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Effect of terminal drought stress on grain yield and some morphological traits in 80 bread wheat genotypes

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ABSTRACT: Genetic variation is the main basis of improvement in crops and plant breeding programs. So, in order to study genetic variation and terminal drought stress on grain yield and some morphological traits in bread wheat, an experiment was conducted on 80 irrigated bread wheat genotypes in a Randomized Complete Blocks Design (RCBD) with three replicates under normal and terminal drought stress conditions in Research Farm of the Campus of Agriculture and Natural Resources, Razi University, Kermanshah, Iran during 2011-2012 cropping season. The results of analysis of variance indicated significant differences among genotypes for all studied traits in both normal and drought stress conditions. Terminal drought stress reduced grain yield, plant high, peduncle length, ratio of peduncle length to plant height, spike length and awn length as much as 23.48%, 1.23%, 2.17%, 0.97%, 2.58% and 2.55%, respectively. Based on grain yield, Ghods and Norstar were the best and worst genotypes when the ranking in both conditions and the percentage of reductions was considered. In addition, the percentage reduction of the most studied traits in Norstar was more than other genotypes due to drought stress. Whereas, Ghods was rather stable due to drought stress based on all studied traits. There were high positive significant correlation between plant height and peduncle length and between peduncle length and the ratio of peduncle length to plant height under both conditions. Under non-stress conditions, a positive and significant correlation of flag leaf length with plant height and peduncle length was found. Whereas, flag leaf width had negative significant correlation with peduncle length and the ratio of peduncle length to plant height. Although, there was a positive correlation between grain yield and flag leaf area, there was no significant associations between grain yield and other traits in both normal and drought stress conditions.

***Keywords*:** Awn length, Flag leaf, Peduncle length, Plant height, Spike length

INTRODUCTION

Wheat (*Triticum aestivum* L.) as the most important cereal crop is cultivated throughout the major agro-climatic zones of the world. World's wheat production was about 704 million tons in 2011 (FAO, 2011). Iran is ranked as 14th in world wheat production. According to the recent reports, wheat was cultivated more than seven million ha and its total production was about 14.3 million tons in Iran, during 2010-2011 cropping season (FAO, 2011). This adaptability of wheat is an advantage, but drought as the most important abiotic stress is a major restriction to wheat and other agricultural production in arid and semi-arid regions (Delmer, 2005; Rajala et al., 2009). In these regions, drought reduces more than 50% of average yields for most major crops such as wheat (Wang et al., 2003). Water is the major environmental factor for wheat production in Iran, where area under rainfed conditions is more than 60% of the total area under wheat cultivation (Najafian, 2003). In the west parts of Iran such as Kermanshah, more than 80% of wheat cultivating area is rainfed (Anonymous, 2011). In these areas, inadequate rainfall and high temperatures during grain filling period at the end of the growing season greatly restrict grain production (Ghobadi et al., 2010).

On the other hand, world demand for grain of wheat, as a stable food crop, is increasing. So, it is an urgent need to develop new genotypes with traits that could not only tolerate serious drought stress at various stages of growth but can also produce higher grain yield under drought stress conditions. Genetic variation among genotypes which is exist for various yield and yield related traits in wheat, is the most important issue in plant breeding programs (Talebi et al., 2009). Therefore, study of genetic variation based on yield related traits

can be useful for introduction drought tolerant genotypes. Phenotypic characters have been successfully used for genetic variation studies and cultivar development. Among these characters, morphological traits are commonly used to evaluate genetic variation because their measurements are simple (Najaphy et al., 2012).

In any crop, the leaves and other green tissues are the original sources of assimilates. The leaves, being the site of photosynthetic activity, appear to have an obvious relation to the plant's grain yield ability (Sharma et al., 2003a). It has been proved that the flag leaf, stem and head are the closest source to the grain. The flag leaf could produce a large proportion of the carbohydrates stored in grains (Li et al., 1998). Therefore, flag leaf is one of the important components in determining grain yield potential in cereal crops and it play a major role in enhancing productivity (Padmaja Rao, 1991). This is due to its short distance to spike and the fact that it stays green for longer than the rest of the leaves. Physiological studies of wheat have indicated that flag leaf contribution towards grain weight accounts for 41- 43% of dry matter in the kernel at maturity and are the major photosynthetic site during the grain filling stage (Ibrahim and Elenein, 1977). Spike length is one of the main components of yield and this is the source of assimilates closer to the caryopsis. Spike will also stay green and functional for a longer time together with the awns (Sharma et al., 2003b). Because of these features, it contributes, on the average, 20–30% of the dry matter accumulated in the kernels (Thorne, 1965). Awns have direct vascular linkage with the spike and they have also received attention because head photosynthesis tends to be much higher when awns are well developed (Weyhrich et al., 1995). Moreover, awns have been shown to be advantageous during drought stress in the driest areas (Motzo and Giunta, 2002).

