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Research Article

Morpho-physiological responses in wheat (*Triticum aestivum L*) influenced by normal and water stress conditions

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Abstract

Drought is a disaster around the world accumulating salt and erosion in lands. Presently, a research was conducted to determine the morpho-physiological response in bread wheat under normal and stress irrigations. This experiment was conducted at the experimental field of Sindh Agriculture University, Tandojam, Hyderabad, Pakistan, for two consecutive years during the Rabi season of the year 2011-12 and 2012-13. Stress was imposed by withholding irrigations at three different growth stages of the plant, i.e. T_1: normal irrigations applied, T_2: stress at tillering stage, and T_3: stress at the booting stage. The progenies Sarsabz x Khirman and Sarsabz x TD-1 contributed the highest heritability% (81.0% and 85.5%) for osmotic potential (-MPa) at stress at booting stage. For grain yield spike^{-1}(g), the progeny Kiran-95 x Khirman showed maximum heritability as 84.37 in T_3. However, the progeny TD-1 x Imdad proved to be the best combiner progeny indicating highest heritability percentage (91.0%) among the progenies for grain yield at booting stress.

Introduction

Bread wheat is the primary source of human food containing high protein content than other major cereal crops (Chen et al., 2012). Wheat is considered not only the major cereal crop of the world, but it is also the critical staple

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food of inhabitants of Pakistan (Mirbahar et al., 2009). Pakistan experiences a variety of climate, and one-third of the total acreage is rainfed areas (Mirbahar et al., 2009). Due to climatic change and increase in temperature the wheat crop is being affected and addressed at the global level (Sial et al., 2012). Drought threat may emerge to low productivity and limit the plant growth (Simova-Stoilova et al., 2006; Khan and Naqvi, 2011; Xu et al., 2018).

Drought tolerance cannot be considered as a simple response to the plant, but some components interact with each other and may vary at different crops, also my response to different types, intensity, and duration of water deficit (Gajewska et al., 2018). Many investigators have suggested that drought stress tolerance can be studied through genetic improvement of physiological traits, also including essential traits such as harvest index and biological yield (Mohammadi et al., 2006). Drought stress directly affects biochemical, and physiology of the plant and the changes is observed by the variable decline of the leaf relative water content (RWC) which is a better indicator of plant water status (Siddique et al., 2000; Vicente et al., 2018). Previous studies have reported that any alteration in the environmental parameters will change the genetic architecture of the traits (Zhang et al., 2018; Li et al., 2018).

Breeding and selection of high heritable traits that provide tolerance to drought will provide valuable information to the breeders to predict the interaction of genes in segregating populations under stress environments (Jatoi et al., 2011; Khan and Naqvi, 2011; Sial et al., 2013). Statistical parameters such as variance, heritability, and genetic advance are a useful measure to evaluate genetic stability and performance of any genotype of a particular trait in that genotype (Firouzian, 2003). The suitable criteria of the crop for selecting high yield performance are low yield, mean productivity and relative yield performance in drought and more favorable environments (Ahmad et al., 2003). Hence, heritability, therefore, increases when it is used to calculate genetic advance, which indicates the degree of gain in character obtained under particular selection pressure (Shukla et al., 2004). Keeping given the above findings, some physiological and phonological parameters were studied to observe the response of the genotypes/hybrids under water stress and non-stress environments.

Materials and methods

Plant materials

Six different bread wheat local cultivars were used for this experiment having high yield and good quality traits. Furthermore, in the second year, six valuable cross combinations viz. TD-1 × Imdad, Sarsabz × TD-1, TJ-83 × Khirman, Kiran-95 × Khirman, Sarsabz × TJ-83 and Sarsabz × Khirman were study.

Experiment design and planting method

The experiment was conducted at Latif farm, the experimental field of Sindh Agriculture University, Tandojam, Hyderabad, Pakistan, for two years during the Rabi season of the year 2011-12 and 2012-13. The innovative design was split plot design along with three replications. In the first-year irrigation was escaped at different stages of growth cycle. In the 2nd generation the crosses developed were grow into assess under different irrigation stages of wheat, evaluating under water stress and non-stress conditions. All agronomical practices such as weeding, rouging was performed as usual for parental lines and offsprings and all were equally treated.

