetic improvement in wheat for drought tolerance could be done through mutation breeding and conventional tools [8].

Genetic variability is the basic utensil of breeding tactics which could be achieved through hybridization of diversified genetic material. The inspection of genetic variation in breeding material is of major tool to plant breeders and useful in achieving higher return per unit area in any crop plant. Heritability isolates the amount of genotypic variation from phenotypic one. The expected response to selection is also called genetic advance. Heritability with value of genetic advance helps the plant breeder predict the

gain under selection. The maximum heritability in whichever trait demonstrates its uppermost conveying skill to the next generation [9].

Heritability plays a vital role in breeding which forecast the performance of the following generations and creates attract choices. The selection procedure becomes easy, if the heritability is higher and the answer to selection converts considerable and drives to genotypic variances that are affected by phenotypic variances [10, 11]. Heritability and genetic advance are more effective for the improvement of plant traits from segregating populations. Hence, it is good practices to choose the traits on the basis of their desirability [12]. Heritability of a character helps to prediction the execution of succeeding creation for greater results of upcoming generation. However, reliable comparison of genetic heritability or variance of the population need huge sample of progeny from each population [13].

Materials and Methods

The research was accompanied to determine the effect of water stress on F₂ populations at Botanical Garden Department of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam, during rabi season 2019-2020. The experiment was held in split plots with three replications. Two irrigation regimes, *i.e.*, normal and water deficit at anthesis considered as main plots and genotypes as sub-plots. Five parental lines along with their ten cross combinations of F₂ populations were grown. The parents were TD-1, Banazir, TJ-83, SKD-1 and Kiran, while the F₂ populations were TD-1 × Banazir, TD-1 × TJ-83, TD-1 × SKD-1, TD-1 × Kiran, Banazir × TD-83, Banazir × SKD-1, Banazir × Kiran, TJ-83 × SKD-1, TJ-83 × Kiran and SKD-1 × Kiran for days to 75% heading, days to 75% maturity, plant height (cm), tillers plant⁻¹, spike length (cm), spikelets spike⁻¹, grains spike⁻¹, seed index (1000 seed weight, g), grain yield plant⁻¹ (g),

biological yield plant⁻¹ (g) and harvest index (%). The obtained data was statistically analyzed according to [14]. Whereas heritability in broad sense and genetic advance was estimated as suggested by [15].

Results and Discussion

The ANOVA exposed that treatments, genotypes were significant for all the traits such as genetic coefficient of variability, genetic variance, heritability percentage in broad sense and genetic advance. Whereas treatments × genotypes were also significant for all the traits except days to 75% heading (Table 1). The significant mean squares showed that genotypes performed variably for all the traits over the environments. Current findings are agreed with [16-18] they observed significant mean squares for all the studied traits.

Effect of water stress on yield and its contributing traits

The mean performance of wheat genotypes (Parents and F₂ populations) for yield and its contributing traits (Table 2-5). Days to 75% heading, ranged from 70.80 to 57.80 under non-stress condition, while in water stress condition it ranged from 67.20 to 53.66 (Table 3). The minimum reduction due to water stress was noted in Benazir followed by TD-1 and TJ-83. The minimum number of days to 75% heading was noted in TD-1 × Benazir and TD-1 under water stress condition. For days to 75% maturity, ranged from genotypes 129.20 to 107.33 under non-stress condition, while in water stress condition it ranged from 127.00 to 104.33. The minimum reduction due to water stress was noted in Benazir followed by TJ-83 × Kiran and Benazir × SKD-1. Among the cultivars TD-1, SKD-1 and TD-1 × Benazir (55.06 cm) displayed desirable minimum plant height under water stress condition. Tillers plant⁻¹ was counted as 12.66 to 6.40 tillers while in stress the tillers were 7.86 to 4.40. According to mean values, water shortage caused - 5.06 tillers deduction plant⁻¹.

¹. Under stress condition, the genotypes TJ-83, Benazir and Benazir × SKD-1 maintained their rank order. Our finding is conformity with [1] also observed that water stress caused significant impact on phenological and yield traits.

Furthermore, longer spikes 13.60 to 7.16 cm is measured in non-stress condition and in water stress 10.60 to 6.13 cm. This average decline of -4.66 was recorded. Among the genotypes, TJ-83, TD-1 and TD-1 × Benazir maintained their spike length in drought conditions. Therefore, the above-mentioned genotypes have resistance to water stress than rest of the genotypes in the test. Similarly, average spikelets spike⁻¹ was 21.13 to 14.13 whereas under water stress condition was 17.73 to 12.60. According to mean values the water deficit condition caused -5.03 declines in terms of spikelets spike⁻¹. However, declines in spikelets spike⁻¹ were smaller in cultivars Benazir, Benazir × SKD-1 and sharper declines were noted in TD-1, SKD-1 × Kiran and TJ-83. Therefore, the first group of genotypes said to be drought resistant while the latter group as drought susceptible [19] observed that water stress caused significant effect on yield and its contributing traits of wheat genotypes. Water stress caused -27.06 seed reduction in grains spike⁻¹. In stress the cultivars, Benazir, TD-1 and TJ-83 × SKD-1 gave higher performance (Table 6). However smaller increase rather than decreased was observed in TD-1 × SKD-1, Benazir × TJ-83 and Benazir × Kiran and highest increase were noted in SKD-1 × Kiran, Benazir × SKD-1 and TD-1 × Benazir [20, 21] they also reported similar type of results. The average reduction occurred by - 5.18 g due to water stress. In stress condition, TD-1, TJ-83 and Benazir × Kiran in addition with these genotypes also give prominent results in water stress, similarly biological yield is an important trait because if total dry matter is greater in adverse environment which is most important. Under deficit

