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Anthesis and Booting: Two Critical Stages Vulnerable to Water Stress in Wheat (*Triticum aestivum* L.) With Respect to Yield Production

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Abstract

Six spring bread wheat varieties (AAS-11, BARS-09, Dharabi-11, Faisalabad-08, Chakwal-50 and Fatehjang-2016) and 4 elite lines of wheat (10FJ01, 12FJ26, 12FJ01 and 11FJS309) were analyzed with respect to water stress by providing them two types of treatments i.e., control (no stress) and strained treatment (20 days of stoppage of irrigation at booting and further 20 days of drought after anthesis) at Barani Agricultural Research Station, Fatehjang during 2017-18. Results of this study exhibited highly significant variations prevailed in all the wheat genotypes by viewing their mean performance with respect of all physiological and yield traits. AAS-11, Fatehjang-2016 and Dharabi-11 exhibited their best performance and pointed out elevated mean productivity (MP), stress tolerance index (STI), relative water content (RWC) and geometric mean productivity (GMP). Moreover, stress susceptibility index (SSI) and tolerance (TOL) was anticipated at lowest among the above-mentioned wheat varieties and lines. Based multivariate analysis (biplot) and dendrogram studies; AAS-11, Fatehjang-2016 and Dharabi-11 are most suitable wheat cultivars for drought tolerance at booting and anthesis stage. MP, STI, RWC, GMP, SSI and TOL are renowned to be favourable gauges for identification of drought tolerance wheat ideotype. Likewise, same wheat varieties also exhibited higher grain yield per plant that put them in higher ranked genotypes for making selections and recombination while improving wheat through breeding for drought resistant.

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1. INTRODUCTION

Drought or deficiency of water is not just a physical event. It may be defined in weather term i.e., shortage of water availability. It can also be explained by the fragile equilibrium among water supply and need of that. In other way drought is defined as the requirements of water surpass the normal accessibility of water that results in drought. It may be due to slight or meager amount of precipitation (rainfall and snow) over a certain period at a certain location. As the population of the planet increasing day by day particularly in developing countries and to feed this increasing amount of people more food needs to be produced. As the area for cultivation also decreasing day by day in these countries particularly the irrigated area[1], therefore, the food production from rainfed area should also be increased either by increasing per acre yield or convert barren land into profitable land. Global warming is the key factor in changing weather blueprints all around the globe, resulting irregular rainfall, that in general influence not only the whole amount of rainfall but also rainfall's period and occurrence in a particular season, and severity of drought to plants at different growth stages[2]. Drought: being an important stress aspect, which adversely affects crop development and origins a quick decline in plants output[3]. Even though droughts may carry on for quite a few consecutive years or months, yet a small but induced water stress can also cause major damage and can spoil the local community's financial system. However, response of plant to water deficit is a composite process of physiological and chemical protocols, where abundant macro and micro-organic elements are alsocontributing[4].

More than 60% of cultivable land of the South Asia is rainfed area and because of that cropping on these dryland will ultimately be the future of these countries[5]. To increase the profitability from this dry land area and to raise crops better and comparable to irrigated area crops, focus should be on the adaptation of future technologies in these areas. Out of total cultivated area of Pakistan about 25% is rainfed area rest of 75% is irrigated. 35% of world's population feeds on wheat *(Triticum aestivum* L.) as a staple food and in Pakistan it is also the staple food which is typically sown as single cropped. In Pakistan 19% area of wheat is under barani or rainfed region. In province of Khyber Pakhtun Khwa of Pakistan, wheat is cultivated on almost 60% of the rain-fed area[6] while in Punjab rainfed area share is about 12%. Barani regions are mainly distinguished by low rainfall (water shortage) and low yield of crops. New and high yielding wheat varieties resistant to drought and other abiotic stresses is dire need for the betterment of farmers of rainfed areas and ultimately the economy of the country will also boost.

Crop growth stage is the main factor that determines the effect of water scarcity on yield of a particular crop. Wheat yield is decreased typically when drought stress took place during the heading or booting and anthesis stages. Water deficit conditions when occur while maturity phase end results in about 10%reduction in production of crop. However modest water deficiency at the early vegetative growth phase has largely no adverse effects on yield[7]. Germination of seed is the initial step of development which is very responsive to water stress in rainfed as well as in irrigated area. Therefore, for the establishment of healthy crop growth, seed germination processes and seedling establishment are key factors. Similarly crop yield and maturity is also dependent upon seedling establishment and the rate at which seedling emergence[8]. Zebarjadi et al.[9] identified some of wheat genotypes through drought indices and reported that Stress Tolerance Index (STI), Harmonic Mean (HAM) and Geometric Mean Productivity (GMP) are best selection parameters for drought related studies. Pourdar[10] also reported that genotypic selection on the basis of Tolerance Index (TOL) has high yield under stressed condition and vice versa. While keeping these factors as a precursor, current research was chalked out to calculate relationship among different physiological parameters and yield contributing traits when water deficit conditions was provided for 20 days at booting and further20 days of water stress after anthesis stage or grain formation stage.

