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Water Stress Tolerance in Relation to Yield and its Contributing Traits in Wheat *(Triticumaestivum L.)*

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Abstract

Drought is one of the crucial factors simultaneously deteriorating the wheat yield. To determine the effects of stress,inheritance studiesrevealed a predominant role in screening out drought tolerant genotypes. Presently, six F_2 segregating progenies were exposed to instant drought by withholding irrigations at different growth stages (tillering and booting) of wheat. Significant reduction was observed in different traits during stress. However, some of the progeniesperformed well in such circumstances. The progenies TD-1 x Imdad, TJ-83 ×Khirman, Sarsabz× TJ-83 and Sarsabz× Khirman for the traits plant height (cm), number of tillersm^{-2}, spike length (cm), grains spike $^{-1}$, grain yield kg ha $^{-1}$ elaborated high heritability during tilleringstress. While at booting stress the hybrids TD-1 × Imdad, Sarsabz× TD-1, and Sarsabz× TJ-83 contributed maximum heritability for plant height, number of tillers m^{-2}, spikelets spike $^{-1}$, grain spike $^{-1}$ and spike length (cm).

Keywords: Drought tolerance, morphological traits, heritability, genetic advance, wheat.

1. Introduction

Wheat (*Triticumaestivum L.*) is the largest source of cereal food essential for the diet of millions of people in the world [1,2]. It is mostly cultivated in Asian and European countries, comprising of 72% calories in human diet [3-5]. In Pakistan wheat is grown as a mono-crop and contributes semi-arid and arid regions having no such reliable Indus river irrigation system, mostly comprising of canal system which sometimes enhance drought affecting critical growth stages of wheat. [3,6,7]. Substantially, the alarming global warming has bought up a huge climatic change and the water requirements for agriculture has been increased [6,8]. Nonetheless, these climatic changes enhancing drought is one of the major constraints of abiotic stresses, restricting the growth of wheat crop and enhancing significant reduction in grain yield [9,10].Previous studies have claimed that drought and saline conditions have reduced crop yields averaging for about 17-70% loss in grain yield [2,11] . Hence, drought severity frequently affects plant growth stages boosting from vegetative till reproductive phase [6,12,13]. In this situation suitable wheat genotypes are required that can stabilize in these circumstances and improve grain production [14,15].

Plant under drought stress provide an aggregate response of morphological, physiological and biochemical interactions, controlled by many genes [16,17]. Nevertheless, it has been observed that the metabolic activity of plants is adjusted and maintained accordingly to the environments and depends upon the intensity of stress provided to the crop [5,12,13]. If water is ceased at any stage of wheat, it will simultaneously effect the quantitative traits and eventually reduce the yield production of wheat [5,12,13]. Hence, selection of drought tolerant cultivars through conventional breeding are prerequisite for developing satisfactory yield over a wide range of stress and non-stress environments in which genetic studies can provide a better implementation [7,18-20].

Drought tolerance mechanism leading to drought avoidance is one of the factors emphasizing a tremendous role to the crop plant [5]. Previous studies interpret that suitable germplasm could be achieved by evaluating between optimum and stress conditions, which could identify genotypes controlling drought tolerant alleles [21]. For the prediction of response to selection in diverse environments, the magnitude of genetic inheritance and expected genetic advance is important for breeding programs [22]. Effective breeding program leads to a huge knowledge of gene action and expression of the trait. The choice of the parent and population involves key importance to produce hybrids with desirable trait combinations [23]. The performance and genetic stability of a particular genotype could be determined by using effective statistical parameters such as variances, Phenotypic Coefficient of Variation, Genotypic Coefficient of Variation, Environmental Coefficient of Variation, heritability and genetic advance [3]. Heritability isolates the amount of genotypic variation from phenotypic variation [23]. The utility of heritability therefore increases when it is used to calculate genetic advance, which indicates the degree of gain in a character obtained under a particular selection pressure.

Thus the genetic advance is yet another important selection parameter that aids breeder in a selection program [24].To determine the goals of genetic studies on drought, the aim of the study was to identify reliable wheat genotypes and hybrids under different irrigations,estimating heritability and genetic advance for yield and its associated traits.