Data analysis and observations to be recorded

Genotypic variance, environmental variance, heritability percentage in broad sense, heritability coefficient was calculated as suggested by (Falconer, 1984).

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

T_1 : normal irrigations all normal or well-irrigated; 5 irrigations

T_2 : Stress induced at tillering stage

T_3 : Stress induced at booting stage

The physiological and phonological traits including leaf area (cm^2), relative water content (%), osmotic potential (-MPa), biological yield (Kg ha^{-1}), harvest index (%) and grain yield/spike (g) were recorded and studied.

Statistical analysis

The entire data was statistically analyzed using Analysis of variance (ANOVA) according to (Gomez & Gomez, 1984). All the data was statistically analyzed, standard error for difference between means (SED) and Least Significant Difference (LSD) were calculated using the following formula: SED = (2EMS/N) ½ LSD = SED × t (0.05) df

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

t (0.05) df = value from the t distribution table at 5% probability level and error degree of freedom. Significance levels are shown in the tables at 0.05%, and 0.01% probability levels, respectively. The non-significant differences are mentioned as N.S.

Results and discussion

In the present study, the results of mean performance for the trait biological yield (Kg ha^{-1}) have indicated that F_2 progenies were significantly decreased (2737 biological yield kg ha^{-1}) in T_3 with 107.0% reduction as compare to T_1, i.e., normal irrigations (Figure 1, 3822 biological yield kg ha^{-1}). Harvest index % reduced with 13.8% in T_2 and 37.4% in T_3 as compared to T_1 (Figure 2). From previous studies it has been observed that the harvest index (%) and biological yield (Kg ha ^{1}) decreased under drought stress conditions (Sial et al., 2010). Moreover, drought stress reduces crop yield regardless of the growth stage at which it occurs in wheat (Ma et al., 2012; Li et al., 2018). The results regarding grain yield (g) depicted the significant decrease in F_2 generation in T_3 (1.0g) which showed reduction (70%) followed by T_2 (Figure 3). Consequently, the physiological traits were also observed to be affected in the F_2 progenies. Relative water content % significantly reduced with 28.9% and 8.0% in T_3 and T_2 respectively, as compared to normal irrigation T_1 (Figure 4). Whereas leaf area (cm^2) and Osmotic potential (-MPa) showed reduction of 34.2% and 25.6% in T_3 as compared to T_1 (Figure 4 & Figure 5). Different studies on water relations under drought effects have declared that water stress at vegetative and anthesis stages both directly leads to decrease in leaf water potential and relative water content (Siddique et al., 2000).

Accordingly, the genetic parameters studied under drought and non-stress conditions revealed a variable response to the physiological and phonological traits. The physiological trait leaf area (cm^2) profound to have high heritability (b.s) in the progenies TD-1x Imdad, TJ-83 x Khirman and Sarsabz x TJ-83 (85.0, 83.3, 80.0%) coupled with more genetic advance in T_1. In T_2, moderate to low heritability was presented reflecting drought stress effect during this stage. Sarsabz x TD-1 (54.9%), Sarsabz x Khirman (54.2) and Sarsabz x TJ- 83 (54.0) progenies considered to have moderate heritability % in T_2. In T_3 also TD-1 x Imdad and Sarsabz x Khirman (58.3, 58.0) revealed moderate heritability% with genetic advance (Table 1). For the trait relative water content %, maximum heritability% was seen in the progeny Sarsabz x TD-1 coupled with more genetic advance (h^2%=78.0, GA=6.9) in T_1. Plants coping with higher RWC under drought stress conditions are mentioned to have high and medium yields, whereas decrease in RWC depends on the plant vigor reduction (Arjenaki et al., 2012). With the trait osmotic potential (-MPa), highest heritability % was revealed in T_1 by two progenies, Sarsabz x TD-1 (85.5%) and Sarsabz x Khirman (81.0%). In T_2 almost all the progenies revealed high heritability % coupled with genetic advance except Kiran-95 x Khirman (15.0), emphasizing low osmotic potential (-MPa). However, in T_3 Sarsabz x Khirman and Sarsabz x TD-1 (87.0, 83.0) contributed maximum heritability percentage, while others revealed moderate to low heritability with genetic advance in T_3 for osmotic potential (-MPa) (Table 3).