2. MATERIALS AND METHODS

Kernels of 6 spring wheat cultivars viz., AAS-11, BARS-09, Dharabi-11, Faisalabad-08, Chakwal-50 and Fatehjang-2016 and 4 advance lines of the research station i.e., 10FJ01, 12FJ26, 12FJ01 and 11FJS309 were sown in pots of 1 m3 sized. Over all 6 pots of each genotype were sown under controlled conditions where drought can be created at our will. The experiment was carried out as under Split Plot Design in which 10 genotypes were tested against two treatments in three replications, at the experimental area of Barani Agricultural Research Station, Fatehjang, District Attock, Pakistan during 2017-18. The site was located at 33.54998 North and 72.57929 East 504m above sea level. The climate was sub humid with rain-fed agriculture. The soil texture was loam with pH 7.81 and deficient in Phosphorus & Potassium. 5-6 kernels per pot were sown and later on thinned to three seeds per pot and left to grow.

There were two treatments devised to assess the drought tolerance in these wheat genotypes. Treatment 1 i.e., T_1 (no stress) and treatment number 2 i.e., T_2 (20 days of stoppage of irrigation at booting and further 20 days of drought post anthesis). Single pot of each genotype (total 10 pots) was exposed to T_1 and similarly single pot of each genotype (total 10 pots) was exposed to T_2. There were three replications in each treatment. Flag Leaf area (LA) was calculated by using an automatic leaf area meter. When 50% spikes emerged in the plants, the date was noted and calculated as DTH 50%. Relative water content (RWC) was measured at booting stage and almost after 75 days of sowing by the procedure given by Schonfeld et al.[11]. Fresh weight, dry weight and turgid weight were determined of samples from all the pots. Fresh weight was recorded from three fully expanded flag leaves in between 2 hours of post removal from plant. Then these leaves were dipped for 16 to 18 hours in distilled water to assess the turgid weight. After wards these leaves were cautiously dried with blotting paper before recording of turgid weight. Then these leaves were dried at 70°C for 72 hours to assess dry weight. Relative water content was determined according to the following formulae:

RWC = [(fresh weight - dry weight) / (turgid weight - dry weight)] * 100

All other agronomic parameters were calculated at various growth phases of the experimental plants for both treatments in all replications. To assess the tolerance indices and susceptibility indices of all the wheat genotypes, following parameters were used:

Stress Susceptibility Index[12]:

$$SSI = 1 - (Y_S / Y_P) / 1 - (S / P)$$

Tolerance[13]:

$$TOL = Y_P - Y_S$$

Mean Productivity[13]:

$$MP = (Y_P + Y_S) / 2$$

Geometric Mean Productivity[13]:

$$GMP = (Y_S \times Y_P)^{1/2}$$

Stress Tolerance Index[14]:

$$STI = (Y_P \times Y_S) / (P)^2$$

"Y_P" is mean yield of the genotypes under controlled condition, "Y_S" is mean yield of the genotypes under stress condition, "P" is mean yield of all genotypes under controlled condition and "S" is mean yield of all varieties under stress condition.

Genetic variability was calculated by means of the formulae given by Steel et al.[15] and detailed by Muhammad[16] in a two factorial randomized complete block design by using the computer program MSTAT-C. Means of all parameters were compared by Duncan's new multiple range test[17]. Correlation among plant phenotypic traits under stressed condition that was related to yield and other stress tolerance assessment traits were computed by the help of the formulae[18]. To assess the significance of correlation, tabulated value given in t-test table against the specific degree of freedom was used. Multivariate analysis was performed by using a statistical software Minitab ver. 17.0.1.

3. RESULTS AND DISCUSSIONS

3.1 Comparison of genotypes based upon stress resistance indices

All the genotypes exhibited significant differences with respect to their performance under stressed and non stressed environment while viewing their field observed traits and RWC (Table 1). Mean values regarding all the agronomic parameters were presented in table 2 of both stressed and controlled conditions. Generally, performance of all the genotypes was decreased due to stress at booting and anthesis stage with a significant difference except for 1000 seed weight.

Table 1. Mean square values of morphological traits of 10 wheat varieties/lines.