condition cultivars TJ-83, TD-1 and SKD-1 gave higher dry matter which is desirable. In normal situation lower dry matter were given by TD-1 $\times$ TJ-83, TD-1 $\times$ Kiran and Benazir $\times$ SKD-1 while in water deficit. In present study, mean values of (HI) were increased by 12.75% however this increase was sharper in

some of the cultivars such as TJ-83 $\times$ Kiran, Benazir $\times$ Kiran and TD-1 $\times$ SKD-1 while smaller increase occurred in TD-1 $\times$ TJ83, Benazir $\times$ SKD-1 and Benazir $\times$ TJ-83 (Table 8). Similarly [22, 23] they noted more or less water stress caused significant reduction in yield and its contributing traits.

Table 1. Mean squares from analysis of variance for various quantitative traits of wheat genotypes grown under non-stress and water stress condition.

Traits	Replications D.F.= 2	Treatment (T) D.F.= 1	Error(a)) D.F.= 2	Genotypes(G) D.F.= 14	T $\times$ G D.F.= 14	Error(b) D.F.= 56
Days to 75% heading	2.25	432.08*	8.97	75.01**	3.35 ^{n.s}	2.65
Days to 75% maturity	6.72	259.42*	5.74	231.56**	8.82*	5.36
Plant height	14.70	1830.61**	0.38	506.14**	37.77*	16.74
Tillers plant ⁻¹	0.17	136.40**	0.36	10.02**	3.07**	0.33
Spike length	0.05	81.79**	0.14	13.46**	5.08**	0.14
Spikelets spike ⁻¹	0.80	136.16*	1.75	9.87**	4.65**	0.92
Grains spike ⁻¹	69.04	2707.12*	39.96	198.65**	165.54**	20.80
Seed index(g)	1523.41	273.04 ^{n.s}	1450.38	144.02**	274.20**	51.10
Grain yield plant ⁻¹	2.29	603.72**	0.96	69.88**	12.93**	1.01
Biological yield plant ⁻¹	2.75	4147.20**	6.02	231.45**	47.59**	7.32
Harvest index %	1147.83	3656.13 ^{n.s}	1502.79	66.70**	79.23**	16.50

Table 2. Mean performance of wheat genotypes for various quantitative traits grown under water stress and non-stress conditions

Genotypes	Days to 75% heading		Days to 75% maturity		Plant height (cm)	
	Non-stress	Water stress	Non-stress	Water stress	Non-stress	Water stress
TD-1	57.80	54.80	112.00	109.40	54.46	50.40
Benazir	59.53	57.80	110.47	109.07	75.93	70.20
TJ-83	63.53	60.33	115.07	104.33	72.46	65.00
SKD-1	66.06	61.33	117.53	114.07	58.46	53.26
Kiran	65.46	60.73	119.33	112.53	80.86	72.06
TD-1 × Benazir	57.86	53.66	122.80	120.20	76.46	55.06
TD-1 × TJ-83	62.60	58.33	127.13	124.33	74.80	66.06
TD-1 × SKD-1	64.46	60.06	129.20	127.00	81.50	71.26
TD-1 × Kiran	66.33	57.93	118.33	114.27	89.33	81.06
Benazir × TJ-83	59.33	55.26	114.00	112.13	75.53	63.53
Benazir × SKD-1	63.46	59.60	113.00	111.27	80.86	74.66
Benazir × Kiran	67.20	61.46	113.93	110.87	80.73	73.26
TJ-83 × SKD-1	67.60	61.93	121.53	117.93	82.13	81.26
TJ-83 × Kiran	70.80	67.20	107.33	105.73	87.46	72.60
SKD-1 × Kiran	65.86	61.73	111.53	109.13	86.40	72.40
Mean	63.85	59.47	116.87	113.48	77.15	68.13
LSD @ 5% (T)	2.17		2.71		0.55	
LSD @ 5% (G)	2.67		1.88		4.73	
LSD @ 5% (T×G)	3.78		2.66		6.69	

Table 3. Mean performance of wheat genotypes for various quantitative traits grown under water stress and non-stress conditions