2. Material and Methods

2.1. *Experimental site, genotypes and method applied*

To determine the response of drought, an experiment was conducted to examine the effect of drought in some morphological traits.A randomized split plot experimental design was conducted at the experimental field of Latif farm at Sindh Agriculture University, Tando Jam, Hyderabad, Pakistan, subsequently for two years 2011-12 and 2012-13. Genotypes of Pakistan with high yield and good quality traits were selected for the experiment i.eImdad,TD-1, Kiran-95, Khirman, Sarsabz and TJ-83. In the 1^{st} year water was escaped at tillering and booting stages of wheat and the genotypes were exposed to these water irrigations. On the basis of good morphological selection,the genotypes were crossed with each other to produce new combinations with variable differences. Six valuable cross combinations viz. TD-1 × Imdad, Sarsabz × TD-1, TJ-83 × Khirman, Kiran-95 × Khirman, Sarsabz × TJ-83 and Sarsabz × Khirman were produced and in the 2^{nd} generation these crosses were prone to grow under different irrigation stages of wheat.

The genotypes were exposed to three different water treatments as below:

T_1: normal irrigations (all normal or well-irrigated; 5 irrigations applied)

T_2: Stress induced at tillering stage (one irrigation escaped during tillering stage)

T_3: Stress induced at booting stage (one irrigation escaped during booting stage)

2.2. *Morphological Observations recorded*

The morphological traits recorded were number of tillers m^{-2}, plant height (cm), spike length (cm), number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, 1000-grains weight (g) and grain yield (kg ha^{-1}). Plant height was measured in centimeters from soil surface to the tip of the plant at maturity stage. The total numbers of tillers were counted at random at the time of maturity. Total fertile tillers from each plant in each replication of treatment were counted. Length of the spike of main tiller was measured in centimeters from the base of the spike to the upper most spikelet excluding awns. The spikelets of main spikes were computed and averaged at the time of harvest. For grains per spike the numbers of seeds per spike of five randomly tagged spikes were sum up and average numbers of seeds per spike were determined.Thousand grains weight (g) were measured and weighed in grams with the help of electronic balance. Grain yield (kg ha^{-1}) was calculated by using the following formula: Grain yield per plot (kg ha^{-1}) divided by plot size (m^2) multiplied with hectare ($10000m^2$).

2.3*Statistical analysis*

Standard error for difference between means (SED) and Least Significant Difference (LSD) were calculated using the following formula:

$$SED = \left(2EMS / N\right)1/2LSD = \times t\left(0.05\right)df$$

Where EMS = error mean square n = number of replications.

2.4 *Heritability analysis (Genetic parameters)*

The heritability parameters were computed according to [25]

Coefficient of variability $\left(Cv\right) = \dfrac{S.D \times 100}{X}$

Genetic variance $\left(Vg\right) = VF_2 - Ve$

Environmental variance $\left(Ve\right) = \left(VP_1 + VP_2\right)/2$

$$h^2 = \frac{VF_2 - (VP_1 + VP_2)/2}{VF_2} X\,100$$

Genetic advance (GA) = K x (H) x SD

Where, V = variance F_2= forth filial generation, and P = parent.

K= Constant (2.06) for selection difference at 5% selection intensity.

Ve = Environmental variance.

Vg = Genetic variance

Vp_1= Variance of parent one

Vp_2 = Variance of parent two

H = Heritability coefficient

h^2 % = Heritability percentage in broad sense.

S.D = Phenotypic Standard Deviation

GA = Genetic advance.

3. Results and discussion

Drought is considered to be the most deleterious factors that constantly reduce the yield in semi-arid and dry regions [26]. In Pakistan, due to climatic changes the yield of wheat is nowadays affected by these abiotic constraints [13]. Hence such genotypes are required which have the ability to enhance yield production under drought environments. Consequently, the genetic studies including heritability (broad sense) and genetic advance would be meaningful to identify genotypes genetically under drought stress.