Mean Squares	SOV & Df			
	Treatments (Tr), Df=1	Varieties (Vr), Df= 9	Tr X Vr, Df= 9	Error, Df=38
Plant height	2788.01**	211.31**	20.79**	2.33
Days to 50% heading	1170.41**	359.26**	18.41**	1.05
Spike Length	198.02**	16.17**	1.35**	1.10
Tillers/meter	2196.15**	306.38**	20.78**	12.43
Grains/spike	1540.27**	61.19**	7.711**	3.82
Flag Leaf Area	564.27**	70.18**	2.82*	1.56
RWC	1179.27**	107.86**	18.23**	3.301
1000-grain weight	224.27**	31.42**	1.49	0.97
Grain Yield/plant	928.27**	245.71**	30.38**	3.05

Note: ** significant at 0.01% , * significant at 0.05%

Maximum plant height (Table 2) was detected in non stressed conditions of all wheat varieties such as Dharabi-11 (107.67cm) and FSD-08 (107cm) while minimum was recorded in Chakwal-50 (92cm). Plant height was reduced in all varieties such as Dharabi-11 (98.33cm), Fatehjang-2016 (91cm) and FSD-08(91cm). It was also observed that highest reduction in plant height was occurred in 11FJS309 (20%) while lowest in Dharabi-11 (8.6%) when received water stress (Table 3). Fatehjang-2016 took maximum (120.3) days to 50% heading while FSD-08 acquired only 95 days to 50% heading (Table 2) under non stressed environment. When speaking about stressed condition maximum %age decrease in days to 50% heading was observed by Chakwal-50 (10.26%) while least stress showed by FSD-08 (3.86%) (Table 3).

Table 2. Mean Performance Values of 10 wheat varieties/lines under control and stresses conditions.

Sr. #	Variety / Line	Treat	X1	X2	X3	X4	X5	X6	X7	X8	X9
1	AAS-11	T1	93.0c	96.0f	14.6ab	114.6a	64.0cd	36.0ab	95.0a	47.3a	88.0a
2	BARS-09	T1	90.6c	116.0b	11.3d	115.3a	71.0a	30.0ef	89.3cd	44.6cd	75.3d
3	Dharabi-11	T1	107.6a	114.0cd	15.6ab	103.3b	72.0a	38.0a	94.0ab	43.0de	84.0b
4	FSD-08	T1	107.0a	95.0f	16.3a	99.6bcd	65.3cd	31.0def	86.6de	44.0cd	81.0bc
5	CH-50	T1	92.0c	113.6d	12.3cd	105.6b	69.0ab	29.0fg	83.0fg	41.6ef	75.6d
6	10FJ01	T1	102.3b	115.6bc	16.3a	94.0d	66.3bc	33.3cd	91.0bc	45.3bc	71.0e
7	12FJ26	T1	101.3b	115.0bcd	14.0bc	94.6d	69.0ab	32.0de	92.3abc	46.6ab	81.0bc
8	12FJ01	T1	105.3a	115.0bcd	12.0d	95.6cd	65.0cd	32.6d	86.0ef	41.6ef	84.0b
9	11FJS309	T1	101.6b	109.0e	11.0d	100.3bcd	62.3d	27.0g	81.3g	41.0f	78.0cd
10	Fatehjang-2016	T1	100.3b	120.3a	14.3b	101.3bc	65.0cd	35.3bc	94.6a	48.0a	87.3a
1	AAS-11	T2	81.3c	89.0g	11.0ab	95.6ba	54.0d	29.3bc	86.6a	43.0ab	83.3a
2	BARS-09	T2	78.0d	110.0a	8.6c	103.0c	56.6bc	25.6de	82.0bcd	40.3c	65.6d
3	Dharabi-11	T2	98.3a	106.6c	11.3ab	88.0d	60.6a	31.6a	83.3bc	41.3bc	81.3a
4	FSD-08	T2	91.0b	91.3f	12.0a	92.3bc	60.3ab	24.3ef	80.6cde	39.6cde	70.0c
5	CH-50	T2	82.0c	102.0de	9.6bc	95.3b	61.0a	23.3f	77.6ef	38.3def	70.0c
6	10FJ01	T2	88.3b	102.3d	10.6ab	82.3de	58.0ab	27.3cd	73.6g	40.0cd	60.6e
7	12FJ26	T2	83.6c	102.0de	10.6ab	81.0e	61.0a	25.6de	82.0bcd	42.3ab	75.0b
8	12FJ01	T2	90.0b	109.6ab	8.3c	82.6de	54.0cd	23.6ef	79.0de	37.6f	66.0d
9	11FJS309	T2	81.3c	100.3e	8.3c	88.0cd	52.0d	20.6g	74.6fg	38.0def	71.6c

10	Fatehjang-2016	T2	91.0b	108.0bc	11.0ab	98.3b	58.0cd	31.3ab	85.0ab	44.0a	83.0a

Note: Means followed by the same letter within a column are not statistically different according to DMR test at P < 0.05. X1= Plant height (cm), X2= Days to heading, X3= Spike length (cm), X4= Number of tillers per meter, X5= Number of grains per spike, X6= Flag leaf area (cm2), X7= Relative water contents (RWT), X8= 1000-grains weight (g), X9= Grain yield per plant (g).