Genotypes	Tillers plant ⁻¹		Spike length (cm)		Spike length (cm)	
	Non-stress	Water stress	Non-stress	Water stress	Non-stress	Water stress
TD-1	10.60	6.53	12.63	9.93	21.13	16.10
Benazir	12.66	7.60	13.60	7.60	18.00	17.73
TJ-83	11.86	7.86	13.10	10.60	19.20	14.73
SKD-1	7.66	5.66	11.26	6.60	14.13	12.86
Kiran	10.13	6.33	12.40	8.53	18.00	15.93
TD-1 × Benazir	7.46	6.66	9.46	9.06	17.66	14.20
TD-1 × TJ-83	6.80	4.80	8.63	7.06	17.26	14.66

TD-1 × SKD-1	7.86	4.40	8.53	7.00	17.80	15.13
TD-1 × Kiran	8.00	5.80	7.16	8.06	16.26	14.33
Benazir × TJ-83	6.40	6.26	8.26	7.40	17.06	14.20
Benazir × SKD-1	7.66	7.26	7.80	7.80	16.40	15.33
Benazir × Kiran	8.53	5.66	8.53	6.13	16.06	14.13
TJ-83 × SKD-1	8.06	5.40	7.60	7.13	14.40	15.86
TJ-83 × Kiran	7.33	5.66	9.00	7.76	19.06	14.80
SKD-1 × Kiran	7.80	6.00	9.86	8.56	17.06	12.60
Mean	8.58	6.12	9.85	7.94	17.29	14.83
LSD @ 5% (T)	0.54		0.33		1.20	
LSD @ 5% (G)	0.66		0.43		1.11	
LSD @ 5% (T×G)	0.94		0.61		1.57	

Table 4. Mean performance of wheat genotypes for various quantitative traits grown under water stress and non-stress conditions

Genotypes	Grains spike ⁻¹		Seed index (1000 seed weight in g)		Grain yield plant ⁻¹ (g)	
	Non-stress	Water stress	Non-stress	Water stress	Non-stress	Water stress
TD-1	67.46	48.73	42.53	28.10	25.53	18.26
Benazir	71.20	49.60	44.80	31.43	27.20	14.73
TJ-83	67.20	44.06	40.73	25.83	25.26	18.20
SKD-1	60.60	42.20	37.86	22.56	21.66	15.83
Kiran	66.46	44.33	40.93	26.30	23.06	14.16
TD-1 × Benazir	59.33	43.53	20.02	33.96	17.30	12.36
TD-1 × TJ-83	48.00	42.00	19.61	33.50	16.10	12.83
TD-1 × SKD-1	41.13	46.13	20.03	26.33	16.39	15.33
TD-1 × Kiran	46.06	41.26	19.82	32.70	15.85	12.56
Benazir × TJ-83	41.80	41.06	18.94	26.80	14.57	8.82
Benazir × SKD-1	48.00	44.86	18.22	35.20	14.24	9.06
Benazir × Kiran	51.06	43.46	17.04	25.60	20.60	15.96
TJ-83 × SKD-1	43.40	47.33	17.97	31.86	16.40	13.82
TJ-83 × Kiran	49.26	44.9	19.05	32.46	14.28	12.50
SKD-1 × Kiran	62.93	35.86	19.36	36.53	16.51	12.83
Mean	54.92	43.95	26.46	29.94	18.99	13.81
LSD @ 5% (T)	5.73		34.54		0.88	
LSD @ 5% (G)	5.27		8.26		1.16	

LSD @ 5% (T×G)	7.45	11.69	1.64
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Table 5. Mean performance of wheat genotypes for various quantitative traits grown under water stress and non-stress conditions

Genotypes	Biological yield plant ⁻¹ (g)		Harvest index (%)	
	Non-stress	Water stress	Non-stress	Water stress
TD-1	50.96	35.73	43.02	51.22
Benazir	53.51	27.60	43.93	53.81
TJ-83	50.53	35.93	42.51	50.90
SKD-1	47.06	32.60	39.15	48.75
Kiran	48.00	26.93	40.33	52.77
TD-1 × Benazir	37.38	24.50	38.30	50.88
TD-1 × TJ-83	29.74	25.83	46.66	49.79
TD-1 × SKD-1	37.40	27.16	38.23	56.82
TD-1 × Kiran	30.78	24.13	39.35	52.19
Benazir × TJ-83	33.79	21.23	35.38	42.11
Benazir × SKD-1	31.46	21.93	35.85	42.18
Benazir × Kiran	48.42	28.33	37.02	56.72
TJ-83 × SKD-1	36.08	26.06	36.68	53.27
TJ-83 × Kiran	33.83	18.92	34.30	67.40
SKD-1 × Kiran	37.48	25.90	36.51	49.66
Mean	40.42	26.85	39.148	51.898
LSD @ 5% (T)	2.22		35.16	
LSD @ 5% (G)	3.12		4.69	
LSD @ 5% (T×G)	4.42		6.64	

Genetic analysis of yield and its contributing traits of wheat genotypes grown under water stress condition

Days to 75% heading

The data regarding days to 75% heading is presented in (Table 6) which indicated that in no-stress condition the range of genetic coefficient of variability is varied from 3.52 to 43.00 % whereas, in stress condition it is varied from 1.67 to 43.42 % however, the ratio of heritability is also ranged from 0.13 to 19.22 and 0.03 to 18.85 % in non-stress and water deficit condition respectively. All the cross combinations showed low heritability in non-stress as well as in stress condition for days to 75% heading associated with a fair amount of genetic advance. Among the F₂ progenies maximum (19.22 and 18.85%) heritability was given by TJ-83 x Kiran in both the conditions respectively.