In T_1, heritability % for biological yield (Kg ha^{-1}) in F_2 segregating progenies range from 43.7% in Kiran-95 x Khirman to 89.3% in TJ-83 x Khirman (Table 4). In this trait the progenies Sarsabz x TD-1, Sarsabz x TJ-83, TD-1x Imdad, and TJ-83 x Khirman showed the highest heritability (b.s) coupled with more genetic advance. Whereas in T_2 the heritability percentage (h^2) ranged from 44.44% to 80.5% in Sarsabz x TD-1 and TD-1 x Imdad, respectively.

Three progenies TD-1 x Imdad, TJ-83 x Khirman and Sarsabz x Khirman attributed maximum heritability (b.s) i.e., 80.5, 70.66 and 75.0% with genetic advance (G.A 46.3, 7.27, and 8.88 %) in T_2, respectively. At stress during booting stage (T_3) Sarsabz x Khirman and Kiran-95 x Khirman provided maximum heritability (b.s %) with genetic advance (80%) revealing that these progenies tolerated with high inheritance for biological yield trait (Table 4). Subsequently, for harvest index % the heritability found to be more in three progenies viz TJ-83 x Khirman (84.2%), Sarsabz x TJ-83, (63.8%) and Sarsabz x Khirman (93.7%) in T_1. In T_2 and T_3 Kiran-95 x Khirman displayed maximum heritability indicating that the genetic variability has been successfully produced for this particular trait in F_2 progeny (Table 5).

Grain yield, a complex quantitative trait (Moghadam et al., 2014) showed high heritability in the progeny TJ-83 x Khirman (86.8%) in T_1. Regarding T_2 and T_3 Kiran-95 x Khirman (69.47%) and TD-1 x Imdad (91.0%) exhibited maximum heritability, in stress conditions. Similarly, other progenies influenced moderate to low heritability with genetic advance under stressed environments, which seems that they were affected by one escape of irrigation at either tillering or booting stages (Table 6). Hence, it can be suggested that those genotypes/hybrids integrating high heritability with genetic advance under stress environments may control tolerant genes and could be implied for further breeding programs. The physiological and morphological traits have a great interaction between them concerned with yield production as previous investigations declare that high osmotic potential and other physiological traits is concerned directly with high yield (Sial et al., 2010).