All the genotypes and their combinations performed well under control irrigations (T_1=treatment having normal five irrigations), whereas during escape of water at tillering and booting stages the crop varied respectively. The mean of the parents and their F_2 progenies revealed that the trait plant height (cm), significantly decreased at T_3 (65.1cm) showing 33.02% reduction followed by T_2 (75.1cm plant height) as one irrigation was escaped at tillering stage and indicated 15.3% reduction as compared to normal (86.6cm) irrigation (T_1) (Fig 1).Similar results were also reported by [27], who noted that water stress caused significant reduction in plant height, grain number and yield. Number of tillers m^{-2}in all parental lines and F_2 progenies revealed significant reduction (485.2) at T_3 with 5.77% as compared to the normal (513.2) irrigation (T_1). Reduction of 1.46% in number of tillers m^{-2} (505.8) was also seen at T_2 as compared to T_1 (Fig 2). In fact, previously it has been reported that stress during vegetative phase reduce plant height and number of tillers [28]. For spike length (cm), F_2 progenies were significantly reduced (7.5) at T_3 with 109% reduction as compared to the control (15.7) irrigation conditions (T_1). In T_2 the reduction appeared 72.5% for spike length (cm) (9.1) (Fig 3). Subsequently, the results also showed that the grains spike^{-1} in F_2 progenies decreased at T_3 (23.0) with 78.2% reduction having compared with normal (41.0) irrigation (T_1). It seems that in T_2 the crop was drastically reduced in grains spike^{-1} (19.8%) and number of tillers m^{-2} (505.8) as compared to T_1 (Fig 4). Spikelets spike^{-1} was significantly reduced (10.7) at T_3 with 54.2% reduction as compared to (16.5) T_1. Reduction of about 4.43% in T_2 for spikelets spike^{-1} was also observed as compared to T_1 (Fig 5). For 1000-grain weight (g), F_2 progenies were significantly reduced (31.7) in T_2 with 22.7% reduction as compared to (38.9) T_1. Reduction of 5.99% in 1000-grain (g) (36.7) also revealed in T_2 (Fig 6). Similar results have earlier been reported that moisture stress at different stages of plant development will eventually lead to the reduction of weight of the grain [22]. Consequently, grain yield (kg ha^{-1}) significantly decreased at T_3

(1520kg), showing 38.8% reduction followed by T_2 (1605grain yield kg ha^{-1}) and indicated 31.46% reduction (Fig 7). [29]also studied the response of durum and bread wheat genotypes for drought stress, in which biomass and yield was significantly decreased under drought stress conditions.

The heritability percentage (h^2) in broad sense varied drastically in different irrigations. For the trait plant height in T_1 (Treatment 1=normal irrigations) among the six F_2 progenies, Kiran-95 × Khirman showed high heritability and genetic advance, whereas in T_2 and T_3 the wheat combinations viz. TJ-83 × Khirman (h^2%=96.90, GA=11.38) and TD-1 x Imdad (h^2%=86.0, GA=12.80) attained better performance under stress environments (Table 1). Substantially, other progenies influenced moderate to low heritability with GA under stress environments, which seem that they were affected by one escape of irrigation at tillering and booting stages. The progenies Sarsabz × Khirman (h^2%=82.58, GA=22.20) in T_2 and Sarsabz x TD-1 in T_3 (h^2%=88.0, GA=7.30) seem to exhibit high heritability percentage with genetic advance during water stress conditions (Table 1). Previous .studies have reported that tillers per plant are a drought affiliated trait and for the number of tillers transgressive hybrids are vulnerable on the genetic expression of their parents [22,30] . Different traits attribute disparate results in each progeny, as for the trait spike length (cm) and spikelets $spike^{-1}$the progeny TD-1 ×Imdad revealed maximum heritability with GA followed by the progeny TJ-83 × Khirman during stress at booting stage (T_3). However, escape at tillering stage (T_2) the genetic variability for spike length (cm) character seem to have progenies with moderate to low heritability reflecting adverse effects during stress conditions (Table 1&2). Low heritability determines that selection for a particular trait may be not effective due to predominant effects of non-additive genes in the population [31].