Days to 75% maturity

The data presented in (Table 7) revealed that the parameter days to 75% maturity in non-stress condition ranged from 3.25 to 45.87 % of genetic coefficient variability (GCV) while in stress condition it is varied from 2.23 to 50.98 however the ratio of heritability is varied from 0.10 to 20.18 and 0.10 to 36.35 % in non-stress and water stress condition

respectively. All the cross combinations showed low heritability in both the conditions non-stress as well as in stress for days to 75% maturity and fair amount of genetic advance. Maximum heritability among F₂ progenies was given by TD-1 × SKD-1 and TD-1 × TJ-83 (20.18 and 20.07 %) while TD-1 × TJ-83 and TD-1 × SKD-1 (26.35 and 22.56 %) was given in stress condition respectively.

Plant height plant⁻¹ (cm)

The plant height plant⁻¹ has direct relation with yield because the plant height plant⁻¹ which is very essential component is largely dependent on this trait. The result regarding genetic coefficient of variability, genetic variance, heritability percentage in broad sense and genetic advance for plant height plant⁻¹ is shown in (Table 8). The data showed that most of the populations recorded medium to maximum genetic coefficient of variability ranging from 18.44 to 63.48 under non-stress whereas, 14.03 to 68.60 in stress condition, heritability ranging from 3.40 to 40.36 in non-stress while 1.97 to 47.06 in stress condition. F₂ progenies also displayed fair amount of genetic advance varied from 4.52 to 63.40 in non-stress and 2.37 to 66.56 in stress condition respectively.

Table 6. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies, for days to 75% heading grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O ² g)		h ² .b.s %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 × Benazir	6.59	5.20	15.00	8.59	0.43	0.27	0.45	0.27
TD-1 × TJ-83	18.70	15.42	137.06	80.94	3.61	2.38	3.92	2.44
TD-1 × SKD-1	13.24	25.00	72.89	225.58	1.83	6.25	2.04	6.61
TD-1 × Kiran	29.64	5.31	386.51	9.47	9.35	0.28	10.58	0.29
Banazir × TJ-83	10.78	4.13	43.11	5.97	1.21	0.17	1.27	0.18
Banazir × SKD-1	11.97	1.67	59.47	0.99	1.50	0.03	1.66	0.03
Banazir × Kiran	36.96	26.41	616.99	263.51	14.11	6.98	16.42	7.55
TJ-83 × SKD-1	28.13	18.74	361.65	134.67	8.20	3.51	9.59	3.83
TJ-83 × Kiran	43.00	43.42	926.78	851.31	19.22	18.85	23.49	22.30
SKD-1 × Kiran	3.52	15.01	5.5	85.83	0.13	2.25	0.15	2.45

GCV= Genetic coefficient of variability, GV= Genetic variance, h²b.s%= Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

Table 7. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies, for days to 75% maturity grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O ² g)		h ² .b.s %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 × Benazir	42.99	41.12	2787.35	2516.19	17.72	17.42	39.11	36.84
TD-1 × TJ-83	45.83	50.17	3394.86	4060.44	20.07	26.35	45.94	57.57
TD-1 × SKD-1	45.87	47.50	3512.68	3639.20	20.18	22.56	46.86	50.43
TD-1 × Kiran	17.15	24.87	412.02	775.88	2.86	5.93	6.04	11.93
Banazir × TJ-83	14.61	30.97	277.33	1205.65	2.05	9.59	4.20	18.92
Banazir × SKD-1	3.82	4.70	19.19	28.70	0.14	0.23	0.29	0.45
Banazir × Kiran	8.31	3.15	92.10	12.21	0.67	0.10	1.38	0.19
TJ-83 × SKD-1	27.97	50.98	1155.33	2975.20	7.53	19.97	16.42	42.90
TJ-83 × Kiran	3.59	6.89	17.92	56.00	0.13	0.47	0.26	0.91
SKD-1 × Kiran	3.25	2.23	14.98	6.37	0.10	0.05	0.22	0.10

GCV= Genetic coefficient of variability, GV= Genetic variance, h²b.s.%= Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