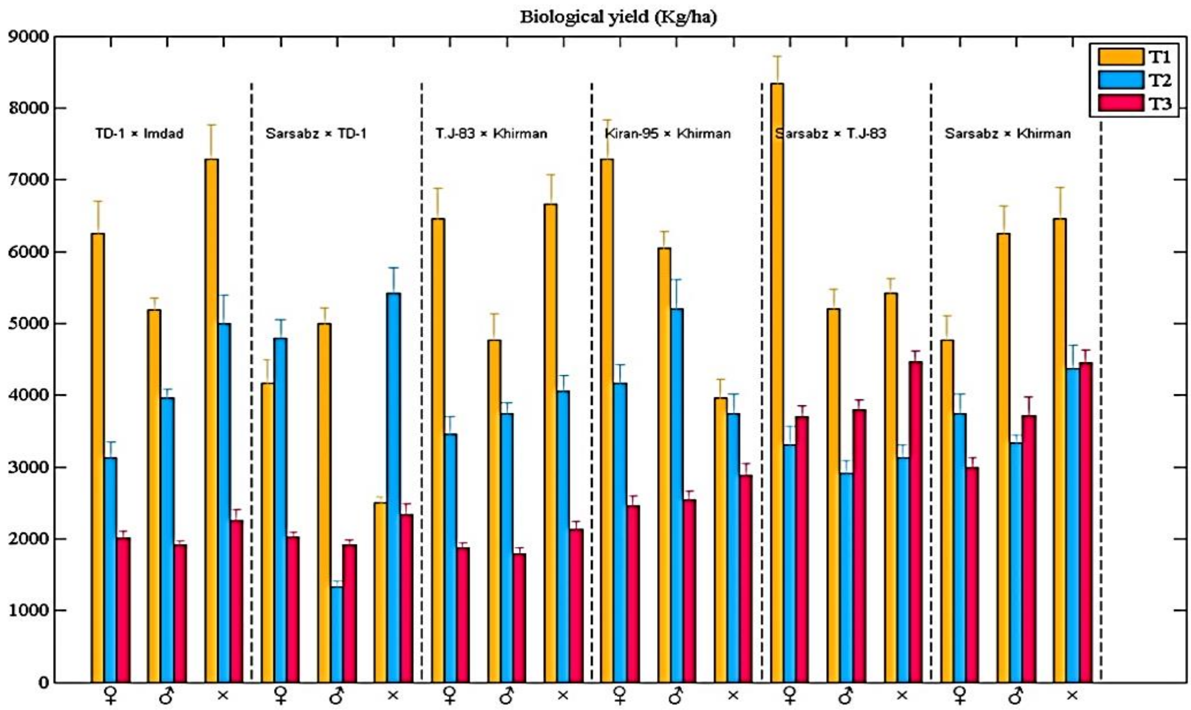

Figure 1. Reduction (%) values of six F_2 progenies and their respective parental lines of wheat for biological yield (Kg ha^{-1}) at different irrigations

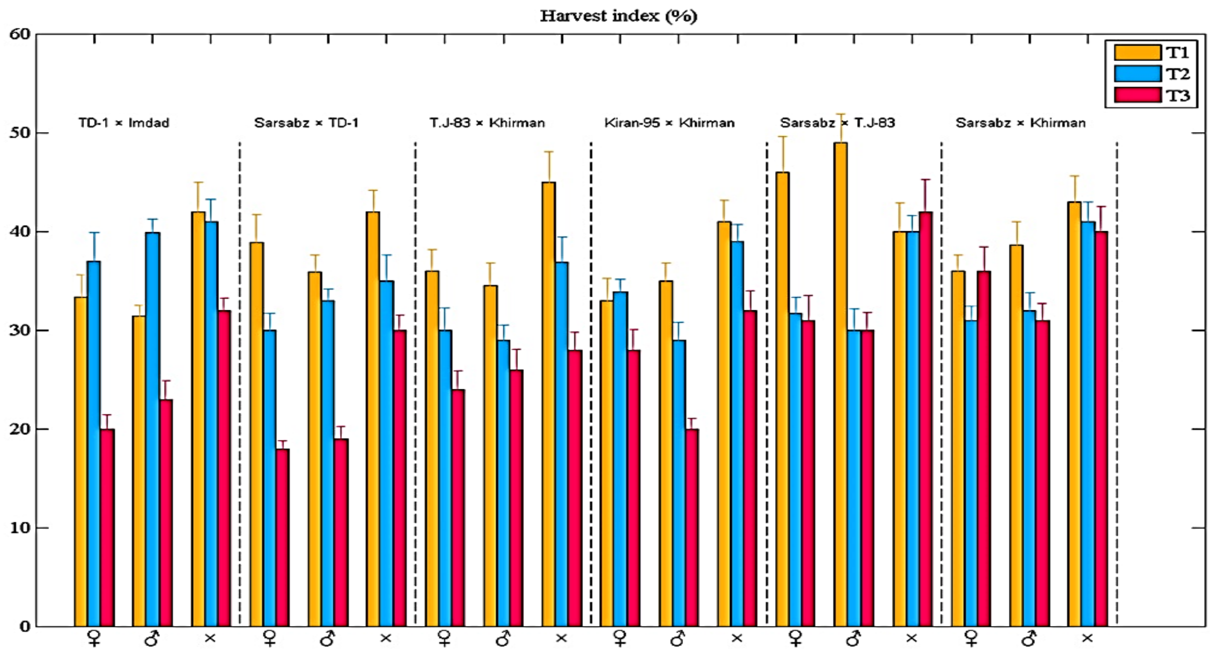

Figure 2. Reduction (%) values of six F_2 progenies and their respective parental lines of wheat for harvest index (%) at different irrigations