On the other hand for the parameter number of grains $spike^{-1}$ the progeny TJ-83 × Khirman profound to have the utmost inheritance as compared to other progenies with a 87.12 h^2% and 17.20 GA at T_2 (escape of irrigation at tillering stage) and T_3 revealed moderate to low heritability for this trait. In 1000 grains weight (g) extreme heritability with 97.5 h^2% coupled with high genetic advance (GA=9.50) was seen by the progeny Sarsabz×Khirman, whereas stress at booting stage influenced moderate to low heritability and genetic advance (Table 2). [32]have reported that every critical stage of crop is sensitive to drought, as in wheat 20-30 days before anthesis and 10 days after anthesis is more crucial when the grain sink is being developed and at that time plant photosynthesis is required more. Dramatically, it has been observed that drought stress during heading till grain filling periods results in infertile spikes and produce less number of grains per spike attaining low productivity [26]. Despite to this situation heritability of a trait represents the efficacy of the variety on the phenotype affiliated with the genotype of the individual and is effective in a certain environment [26]. Grain yield is a polygenetic trait [26], while water is the main factorto get better crop yields. Hence, alteration will elaborate in the crop due to different water intervals and the yield may fluctuate or reduce. Grain yield (kg ha^{-1}) in six F_2 segregating progenies ranged from 26.6% in TJ-83x Khirman to 96% in Sarsabz × Khirman at T_1, 50.33% in Sarsabz × TD-1 to 90.2% in Kiran-95 x Khirman at T_2 and 52.4% in Kiran-95 × Khirman to 77.24% in Sarsabz × Khirman at T_3(Table 3). Similar findings were also attributed by some researchers [23,30,33] who declared that some wheat cultivars adopt themselves in stress environments and obtain higher yields.

Despite to the worst effect of stress environments some genotypes/hybrids can tolerate in severe conditions interpreting with significant yields and consisting of good inherited characters. Such tolerant genotypes could be advisable to drought prone regions where rainfall is less. In conclusion, the genotypes/hybrids which accounted for high yield under drought escape at tillering and booting stress using heritability estimates can be considered to esteem for future breeding programs. It has been observed from the present study that different segregating cross progenieshad different patterns of inheritance for grain yield and its contributing traits. Four progenies TJ-83 × Khirman, TD-1 x Imdad, Sarsabz × Khirman and Sarsabz × TD-1 had proven to be the best combiners for genetic parameters. Some of the progenies revealed low heritability probably due to non-additive gene effects. Hence, transfer of desirable genes from parents to their offspring indicated more effective selection from segregating progenies.

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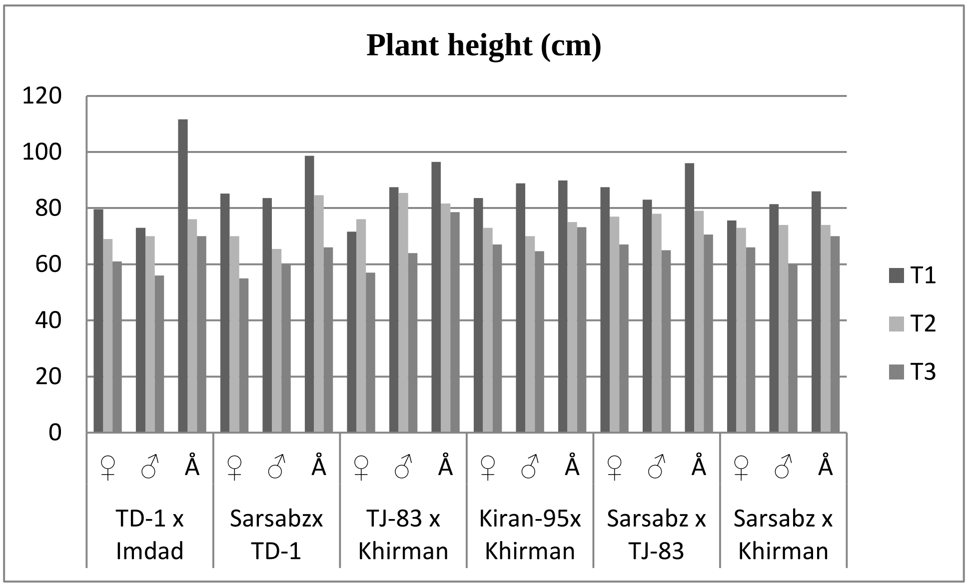
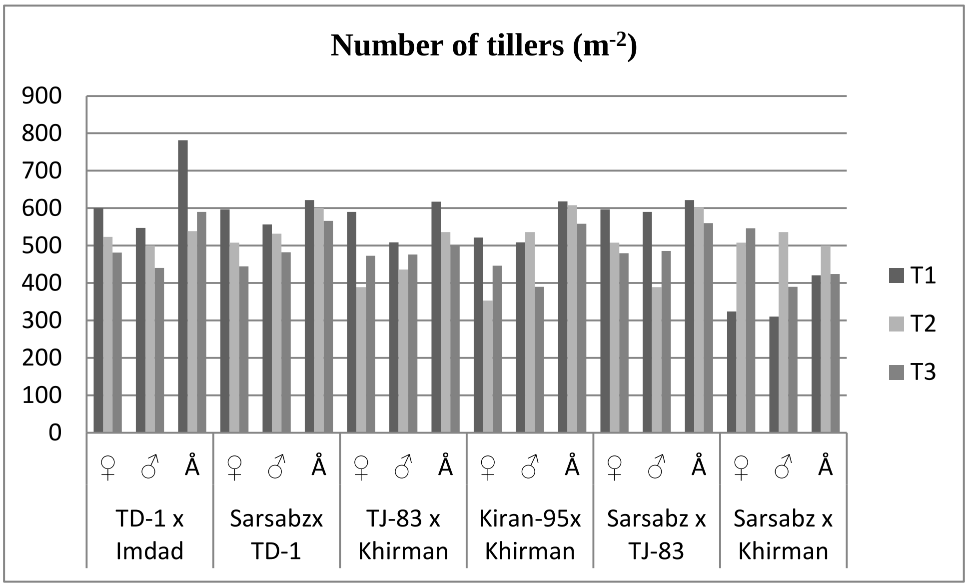
Fig 1.Mean performance of six F_2 progenies and their respective parental lines of wheat for plant height (cm) at different irrigations.