Table 3. Percentage decrease in 10 wheat genotypes/lines due to stress conditions.

Varieties/ lines	PH	DTH	Spike Length	Tillers/ Meter	Grains/ Spike	FL Area	RWC	1000 Grain wt.	G. Yield/ plant
AAS-11	12.54	7.29	25.00	16.57	15.63	18.52	8.77	9.15	5.30
BARS-09	13.97	5.17	23.53	10.69	20.19	14.44	8.21	9.70	12.83
Dharabi-11	8.67	6.43	27.66	14.84	15.74	16.67	11.35	3.88	3.17
FSD-08	14.95	3.86	26.53	7.36	7.65	21.51	6.92	9.85	13.58
CH-50	10.87	10.26	21.62	9.78	11.59	19.54	6.43	8.00	7.49
10FJ01	13.68	11.53	34.69	12.41	12.56	18.00	19.04	11.76	14.55
12FJ26	17.43	11.30	23.81	14.44	11.59	19.79	11.19	9.29	7.41
12FJ01	14.56	4.64	30.56	13.59	16.92	27.55	8.14	9.60	21.43
11FJS309	20.00	7.95	24.24	12.29	16.58	23.46	8.20	7.32	8.12
Fatehjang-2016	9.30	10.25	23.26	2.96	10.77	11.32	10.21	8.33	4.96

Wheat genotype 10FJ01 and a variety FSD-08 showed maximum spike length (16.33cm) under normal condition while the least length was shown by 11FJS309 (11cm). Similarly like all traits spike length also affected by water stress and booting and anthesis stage. Maximum vulnerability showed by the same genotype 10FJ01 (34.69%) while Chakwal-50 showed minimum affect (21.62%) as compared to other ones (Table 3). Highest number of tillers was formed by wheat variety BARS-09 (115.33) followed by AAS-11 (114.67) while minimum tillers per meter were produced by 10FJ01 (94). AAS-11 was amongst most affected wheat varieties / genotypes that got effects of water stress with respect of tillers per meter (16.57%) while least effects was exhibited by wheat variety Fatehjang-2016 (2.96%). Dharabi-11 produced highest number of grains per spike i.e., 72 while least was produced by 11FJS309 (62.33). BARS-09 was highly affected by as far as grains per spike (20.19%) while least affect to water stress was showed by FSD-08 (7.65%). Flag leaf area under controlled or normal condition was exhibited by Dharabi-11 (38cm2) while lowest was produced by 11FJS309 (27cm2). Least affect of water stress on flag leaf area was witnessed in Fatehjang-2016 (11.32%) while highest affected wheat genotype was 12FJ01 (27.55%). Relative water content is a vital aspect of stress tolerance studies. Maximum RWC was exhibited byFatehjang-2016 (94.67%) while least RWC was showed by 11FJS309 (81.33%). Relative water contents were also decrease significantly in wheat genotypes. 10FJ01 showed highest effect (19.04%) while Chakwal-50 showed least (6.43%). Highest 1000-grain weight was recorded in Fatehjang-2016 (48 g) under normal condition while wheat advance line 11FJS309 showed least 1000 kernel weight (41g). Least affected genotype for 1000-grain weight was Dharabi-11 (3.88%) on the other hand 10FJ01 was most affected wheat genotype (11.76%). Maximum kernel yield per plant was recorded in wheat variety AAS-11 (88 g) while 10FJ01 showed lowest kernel yield per plant (71 g) under normal or full field capacity. All the wheat varieties and genotypes exhibited significant amount of variations under stressed condition. Higher affect was revealed by wheat genotype 12FJ01 (21.43%) while Dharabi-11 was amongst the lower ones.

The derived parameters (Table 4) such as Mean Productivity (MP), Geometric Mean Productivity (GMP) and Stress Tolerance Index (STI) were higher in wheat varieties AAS-11, Fatehjang-2016 and Dharabi-11 followed by their lower indices of Tolerance (TOL) and Stress Susceptibility Index (SSI) pointed out greater water sacristy flexibility in these varieties. The results showed that SSI values ranged from 0.37 (12FJ01) to 0.15 (AAS-11 and Fatehjang-2016). TOL values ranged from 18.00 (12FJ01) to 2.67 (Dharabi-11). Similarly, MP values ranged from 85.17 (Fatehjang-2016) to 65.83 (10FJ01). GMP ranged from 85.63 (AAS-11) to

65.63 (10FJ01) and STI ranged from 1.13 (AAS-11) to 0.66 (10FJ01) in all wheat genotypes under stressed conditions.

Table 4. Average values of tolerance and susceptibility indices at water stress conditions.