Table 8. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies for plant height grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O ² g)		h ² .b.s %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 × Benazir	50.21	18.95	76.42	139.30	25.24	3.60	33.95	3.94
TD-1 × TJ-83	51.48	47.43	1482.69	981.71	26.52	22.50	34.90	26.15
TD-1 × SKD-1	19.48	68.60	252.01	2390.15	3.80	47.06	5.44	59.03
TD-1 × Kiran	63.48	64.15	3215.81	2704.81	40.36	41.16	63.40	58.72
Banazir × TJ-83	18.44	14.03	194.03	91.86	3.40	1.97	4.52	2.37
Banazir × SKD-1	54.46	55.09	1939.24	1691.73	29.69	30.35	42.23	39.88
Banazir × Kiran	23.65	23.92	364.60	307.04	5.59	5.72	7.95	7.38
TJ-83 × SKD-1	59.73	68.22	2406.60	3073.27	35.70	46.54	51.59	66.56
TJ-83 × Kiran	47.86	32.64	1752.08	561.37	22.91	10.65	35.26	13.61
SKD-1 × Kiran	57.69	48.37	2484.30	1226.40	10.43	23.40	15.81	29.81

GCV= Genetic coefficient of variability, GV= Genetic variance, h²b.s.%= Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

Tillers plant¹

The results revealed significant amount of genetic coefficient of variability (GCV=10.92-45.75) under non-stress, (GCV=11.74-38.49) under water deficit condition which was also associated with genetic variability (O²g=1.66-26.57 and 0.71-7.82) under both conditions. Heritability percentage in broad sense was recorded ranging from 1.20 to 21.03 and 1.38 to 14.86 in non-stress and water stress condition however genetic advance varied from 0.25-

4.16 under non-stress while 0.17-1.90 in stress condition respectively (Table 9).

Spike length

The data regarding spike length presented in (Table 10) which revealed that genetic coefficient of variability ranging from 3.32 to 18.44 and 6.81 to 45.49 in both non-stress and water stress conditions respectively. Genetic variance varied from 0.15 to 5.57 in non-stress and 0.43 to 15.19 under water stress condition. Though heritability showed that majority of the progenies have low- to

medium which is varied from 0.11 to 3.41 and 0.47 to 20.73 in non-stress and water stress condition. Genetic advance ranged from 0.02

to 0.77 in non-stress while 0.08 to 3.12 in stress condition respectively.

Table 9. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies for tillers plant⁻¹ grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O ² g)		h ² .b.s %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 × Benazir	10.92	17.33	1.66	1.56	1.20	3.01	0.25	0.38
TD-1 × TJ-83	14.20	15.94	2.62	1.37	2.03	2.55	0.41	0.33
TD-1 × SKD-1	40.33	24.94	16.70	2.50	16.33	6.26	2.91	0.70
TD-1 × Kiran	16.60	21.50	3.06	2.01	2.77	4.65	0.51	0.54
Banazir × TJ-83	16.37	11.80	4.17	0.85	2.69	1.40	0.59	0.19
Banazir × SKD-1	31.76	38.49	12.35	7.82	10.13	14.86	1.97	1.90
Banazir × Kiran	19.97	22.96	5.49	2.73	4.01	5.30	0.83	0.67
TJ-83 × SKD-1	45.75	13.90	26.57	0.93	21.03	1.94	4.16	0.24
TJ-83 × Kiran	37.55	11.74	20.08	0.71	14.16	1.38	2.97	0.17
SKD-1 × Kiran	26.50	28.35	6.12	3.16	7.05	8.06	1.16	0.89

GCV= Genetic coefficient of variability, GV= Genetic variance, h²b.s%= Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

Table 10. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies for spike length grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O ² g)		h ² .b.s %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 × Benazir	16.63	22.09	4.91	4.01	2.77	4.88	0.65	0.78
TD-1 × TJ-83	14.99	9.95	3.82	1.06	2.25	0.99	0.52	0.18
TD-1 × SKD-1	13.86	25.46	2.81	4.94	1.93	6.51	0.41	1.00
TD-1 × Kiran	6.88	11.78	0.73	1.21	0.48	1.39	0.10	0.23
Banazir × TJ-83	18.44	8.02	5.57	0.55	3.41	0.65	0.77	0.11
Banazir × SKD-1	7.79	40.93	0.87	10.19	0.61	16.76	0.13	2.30
Banazir × Kiran	17.30	9.29	4.83	0.57	3.00	0.87	0.67	0.12
TJ-83 × SKD-1	16.65	18.99	4.06	2.92	2.78	3.61	0.59	0.57
TJ-83 × Kiran	6.00	6.81	0.56	0.43	0.36	0.47	0.08	0.08
SKD-1 × Kiran	3.32	45.49	0.15	15.19	0.11	20.72	0.02	3.12

GCV= Genetic coefficient of variability, GV= Genetic variance, h²b.s%= Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

Spikelets spike⁻¹

The most important among the grain properties in wheat is the spikelets spike⁻¹ (Table 11). The results indicated fair amount of genetic coefficient of variability among the progenies with few exceptions which ranged from 7.21-50.34 in non-stress condition and 5.56-48.97 under deficit

condition with genetic variance ranging from 1.88-101.35 under non-stress while 0.82-60.36 in stress condition. Heritability percentage in broad sense varied from 0.66 to 27.91 and 0.31 to 24.00 under both conditions associated with reasonable genetic advance ranging from 0.20 to 9.36 under non-

stress and 0.09 to 6.70 in stress condition respectively.