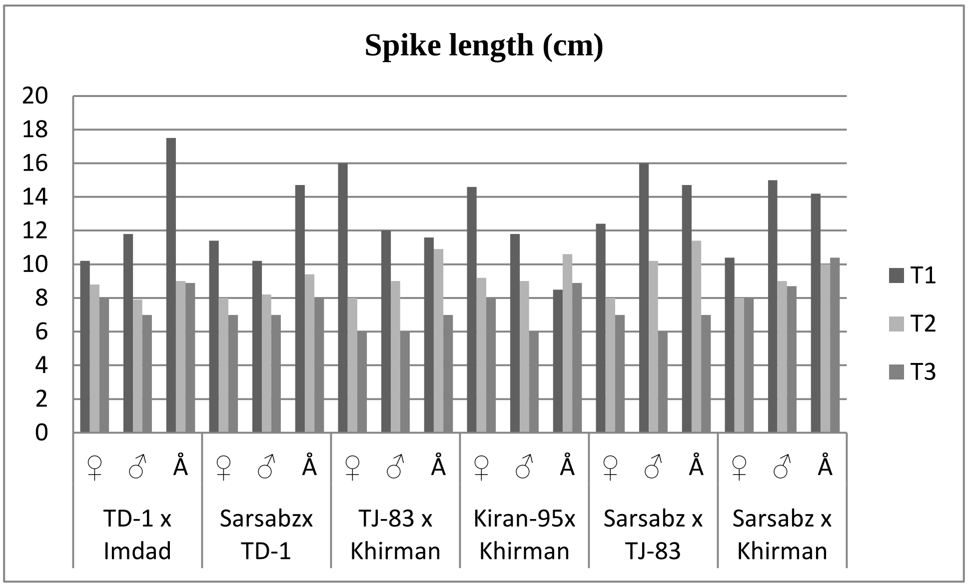
T_1=normal irrigations; T_2= one irrigation escaped at tillering stage; T_3=one irrigation escaped at booting stage

Fig 2. Mean performance of six F_2 progenies and their respective parental lines of wheat for number of tillers (m^{-2}) at different irrigations