Varieties / Lines	STI	GMP	MP	TOL	SSI
AAS-11	1.13	85.63	85.67	4.67	0.15
BARS-09	0.76	70.33	70.50	9.67	0.24
Dharabi-11	1.05	82.66	82.67	2.67	0.13
FSD-08	0.87	75.30	75.50	11.00	0.25
CH-50	0.82	72.78	72.83	5.67	0.18
10FJ01	0.66	65.63	65.83	10.33	0.27
12FJ26	0.94	77.94	78.00	6.00	0.18
12FJ01	0.85	74.46	75.00	18.00	0.37
11FJS309	0.86	74.77	74.83	6.33	0.19
Fatehjang-2016	1.12	85.14	85.17	4.33	0.15

Note: STI= Stress Tolerance Index, GMP= Geometric Mean Productivity, MP= Mean Productivity, TOL= Tolerance, SSI= Stress susceptibility Index

3.2 Correlation Studies

The correlation coefficients among different traits under water stressed conditions are presented in table 5. Significant correlations were found among various parameters under this study. A positive and significant correlation was recorded among grain yield per plant with 1000 kernel weight (0.72), flag leaf area (0.62) and RWC (0.78), however a non-significant positive correlation was observed with grains per spike, tillers per meter, spike length and plant height. A positive and significant correlation was observed among RWC and kernel yield per plant (0.78), flag leaf area (0.67) and 1000 kernel weight (0.77). Similarly flag leaf area also showed a significant and positive association among grain yield per plant, RWC, spike length (0.63) and 1000-grain weight (0.82). A positive and significant correlation was observed 1000grain weight and spike length (0.62). Another momentous and positive association was exhibited by spike length with grain per spike (0.62). Days to 50% heading revealed its negative but insignificant behaviour among spike length (-0.49), tillers per meter (-0.021), RWC (-0.123), 1000-grain weight (-0.126) and kernel yield per plant (-0.231). Plant length also reported negative association with tillers/meter (-0.342). It is implicit that wheat genotypes that gave high grain yield also showed ample amount of RWC under stressed environmental regarding water scarcity than others wheat genotypes.

Table 5. Correlation Matrix of wheat varieties /lines regarding morphological traits under stressed condition.

	X1	X2	X3	X4	X5	X6	X7	X8
X2	0.172							
X3	0.525	-0.498						
X4	-0.342	-0.021	0.002					
X5	0.372	0.041	**0.618**	-0.030				
X6	0.515	0.091	**0.632**	0.199	0.298			
X7	0.129	-0.123	0.444	0.468	0.144	**0.674**		
X8	0.139	-0.126	**0.625**	0.269	0.243	**0.820**	**0.775**	
X9	0.242	-0.231	0.468	0.265	0.065	**0.621**	**0.784**	**0.723**

Note: Bold are significant at 0.05% level of significance. X1= Plant height (cm), X2= Days to heading, X3= Spike length (cm), X4= Number of tillers per meter, X5= Number of grains per spike, X6= Flag leaf area (cm^2), X7= Relative water contents (RWT), X8= 1000-grains weight (g), X9= Grain yield per plant (g).

A highly momentous association was observed among grain yield of all wheat genotypes under stress regimes with STI, MP and GMP but showed a significant negative association with SSI and TOL (Table 6). Similar findings were also presented in the same table under non stresses environment grain yield (YP) regarding MP, STI and GMP. However, an insignificant negative correlation was observed with SSI and TOL. It was revealed by looking at Table 5 that MP, GMP and STI were better forecaster of grain yield under control (Yp) and stressed condition (Ys), than rest of the predictors under both environmental regimes. Generally, STI was an improved forecaster of YP and YS under both environmental conditions. A huge magnitude of positive correlation was also experienced among Yp and Ys.

Table 6. Correlation Matrix of wheat varieties /lines regarding stress tolerance indices.

	STI	GMP	MP	TOL	SSI	Yp
GMP	**0.999**					
MP	**0.999**	**0.999**				
TOL	-0.565	-0.557	-0.539			
SSI	-0.626	-0.620	-0.603	**0.995**		
Yp	**0.927**	**0.931**	**0.939**	-0.217	-0.293	
Ys	**0.977**	**0.975**	**0.970**	**-0.726**	**-0.777**	**0.828**

Note: Bold are significant at 0.05% level of significance. Ys= Grain yield under stress condition, Yp= Grain yield under normal condition, STI= Stress Tolerance Index, GMP= Geometric Mean Productivity, MP= Mean Productivity, TOL= Tolerance, SSI= Stress susceptibility Index.