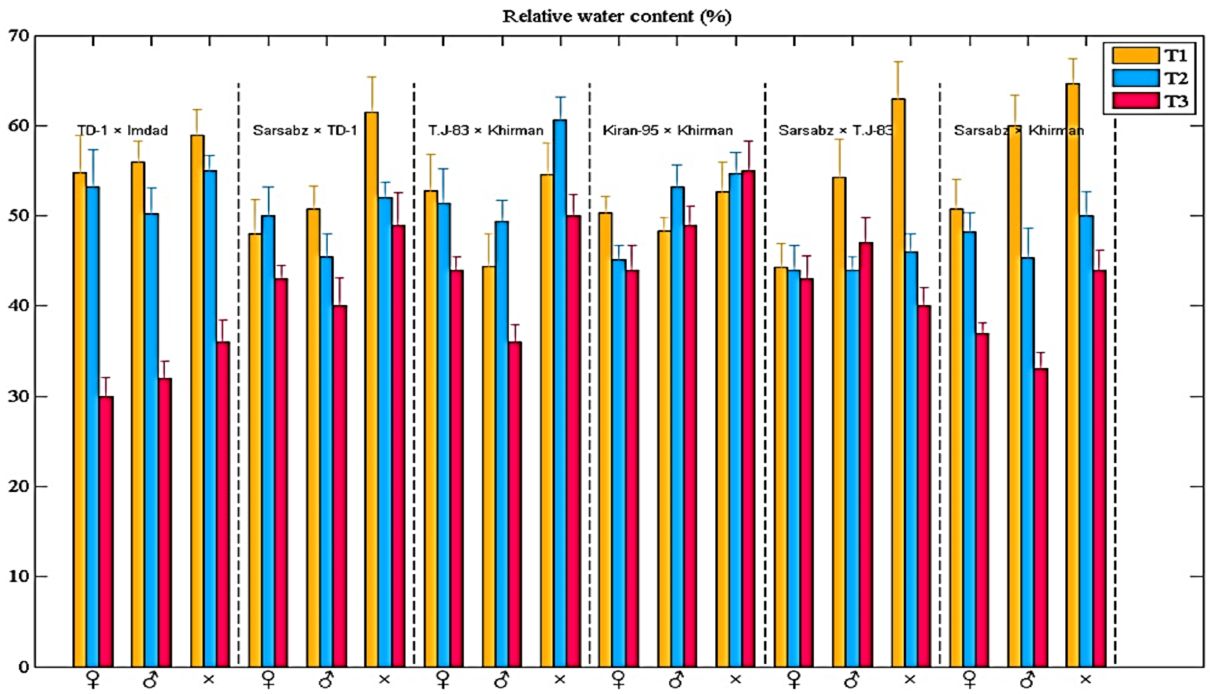

Figure 3. Reduction (%) values of six F_2 progenies and their respective parental lines of wheat for relative water content (%) at different irrigations