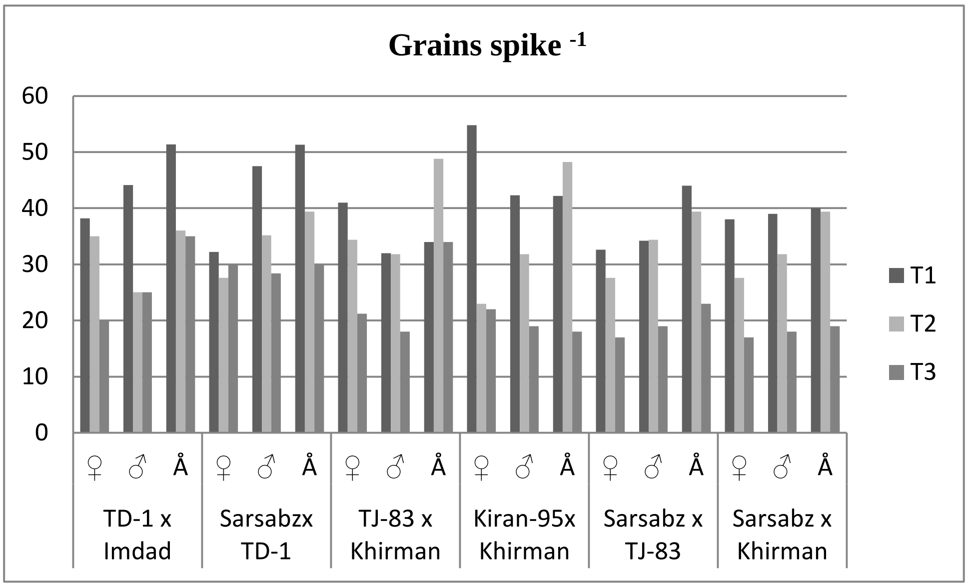
T_1=normal irrigations; T_2= one irrigation escaped at tillering stage; T_3=one irrigation escaped at booting stage

Fig 3.Mean performance of six F_2 progenies and their respective parental lines of wheat for number of spike length (cm) at different irrigations.



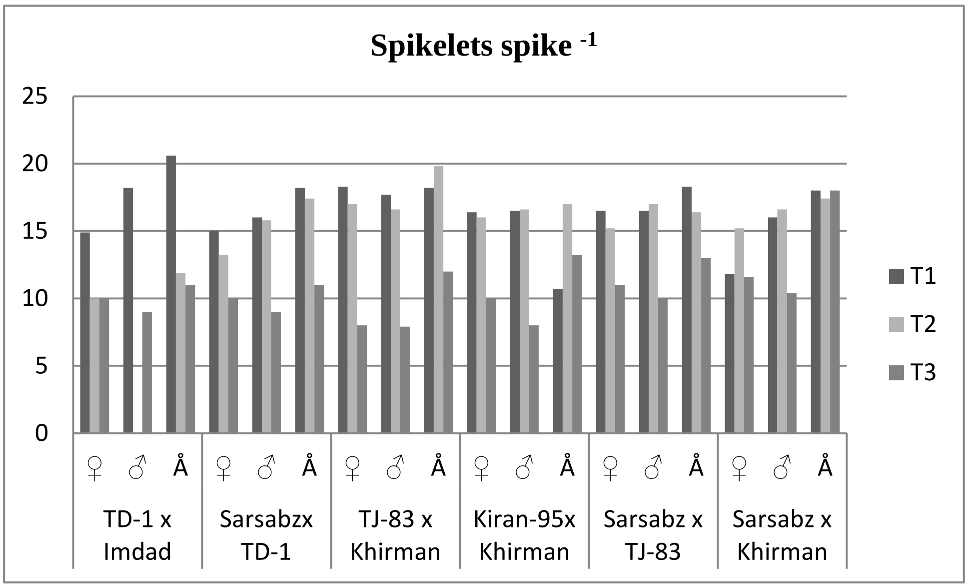
T_1=normal irrigations; T_2= one irrigation escaped at tillering stage; T_3=one irrigation escaped at booting stage

Fig 4.Mean performance of six F_2 progenies and their respective parental lines of wheat grains spike^{-1} at different irrigations.