Grains spike⁻¹

The results indicated fair level of genetic coefficient of variability ranging from 0.21-16.75 and 7.85-41.12 under non-stress and water deficit conditions associated with genetic variability ranging under non-stress

condition and water stress condition as 4.68-281.47 and 15.01-378.74. Whereas heritability estimates in broad sense were found 0.10-6.51 and 0.62-16.91 under both conditions which resulted in more genetic advance ranging from 0.12-7.53 under non-stress while 0.54-14.08 under water deficit condition respectively (Table 12).

Table 11. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies for spikelets spike⁻¹ grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O ² g)		h ² .b.s %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 × Benazir	15.91	7.71	9.14	1.72	2.46	0.60	0.84	0.18
TD-1 × TJ-83	11.26	21.29	4.94	11.31	1.27	4.54	0.44	1.26
TD-1 × SKD-1	18.54	26.94	16.63	16.62	5.26	7.26	1.65	1.93
TD-1 × Kiran	13.68	14.68	7.48	5.66	2.03	2.16	0.69	0.61
Benazir × TJ-83	16.18	5.56	8.49	0.82	2.70	0.31	0.84	0.09
Benazir × SKD-1	40.47	24.89	47.32	15.86	17.61	6.20	5.08	1.75
Benazir × Kiran	17.16	8.88	9.54	2.26	3.26	0.79	0.98	0.24
TJ-83 × SKD-1	7.21	48.97	1.88	60.36	0.66	24.00	0.20	6.70
TJ-83 × Kiran	50.34	7.94	101.35	1.50	27.91	0.63	9.36	0.17
SKD-1 × Kiran	38.43	17.85	28.94	6.91	9.96	3.19	2.99	0.83

GCV= Genetic coefficient of variability, GV= Genetic variance, h²b.s%= Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

Table 12. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies, for grains spike⁻¹ grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O ² g)		h ² .b.s %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 × Benazir	16.75	7.85	157.88	15.01	3.23	0.62	3.97	0.54
TD-1 × TJ-83	0.21	10.69	4.68	24.98	0.10	1.14	0.12	0.94
TD-1 × SKD-1	0.43	15.35	16.96	50.17	0.40	2.36	0.46	1.91
TD-1 × Kiran	0.67	9.27	46.09	18.82	1.02	0.86	1.21	0.71
Benazir × TJ-83	1.51	15.81	255.16	56.51	5.13	2.50	6.37	2.09
Benazir × SKD-1	1.38	15.20	193.74	50.17	4.32	2.31	5.09	1.90
Benazir × Kiran	1.41	21.08	218.40	102.96	4.47	4.45	5.50	3.77
TJ-83 × SKD-1	1.56	41.12	238.75	378.74	5.51	16.91	6.38	14.08
TJ-83 × Kiran	0.40	17.99	16.00	65.32	0.36	3.24	0.42	2.56
SKD-1 × Kiran	1.70	12.65	281.47	30.52	6.51	1.60	7.53	1.23

GCV= Genetic coefficient of variability, GV= Genetic variance, h²b.s%= Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

Grain yield plant⁻¹

Grain yield in wheat is very crucial due to the fact it has direct influence on wheat yield.

The genetic coefficient of variability, genetic variance, heritability percentage in broad sense and genetic advance for seed yield are

revealed in (Table 13). The results revealed fair level of genetic coefficient of variability range from 2.01-26.67 in non-stress and 2.33-42.38 under stress condition. Maximum genetic variability was given by Benazir $\times$ Kiran (45.24 and 45.67) in both conditions. However, heritability estimates in broad sense were found (0.04-7.14 and in stress condition 0.05-17.97) which resulted in more genetic advance ranging from 0.02-3.16 and 0.02-5.05 under both conditions respectively.

Biological yield plant⁻¹

The most important among the yield properties in wheat is the biological yield per plant from economic point of view. The genetic parameters like genetic coefficient of variability, genetic variance, heritability percentage in broad sense and genetic advance are summarized in (Table 14). The maximum amount of genetic coefficient of variability was noted in progenies Benazir $\times$ Kiran (24.06 and 27.15) in both conditions with genetic variance ranged from 1.38 to 159.40 and 2.66 to 59.18 under non stress and water stress, maximum O^2g were noted in Benazir $\times$ Kiran (159.40 and 59.18).

Heritability percentage in broad sense in most of the progenies varied from low to moderate 0.06-5.81 in non-stress while in stress 0.23-7.37 with reasonable genetic advance 0.05-3.51 and 0.14-3.68 under non-stress and water stress conditions.