3.3 Principal Component Analysis and Cluster Analysis

Principal Components Analysis is used to recognize a smaller number of unassociated variables, called "principal components", from a big set of databases. New variables (principal components) that are linear combinations of the experiential factors are created and then analyzed. Grouping of variables were performed and showed into a biplot diagram. In this study 5 PC were created while PC1 contains 80 % of the data information as showed in table 7. The cumulative ration of PC1 and PC 2 are about 99 % of the total variance of the data and mainly distinguish the stress tolerance indices into two groups as shown in figure1 of biplot. MP, GMP and STI are referred into group 1 while rest of two SSI and TOL managed to show in group 2. Based upon PCA cluster analysis was performed and dendrogram was built (Figure 2). It was observed that AAS-11, Fatehjang-2016 and Dharabi-11 were most suitable genotypes for drought tolerant studies showing similarity levels in one cluster.

Table 7. PCA of Stress tolerance indices showing Eigen and cumulative values.

Variable	PC1	PC2	PC3	PC4	PC5
STI	0.473	-0.321	0.503	0.644	-0.074
GMP	0.472	-0.329	-0.232	-0.243	0.746
MP	0.468	-0.35	-0.21	-0.429	-0.656
TOL	-0.398	-0.608	-0.547	0.411	-0.053
SSI	-0.42	-0.544	0.591	-0.416	0.074
Eigen value	4.016	0.9811	0.0026	0.0003	0
Proportion	0.803	0.196	0.001	0	0
Cumulative	0.803	0.999	1	1	1

This research experiment was planned to evaluate some genotypes by providing them 20 days of stoppage of irrigation at booting and further 20 days of drought after anthesis. Ten wheat genotypes cultivated under water deficit regimes showed remarkable decrease in all the measured traits as judged against the control plants or non stressed plants. Bayoumi et al.[19] also experienced similar kind of observation regarding reduction of performance in certain traits (1000 kernel weight, spike length, grain yield/plant and relative water contents) under droughty conditions. Ghobadi et al.[20] also came with the statement that there was a significant decrease in biological yield and grain yield due to stress water deficit conditions. Mohammadi et al.[21] also studied wheat stressed indexes in different planting dates and emphasized upon the Stress tolerance index (STI), Mean Performance (MP) and Geometric mean productivity traits for their useful contribution towards the identification of novel wheat genotypes to perform better in water deficit regions. Blum andPnuel[22]also reported a significant amount of reduction in yield contributing factors and ultimately yield while conducting a field study among twelve wheat genotypes when they receive below average amount of annual rainfall. Present findings confirmed that grains/spike, 1000 kernel weight, tillers/meter, spike length and grain yield/plant were reduced under stressed condition. Yield and biological yield predominantly exhibited greatest susceptibility to moisture deficiency as already reported[23]. Another critical point in the present study was the timing of the moisture stress, which is vital for some yield contributing factors in wheat and other cerealcrops[21, 24], such a critical time was booting and anthesis and yield was prominently reduced while keeping the plants under drought regime for 20 days at both stages. The motive behind the less grain yield under stressed environment was solely due to decrease in yield contributing traits.

These results depicted that the 1000 grain weight and RWC added more as compared to tillers/meter in the total grain yield per plant. Nutrient uptake deficiency and food transportation at stressed conditions were main reason behind the decline in 1000 kernel weight[25] which produced shriveled kernels due to accelerated maturity, as lack of available water would result in less accumulated food/nutrients in the grain. It is only because of moisture shortage that pushes plant to complete reproductive phase in some what a lesser amount of time giving for grain filling by food particles produced in leaf and other producing parts of plants like awns as well[26].

Wheat varieties AAS-11 and FSD-08 were considerably influenced by stressed regimes as regards days to 50% heading and reduced life cycle, as being varieties of irrigated areas. The findings are also confirmed by Majer et al.[27]who reported that due to stressed environment there was no significant difference among resistant / tolerant wheat genotypes hence proved that, recording the time of heading a useful tool to characterize wheat varieties. Early heading and maturing wheat varieties have been preferential by fractional flee from drought and have a capacity to fulfill their life cycle before temperature rising during late March and early April. Flag leaf area also significantly decreased due to stressed conditions hence proving to low yield in those wheat varieties as not sufficient surface area and chlorophyll contents and stomata availability to produce and respire more. The results are confirmed with the findings of Lonbani and Arzani[28]. One of the two aspects that characteristic most importantly to attain better production are less days taken to heading (early flowering) in springwheat[29,30] and plantheight[31]. Due to earlier flowering enhanced equilibrium between pre and post-anthesis water utilization took place in rainfed areas hence that circumstances during grain filling are more positive for healthy seed size. The semi-dwarfing genes in wheat had granted profits in both normal and stressed regimes[31]. Due to the reason that more assimilates, or food particles are in hand for growing spikes and seed development (as minimum is used for stem elongation) and hence guided to better floret productiveness and more number of grains[32,33]. Current findings were also pointed out a reduction in plants tallness in all wheat genotypes under water deficit environments. The reduction of plant height in stressed environment was possibly because of drop off in comparative turgidity and dehydration of protoplasm that is linked by means of failure of turgor pressure and incomplete growth of cell and its division[34].