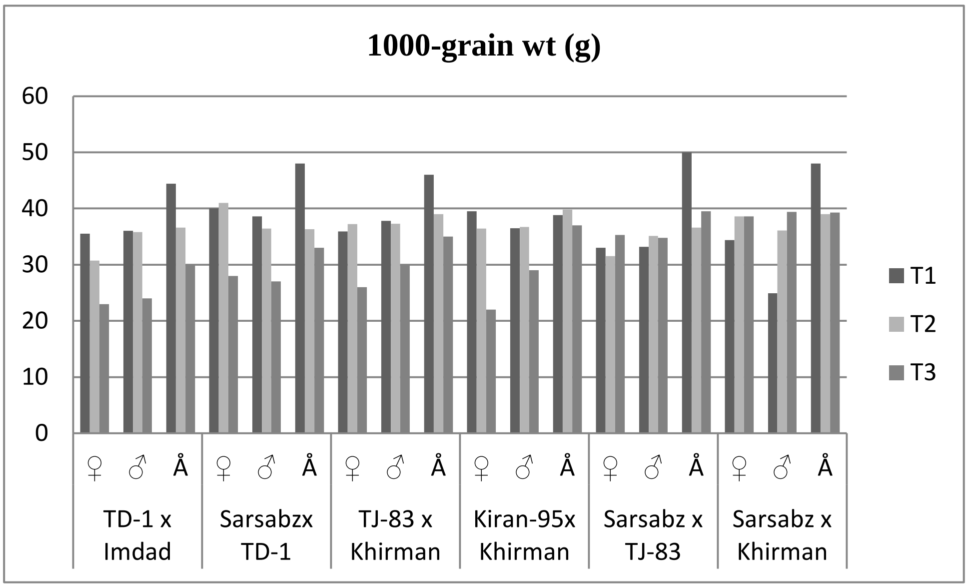
T_1=normal irrigations; T_2= one irrigation escaped at tillering stage; T_3=one irrigation escaped at booting stage

Fig 5.Mean performance of six F_2 progenies and their respective parental lines of wheat for spikelets spike $^{-1}$ at different irrigations.



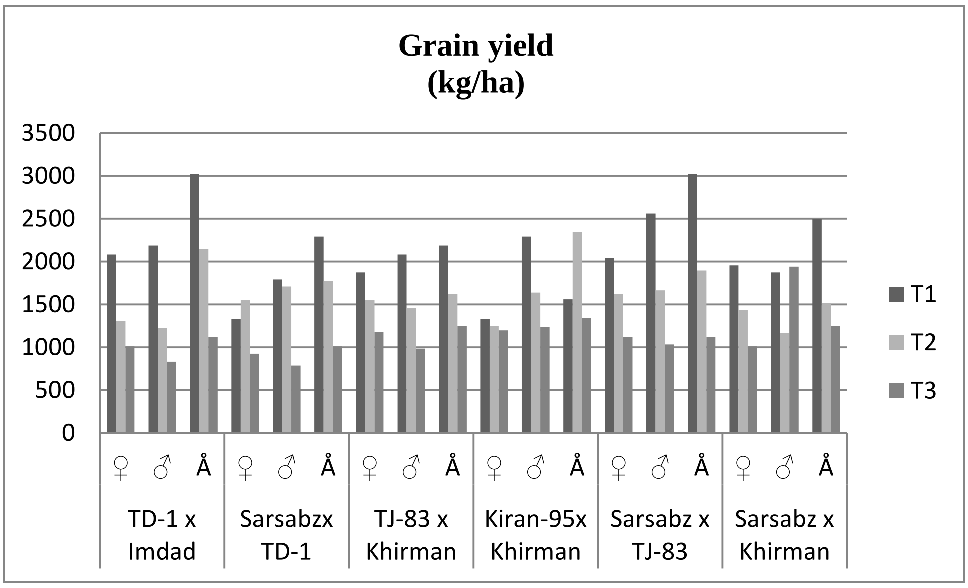
T_1=normal irrigations; T_2= one irrigation escaped at tillering stage; T_3=one irrigation escaped at booting stage

Fig 6.Mean performance of six F_2 progenies and their respective parental lines of wheat for1000-grain wt (g) at different irrigations.



T_1=normal irrigations; T_2= one irrigation escaped at tillering stage; T_3=one irrigation escaped at booting stage

Fig7.Mean performance of six F_2 progenies and their respective parental lines of wheat forgrain yield (kg ha^{-1}) at different irrigations.



T_1=normal irrigations; T_2= one irrigation escaped at tillering stage; T_3=one irrigation escaped at booting stage

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Table-1.Genetic parameters involving heritability percentage (h^2% broad.sense) and genetic advance (GA) for some morphological traits of 6 F_2 progenies at different irrigations.