Seed index (g)

The results for seed index are given in (Table 15) for the genetic parameters viz. GCV, O^2g , $h^2b.s$ and GA. The data revealed that high genetic coefficient of variability was found in SKD-1 $\times$ Kiran (27.95) followed by the cross TD-1 $\times$ TJ-83 (24.48) and TJ-83 $\times$ SKD-1 (23.72) in non-stress conditions while (74.18, 64.86 and 62.90) SKD-1 $\times$ Kiran, TJ-83 $\times$ SKD-1 and Benazir $\times$ SKD-1 under water stress condition. Maximum genetic variability was given by SKD-1 $\times$ Kiran (131.89 and 734.44) under both conditions. Heritability estimates ranging from 0.11-7.82 in non-stress and 0.83-55.03 under stress condition associated with genetic advance varied from 0.08-5.65 and 0.42-35.38 under non-stress and water deficit condition respectively.

Table 13. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies, for grain yield plant⁻¹ grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O^2g)		$h^2b.s$ %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 $\times$ Benazir	14.13	25.50	13.92	19.23	2.00	6.53	0.93	1.97
TD-1 $\times$ TJ-83	15.22	9.91	15.00	3.30	2.32	0.98	1.04	0.32
TD-1 $\times$ SKD-1	10.08	2.33	5.64	0.16	1.02	0.05	0.42	0.02
TD-1 $\times$ Kiran	7.03	7.18	2.88	1.39	0.50	0.52	0.21	0.15
Benazir $\times$ TJ-83	8.85	13.55	5.06	5.14	0.78	1.84	0.35	0.54
Benazir $\times$ SKD-1	24.62	10.07	35.99	2.40	6.07	1.02	2.60	0.28
Benazir $\times$ Kiran	26.67	42.38	45.24	45.76	7.14	17.97	3.16	5.05
TJ-83 $\times$ SKD-1	2.01	5.09	0.23	0.76	0.04	0.26	0.02	0.08
TJ-83 $\times$ Kiran	21.93	11.78	29.62	3.75	4.82	1.39	2.10	0.40
SKD-1 $\times$ Kiran	8.95	11.67	4.06	3.12	0.80	1.36	0.32	0.36

GCV= Genetic coefficient of variability, GV= Genetic variance, $h^2b.s$ = Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

Table 14. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies, for biological yield plant⁻¹ grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O ² g)		h ² .b.s %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 × Benazir	5.37	16.03	7.89	26.90	0.29	2.57	0.27	1.46
TD-1 × TJ-83	14.58	6.67	56.01	5.74	2.13	0.45	1.92	0.28
TD-1 × SKD-1	2.39	12.45	1.38	18.46	0.06	1.55	0.05	0.94
TD-1 × Kiran	8.72	6.52	18.78	4.28	0.76	0.43	0.67	0.24
Benazir × TJ-83	11.55	13.62	36.65	19.42	1.33	1.86	1.23	1.06
Benazir × SKD-1	7.70	10.94	15.16	11.06	0.59	1.20	0.53	0.64
Benazir × Kiran	24.04	27.15	159.40	59.18	5.81	7.37	5.36	3.68
TJ-83 × SKD-1	19.96	4.74	99.27	2.66	4.00	0.23	3.51	0.14
TJ-83 × Kiran	18.01	16.91	81.52	29.76	3.25	2.87	2.86	1.63
SKD-1 × Kiran	10.93	12.76	27.33	14.81	1.20	1.63	1.01	0.86

GCV= Genetic coefficient of variability, GV= Genetic variance, h²b.s.%= Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

Table 15. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies, for seed index grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O ² g)		h ² .b.s %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 × Benazir	11.13	47.91	23.94	264.80	1.24	22.96	0.96	13.72
TD-1 × TJ-83	24.48	59.23	110.67	393.68	6.00	35.09	4.53	20.69
TD-1 × SKD-1	22.82	25.23	89.17	44.13	5.21	6.36	3.79	2.95
TD-1 × Kiran	6.63	55.42	7.69	328.40	0.44	30.73	0.32	17.68
Benazir × TJ-83	17.31	12.24	56.65	12.60	3.00	1.50	2.29	0.77
Benazir × SKD-1	14.73	62.90	38.20	490.21	2.17	39.57	1.60	24.51
Benazir × Kiran	3.26	9.09	1.96	7.01	0.11	0.83	0.08	0.42
TJ-83 × SKD-1	23.72	64.86	92.29	427.20	5.63	42.08	4.01	23.60
TJ-83 × Kiran	12.22	59.60	25.30	374.46	1.49	35.54	1.08	20.30
SKD-1 × Kiran	27.95	74.18	131.89	734.44	7.82	55.03	5.65	35.38

GCV= Genetic coefficient of variability, GV= Genetic variance, h²b.s.%= Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