Wheat varieties AAS-11 and Fatehjang-16 maintained highest RWC in both environmental conditions. Sinclair and Ludlow[35]projected that RWC was improved parameter for plant's water condition than thermodynamic variables like water potential, turgor potential and solute potential. Lonbani and Arzani[28] also emphasized upon the importance of RWC in drought related studies. In present study, RWC was calculated to provide signals on the plant water condition under drought environments. RWC declined under water deficit conditions in all the varieties however AAS-11 and Fatehjang-16gainedhighest RWC under stressed situation. Same findings had been described in common bean[36] and in wheat[37]. The divergence in RWC may be endorsed by diversity in the skill of wheat genotypes to suck additional water from the soil and or the ability to retain more water in it and less loss through the stomata. It could also be because of deviations in the capability of the under-consideration wheat genotypes to gather and regulate

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osmotically to uphold tissue turgor and hence physiological processes. These variations in experimental materials with respect to relative water contents (RWC)were due to result of their gene source that differentiate them to up lift water more efficiently that is prevailing in rooting zone in soil and or elongating roots to more depth to enhance water reserve for crops[37, 38, 39]. At molecular level, every plant tries to compensate the harmful consequences of drought by changing its metabolism to deal with the problem. Greater values of RWC under water deficit regimes may be favorable. The similar varieties (AAS-11 and Fatehjang-16) also showed higher assessments of stress tolerance index, mean productivity and geometric mean productivity. Whereas lesser rates of stress susceptibility index and stress tolerance signified it a potential upcoming cultivar for drought influenced areas.

As far as correlation under stressed condition among different derived attributes like STI, GMP and MP with grain yield/plant, a positive significant association was experienced as shown in table6 and negative correlation was detected among SSI and TOL with grain yield under stressed and non stressed environments. Therefore, it can be said that while breeding for drought tolerance these parameters with this correlation pattern must be kept in mind and it could be selection criteria. Similar observations were also described by Toorchi et al.[40] in canola[9] and Farshadfar et al.[41] in wheat cultivars. The positive significant correlation was among Y_p and Y_s pointed towards the elevated grain yield under normal condition does contribute ultimate grain yield of the plants. Zebarjadi et al.[9] conflicted these findings from this study.

While seeing the biplot graph (Fig 1.) it can easily be seen of formation of two groups. MP, GMP and STI had shown a tendency towards the positive side of PC-1 with equal contribution towards the yield and forming one group. While SSI and TOL falls into second group and showed negative impression on yield under stressed condition. Therefore, it can be said that under stressed conditions parameters (MP, GMP and STI) are of immense value collectively. Major of the data variance was recorded in first two PC. Therefore, biplot graph was established among these two principal components. High eighen value for the principal component number 1 also confirms the presence of 80% variance lies in this group and cumulative value of 99% lies in PC1 and PC2. Similar kind of results was also reported[9, 41]. Based upon this principal component analysis it can be said that those genotypes that showed elevated values in PC-1 and lesser values in PC-2 are most stable genotypes in stressed condition[42]. Wheat genotypes AAS-11, Dharabi-11 and Fatehjang-2016 also appeared in a single group in the biplot graph showing the best genotypes under stressed environment. Cluster analysis also revealed three groups of sensitivity to drought. Genotypes AAS-11, Dhariabi-11 and Fatehjang-2016 were most suitable wheat genotypes and most tolerant ones in stressed environment. (Fig -2) while BARS-09 and 10FJ01 were among acceptable limits showed some sort of tolerance and showed in second group. Rest of wheat genotypes were not suitable ones for water deficit environments and appeared in susceptible genotypes groups. Farshadfar et al.[41] also reported the same regarding performance of wheat genotypes connection of biplot and cluster analysis studies.