F_2 progenies	Plant height (cm)						Number of tillers m^2						Spike length (cm)					
	T1		T2		T3		T1		T2		T3		T1		T2		T3	
	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA
TD-1 x Imdad	44.75	3.40	10.50	1.01	86.0	12.80	89.0	36.0	72.80	8.60	84.0	8.0	45.88	0.20	50.0	0.72	93.0	0.94
Sarsabz x TD-1	73.70	10.30	47.90	5.72	70.19	7.80	64.30	19.10	45.60	12.30	88.0	7.30	55.88	1.49	45.0	0.92	50.0	1.03
T.J-83 x Khirman	79.56	11.40	96.90	11.38	42.96	6.90	31.45	15.35	43.80	5.0	81.0	7.20	38.83	0.23	66.0	3.50	91.35	4.29
Kiran-95 x Khirman	88.90	7.30	57.26	5.04	40.18	2.46	84.0	29.64	67.38	6.80	55.4	2.0	70.0	1.83	19.33	3.74	89.72	2.58
Sarsabz x T.J 83	81.35	11.9	83.30	9.90	80.0	7.71	93.0	33.40	81.64	21.90	61.28	5.84	37.30	0.31	66.08	21.09	40.0	0.82
Sarsabz x Khirman	83.58	11.9	78.27	9.33	25.80	0.90	78.90	26.90	82.58	22.20	29.84	3.80	48.80	1.30	60.0	3.92	65.0	1.33

T1 (normal irrigation), T2 (escape of irrigation at tillering stage) and T3 (escape of irrigation at booting stage) .

ISSN 2348 – 7968

Table-2.Genetic parameters involving heritability percentage (h^2% broad.sense) and genetic advance (GA) for some morphological traits of 6 F_2 progenies at different irrigations.

F_2 progenies	Spikelets spike^{-1}						Number of grains spike^{-1}						1000-grains weight (g)					
	T1		T2		T3		T1		T2		T3		T1		T2		T3	
	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA	h^2%	GA
TD-1 x Imdad	16.25	0.25	81.72	4.0	84.0	3.60	20.05	2.15	37.0	8.72	54.93	5.31	73.3	5.70	75.0	5.71	46.0	4.7
Sarsabz x TD-1	12.5	0.15	68.86	3.22	75.0	2.10	53.66	8.09	75.15	9.64	10.58	0.632	86.0	8.37	14.6	0.60	50.0	2.78
T.J-83 x Khirman	19.54	1.16	79.80	3.40	82.69	3.74	40.0	3.378	87.12	17.20	33.85	2.44	30.0	1.70	43.3	3.30	94.0	10.41
Kiran-95 x Khirman	47.39	2.98	19.23	0.98	28.12	0.98	27.95	3.28	67.17	7.04	44.85	4.52	86.9	8.17	20.2	1.50	24.0	3.52
Sarsabz x T.J 83	7.40	0.30	66.03	3.75	75.0	2.70	72.46	10.9	70.8	7.65	26.47	1.58	73.3	7.13	43.5	3.30	20.0	1.11
Sarsabz x Khirman	69.2	9.27	18.80	0.08	55.0	1.50	63.73	9.58	66.49	8.48	55.88	3.38	55.12	12.8	97.5	9.50	53.0	3.9

T1 (normal irrigation), T2 (escape of irrigation at tillering stage) and T3 (escape of irrigation at booting stage) .

Table-3.Genetic parameters involving heritability percentage (h^2% broad.sense) and genetic advance (GA) for grain yield (kg ha^1) trait of 6 F_2 progenies at different irrigations.

F_2 progenies	Grain yield (kg ha^{-1})					
	T1		T2		T3	
	h^2%	GA	h^2%	GA	h^2%	GA
TD-1 x Imdad	78.5	10.13	86.9	13.9	53.44	16.2
Sarsabz x TD-1	80.3	10.8	50.33	5.5	62.42	10.09
T.J-83 x Khirman	26.88	6.88	56.70	6.4	70.0	36.2
Kiran-95 x Khirman	58.47	24.1	90.2	24.4	52.4	12.95
Sarsabz x T.J 83	94.2	12.71	77.59	12.5	65.1	26.8
Sarsabz x Khirman	96.0	14.3	88.5	18.8	77.24	38.1

T1 (normal irrigation), T2 (escape of irrigation at tillering stage) and T3 (escape of irrigation at booting stage) .