Harvest index

The results of genetic parameters such as GCV, O²g, h²b.s.% and GA of F₂ progenies are summarized in (Table 16). The results showed a fair amount of genetic coefficient of variability varied from 6.27-141.69 under non-stress while 3.91-63.71 in stress condition associated with maximum genetic variability. In non-stress maximum (1239.14) genetic variability was observed in TD-1× TJ-83 and in stress, maximum (1843.79)

genetic variability was noted in TJ-83 × Kiran whereas, minimum (0.39 and 0.15) heritability estimates in Benazir × TJ-83 under both conditions while maximum (57.95) TD-1 × TJ-83 in non-stress condition and in stress condition (40.70) TJ-83 × Kiran however, genetic advance ranging from 0.30-11.54 and 0.14-48.21 under normal and water deficit condition for harvest index respectively.

Table 16. Genetic coefficient of variability, Genetic variance, heritability and genetic advance of F₂ progenies, for harvest index grown in non-stress and water stress conditions

F ₂ progenies	Genetic parameters							
	GCV		G V (O ² g)		h ² .b.s %		GA	
	N.S	W.S	N.S	W.S	N.S	W.S	N.S	W.S
TD-1 × Benazir	141.69	17.12	15.60	83.44	0.82	2.94	0.63	2.76
TD-1 × TJ-83	75.43	12.84	1239.14	43.72	57.95	1.65	0.63	1.49
TD-1 × SKD-1	36.79	47.46	264.04	727.27	13.57	22.54	10.54	22.54
TD-1 × Kiran	38.08	8.35	294.95	18.98	14.58	0.70	11.54	0.64
Benazir × TJ-83	6.27	3.91	7.35	4.20	0.39	0.15	0.30	0.14
Benazir × SKD-1	10.75	7.25	20.19	13.96	1.16	0.53	0.85	0.48
Benazir × Kiran	9.44	34.18	15.93	375.90	0.89	11.70	0.66	11.67
TJ-83 × SKD-1	17.34	35.26	51.62	352.79	3.02	12.44	2.20	11.66
TJ-83 × Kiran	12.85	63.71	28.80	1843.79	1.66	40.70	1.22	48.21
SKD-1 × Kiran	25.62	7.72	110.75	15.48	6.59	0.60	4.76	0.53

GCV= Genetic coefficient of variability, GV= Genetic variance, h²b.s.%= Heritability in broad sense, GA= Genetic Advance, NS= Non-stress and WS= Water stress

The genetic analysis like genetic coefficient of variability, heritability and genetics advance for traits of wheat genotypes under water stress conditions of F₂ progenies showed that the proportion genetic parameters were greater in non-stress as compared in water stress conditions (Table 9 -19) which indicated that water were more influenced the genetic parameter however low to high heritability were recorded in F₂ populations for all the traits where as in stress conditions all the progenies were also showed low to high heritability along with desirable genetic advance for most of the traits. The present results indicated that material should be utilized for further selection in lateral generations for the development of water tolerant genotypes. Similarly, [17] studied the genetic parameters of F₃ progenies they also observed high heritability along with desirable genetic advance for yield and its associated traits. Further results exhibited that among the F₂ populations, TJ-83 × Kiran recorded maximum genetic variability, heritability and genetic advance for days to 75% heading, harvest index TD-1 × TJ-83 for days to 75% maturity, TD-1 × SKD-1 for plant height, SKD-1 × Kiran for spike length, seed

index, TJ-83 x SKD-1 for spikelets spike⁻¹, grains spike⁻¹, Benazir x SKD-1 for tillers plant⁻¹, Benazir x Kiran for grain yield, biological yield. These populations could be utilized for future breeding programme for the development of water stress tolerant breeding material with improved yield and its contributing traits. Similarly, [18, 19] noted low to moderate broad-sense heritability for yield and its components.

Conclusion

Cultivars like TD-1, Benazir, TJ-83 and Kiran were proved water stress tolerant and F₂ progenies, Benazir x Kiran, TJ-83 × SKD-1, TJ-83 × Kiran and SKD-1 × Kiran performed well under stress environments. The genetic parameters such as genetic coefficient of variability, genetic variance, heritability and genetic advance were higher in non-stress as compared to water stress conditions which indicated that F₂ progenies were more influenced by water stress. Among the progenies TJ-83 × Kiran, TD-1 × TJ-83, TD-1 × SKD-1, SKD-1 × Kiran, TJ-83 × SKD-1, Benazir × SKD-1 and Benazir × Kiran showed high genetic variability, heritability and genetic advance for most of the traits in water stress conditions.

Authors' contributions

Conceived and designed the experiments: WA Jatoi, Performed the experiments: QA Channa, Analyzed the data: S. Memon, AN Chahjro, Contributed materials/ analysis/ tools: MM Lund, MS Kaimkhani, RA Khokhar, AA Bhutto, MH Kaleri & HA Bhattai, Wrote the paper: WA Jatoi.

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