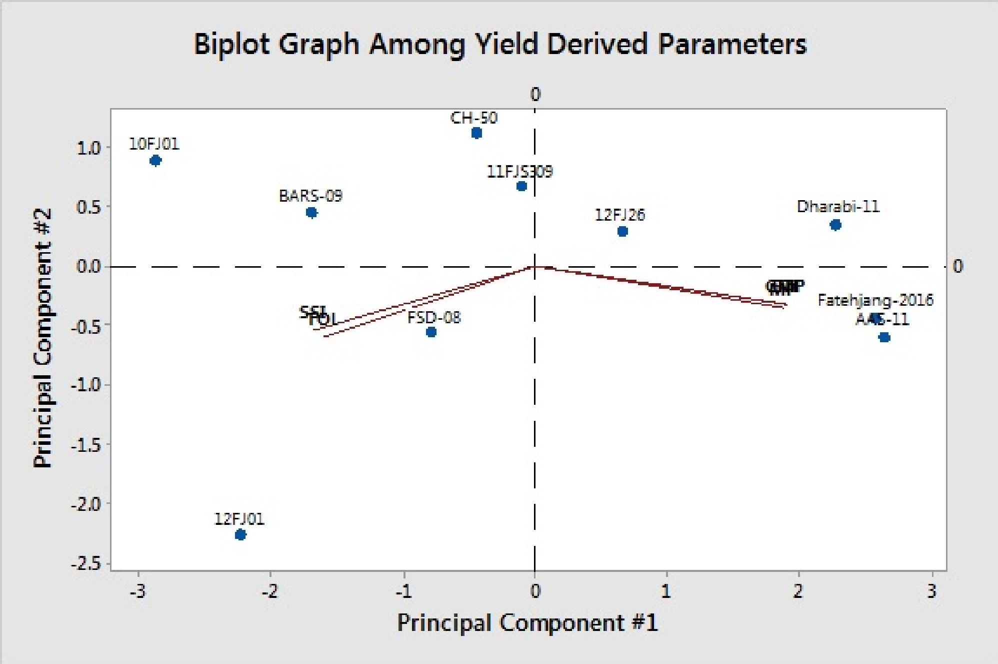

Fig. 1. Biplot analysis among PC1 and PC2 for Stress tolerance indices showing selection criteria.

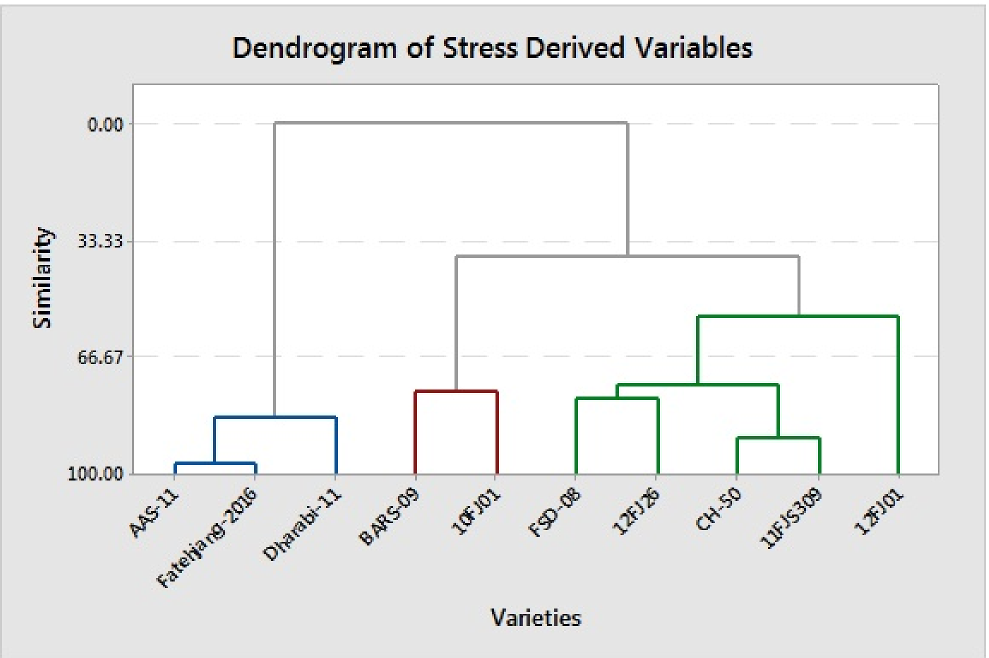

Fig. 2. Dendrogram showing classification with respect of stress tolerance indices.

5. CONCLUSIONS

While concluding the results from present experiment it can be said that almost all varieties and genotypes survived and performed acceptably fine when they were given 20 days of stoppage of irrigation at booting and further 20 days of drought after anthesis. However, permitted spring wheat cultivars AAS-11, Dharabi-11 and Fatehjang-2016attainedthe majority of the yield contributing parameters and eventually generated premier production under water deficit regimes as judged against to others. Fatehjang-2016 that is locally developed wheat cultivar by this research station and predominantly cultivated in the pothowar area of Punjab exhibited well results in water stressed regime. Wheat variety AAS-11 which is of irrigated areas also has the tendency to perform well in water stressed environments. Hence, approved varieties Fatehjang-2016, Dharabi-11 and AAS-11are suggested for rainfed areas to attain enhanced yield. Further studies on molecular level can also increase the chances of precise breeding related to drought stress. However, new gene recombination by using these genotypes can also be helpful in this regard.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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