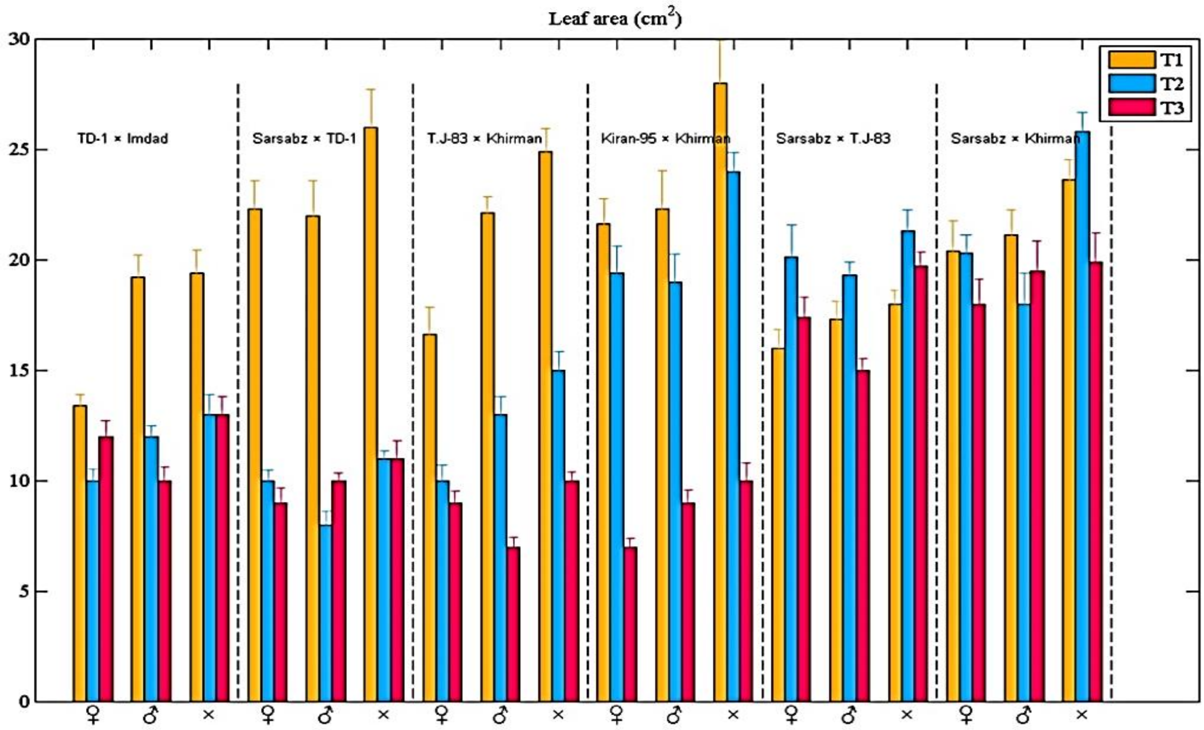

Figure 4. Reduction (%) values of six F_2 progenies and their respective parental lines of wheat

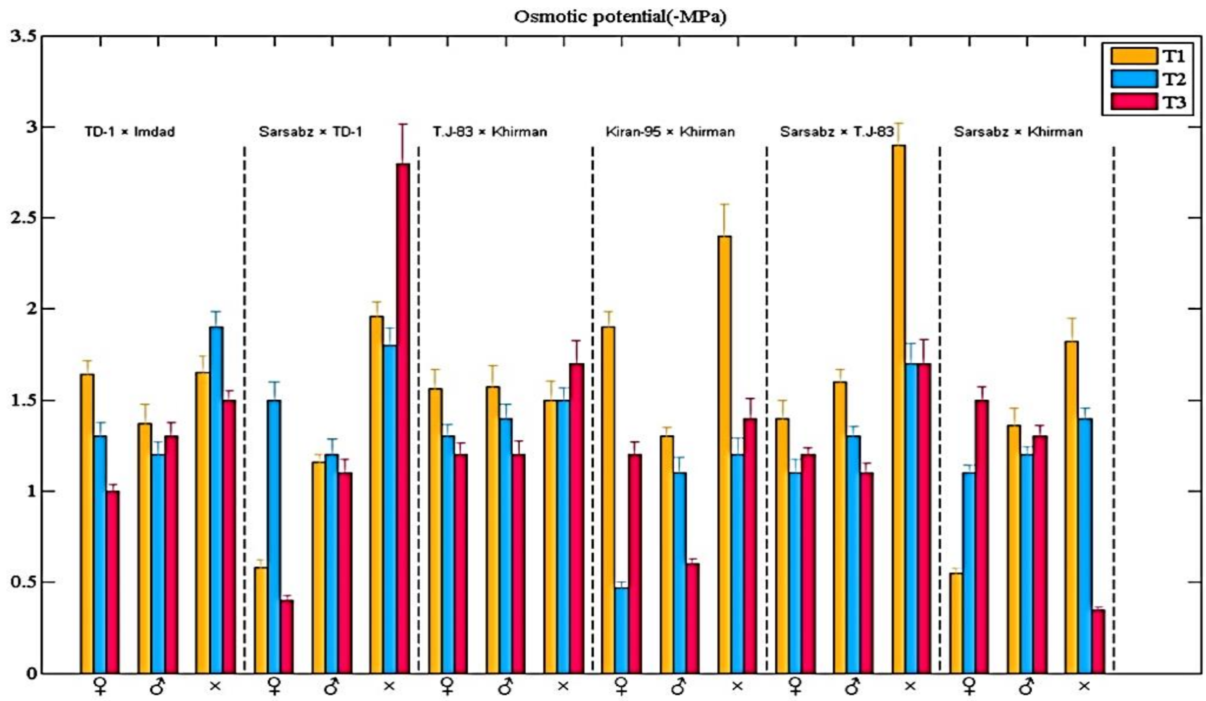

Figure 5. Reduction (%) values of six F_2 progenies and their respective parental lines of wheat for osmotic potential (-MPa) at different irrigations

Table 1. Heritability percentage (h^2 % broad. sense) and genetic advance (GA) of six F_2 progenies in wheat for leaf area (cm^2)

F_2 progenies	Leaf area (cm^2)					
	T_1		T_2		T_3	
	h^2 %	GA	h^2 %	GA	h^2 %	GA
TD-1 x Imdad	85.00	7.5	16.60	0.5	58.30	2.1
Sarsabz x TD-1	72.00	5.1	54.90	2.6	45.80	2.2
TJ-83 x Khirman	83.30	2.9	33.30	1.4	41.50	2.0
Kiran-95 x Khirman	70.80	3.5	12.50	0.3	25.00	0.7
Sarsabz x TJ- 83	80.00	5.7	54.00	2.6	16.60	0.8
Sarsabz x Khirman	78.00	5.6	54.20	2.6	58.00	2.8

Table 2. Heritability percentage (h^2 % broad. sense) and genetic advance (GA) of six F_2 progenies in wheat for Relative water content (%)

F2 progenies	Relative water content (%)					
	T_1		T_2		T_3	
	h^2 %	GA	h^2 %	GA	h^2 %	GA
TD-1 x Imdad	38.40	1.9	76.60	4.2	76.00	7.0
Sarsabz x TD-1	78.00	6.9	58.30	2.8	62.50	6.1
TJ-83 x Khirman	18.20	0.8	60.00	1.8	44.40	1.9
Kiran-95 x Khirman	88.00	8.4	70.00	2.9	77.20	9.0
Sarsabz x TJ- 83	86.50	7.6	58.30	2.8	47.30	2.9
Sarsabz x Khirman	68.40	6.0	62.00	3.0	44.70	2.7

Table 3. Heritability percentage (h^2 % broad. sense) and genetic advance (GA) of six F_2 progenies in wheat for Osmotic potential (-MPa)

F_2 progenies	Osmotic potential (-MPa)					
	T_1		T_2		T_3	
	h^2 %	GA	h^2 %	GA	h^2 %	GA
TD-1 x Imdad	50.00	0.2	97.00	0.4	42.00	0.2
Sarsabz x TD-1	85.50	0.5	96.00	1.0	83.00	0.8
TJ-83 x Khirman	35.00	0.1	80.60	0.5	44.40	0.5
Kiran-95 x Khirman	35.00	0.4	15.00	0.0	73.00	0.6
Sarsabz x TJ- 83	36.10	0.3	96.20	0.9	66.00	0.7
Sarsabz x Khirman	81.00	0.5	80.90	0.8	87.00	1.0

Note: low heritability: less than 0.20; moderate heritability: scores of 0.21; 0.40;
High heritability: scores above 0.40

Table 4. Heritability percentage (h^2 % broad. sense) and genetic advance (GA) of six F_2 progenies in wheat for Biological yield (Kg ha^{-1})

F_2 progenies	Biological yield (Kg ha^{-1})					
	T_1		T_2		T_3	
	h^2 %	GA	h^2 %	GA	h^2 %	GA
TD-1 x Imdad	74.00	26.1	80.50	46.3	68.00	8.9
Sarsabz x TD-1	80.00	23.4	44.44	7.4	23.80	1.9
TJ-83 x Khirman	89.30	49.0	70.66	7.2	66.00	15.0
Kiran-95 x Khirman	43.70	10.3	67.80	4.7	99.00	29.0
Sarsabz x TJ- 83	76.00	8.8	50.44	2.8	80.00	21.0
Sarsabz x Khirman	60.00	7.3	75.00	8.8	98.00	22.0

Table 5. Heritability percentage (h^2 % broad. sense) and genetic advance (GA) of six F_2 progenies in wheat for Harvest index (%)

F_2 progenies	Harvest index (%)					
	T_1		T_2		T_3	
	h^2 %	GA	h^2 %	GA	h^2 %	GA
TD-1 x Imdad	25.00	1.2	86.00	7.8	55.60	7.4
Sarsabz x TD-1	59.90	13.9	73.00	8.2	57.70	8.8
TJ-83 x Khirman	84.20	15.6	26.20	3.4	21.00	1.9
Kiran-95 x Khirman	49.80	7.0	89.00	9.8	78.00	9.4
Sarsabz x TJ- 83	63.80	14.8	26.20	3.4	41.30	9.1
Sarsabz x Khirman	93.70	9.0	38.30	4.3	58.00	8.9

Table 6. Heritability percentage (h^2 % broad. sense) and genetic advance (GA) of six F_2 progenies in wheat for Grain yield spike[1] (g)

F_2 progenies	Grain yield spike[1] (g)					
	T_1		T_2		T_3	
	h^2 %	GA	h^2 %	GA	h^2 %	GA
TD-1 x Imdad	75.80	0.3	48.57	0.5	91.00	1.2
Sarsabz x TD-1	82.06	0.7	46.00	0.3	35.00	0.2
TJ-83 x Khirman	86.80	0.5	18.22	0.5	84.61	2.9
Kiran-95 x Khirman	61.11	0.2	69.47	1.4	84.37	1.0
Sarsabz x TJ- 83	82.37	1.5	48.66	0.3	60.00	0.3
Sarsabz x Khirman	82.06	1.3	28.66	0.2	65.00	0.4

Conclusion

Water stresses consequently reduce the overall yield of crops. To overcome these facts, current study was conducted to identify the potentiality for tolerance as well as for yield performance in selected bread wheat lines. In current study, a detailed examination on the morpho-physiological responses to water stress in six different bread wheat crossed cultivars including Imdad × TD-1×Kiran-95×Khirman×Sarsabz×TJ-83 was conducted. Results suggested genetic improvement as well as tolerance ability in several traits. For instance, a comparative analysis suggested the potential of heritability % for osmotic potential (-MPa) in progenies Sarsabz × Khirman and Sarsabz × TD-1. Similarly, progeny Kiran-95 × Khirman also performed well with maximum heritability with genetic advance for harvest index% and grain yield. Despite these results, our examination found that the progeny TD-1 × Imdad was worth cross with a significantly higher heritability% of 90% for grain yield as well as for trait comparative water content% among all other crosses. These results opened the way for further advance research and provided a potential reference for genetic improvement of suggested cultivars for better yield, as well as for tolerance in water stress conditions.

Author declaration

Authors declare that there is no conflict of interest. Conceived and designed the experiments: PAS. Performed the experiments: PAS, AHS. Analyzed the data: SM & SAN. Contributed materials/analysis/ tools: AL, AAS, NAR, SAO, & KHR. Wrote the paper: PAS. PM advised about format and proofreading before submission. All authors read and approved the final version of the manuscript.

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