There are several approaches to the investigation of morphological traits (such as plant height, peduncle length, etc) for the purpose of increasing yield under water-limited conditions (Bogale et al., 2011). For example peduncle length has been suggested as a useful indicator of yield capacity in dry environments (Niari Khamssi and Najaphy, 2012). The aims of this investigation were: 1) evaluate genetic variation for grain yield and some morphological traits among 80 bread wheat genotypes, 2) identification of relationships between traits and grain yield, their response in stress and normal conditions and 3) introduction of genotypes that can produce the highest grain yield in drought stress condition.

Table 1. Names and codes of genotypes.

Code	Genotype	Code	Genotype	Code	Genotype	Code	Genotype
1	Karaj-1	21	Alamout	41	Kaveh	61	Aflak
2	Karaj-2	22	Alvand	42	Rassoul	62	Baaz
3	Karaj-3	23	Zarin	43	Tajan	63	Shahpasand
4	Azadi	24	MV-17	44	Shiroudi	64	Omid
5	Ghods	25	Gaspard	45	Darya	65	Roshan
6	Mahdavi	26	Gascogne	46	Arta	66	Tabassi
7	Niknejad	27	Soisson	47	Morvarid	67	Sholleh
8	Marvdasht	28	Shahryar	48	N-85-5	68	Sorkhtokhm
9	Pishtaz	29	Tous	49	Arvand	69	Adl
10	Shiraz	30	Pishgam	50	Chenab	70	Sabalan
11	Sepahan	31	Mihan	51	Bayat	71	SpringB.C.of Roshan
12	Bahar	32	Oroom	52	Falat	72	Winter B.C.of Roshan
13	Parsi	33	Zaree	53	Heirmand	73	Cross of Shahi
14	Sivand	34	Inia	54	Darab-2	74	Maroon
15	M-85-7	35	Khazar-1	55	Atrak	75	Kavir
16	WS-82-9	36	Mughan-1	56	Chamran	76	Hamoon
17	Sirwan	37	Mughan-2	57	Star	77	Bam
18	DN-11	38	Mughan-3	58	Dez	78	Akbari
19	Bezostaya	39	Golestan	59	Vee/Nac	79	Sistan
20	Navid	40	Alborz	60	LineA	80	Norstar

MATERIALS AND METHODS

Eighty bread wheat genotypes listed in Table 1 were provided from Agricultural and Natural Resources Research Centre of Kermanshah, Iran. Experiment was conducted at the Research Farm of Campus of Agriculture and Natural Resources, Razi University, Kermanshah, Iran in 2011-2012 cropping season. The characteristics of the Farm is latitude 34° 21' north, longitude 47° 9' east, altitude 1319 m above sea level, clay soil texture and 450-480 mm average annual precipitation. The precipitation at the cropping season of the experiment was 308 mm. Experimental layout was in two Randomized Complete Blocks Designs (RCBD) each in three replicates under stress and normal conditions. Sowing was performed by hand in plots with five rows, 1.2 m length, and 0.2 m row spacing and 400 seed/m^2 plant density. Terminal (end-season) drought stress was imposed in May 17, 2012, but, non-stressed plots were irrigated three times after that, while stressed plots received no water. Stress intensity was calculated according to following formula:

Stress intensity =1- ($\overline{Y}s$ / $\overline{Y}p$), $\overline{Y}s$ and $\overline{Y}p$ are the means of grain yield of all genotypes in stress and non stress conditions, respectively.

After physiological maturity stage, grain yield was measured from two middle rows with 1.2 m length. Morphological studied traits were plant height, peduncle length, ratio of peduncle length to plant height, spike length, awn length, flag leaf length, flag leaf width and flag leaf area. Each trait was calculated from five samples. Plant height (cm) was measured from soil surface to the end of spike without considering awn length. Peduncle length (cm) was determined as average height of peduncle which is the last inter-node of the main stem. Flag leaf length, flag leaf width and flag leaf area were measured only for non-stress condition because the stage of measurement was before imposing drought stress.

Analysis of variance was carried out using SAS ver.9.1 software. Least significant difference (LSD) test was used for the mean comparisons. Correlation among traits was performed by SPSS ver.16 software

RESULTS AND DISCUSSION

Analysis of variance

The results of analysis of variance (Table 2 and 3) showed high significant genotypic differences (P<0.01) for all traits in both conditions, except grain yield which was significant (P<0.05) in stress and highly significant (P<0.01) in non-stress conditions. Results indicated that there is a high variation for all traits which revealed the presence of genetic diversity for these attributes in the materials. The traits recorded here are very important for clustering wheat genetic resources which are essential and helpful for breeders seeking to improve the existing germplasm by introducing novel genetic variation for certain traits into the breeding populations (Salem et al., 2008; Pagnotta et al., 2009; Zarkti et al,. 2010). Therefore, these traits have good potential in order to select and to conserve genotypes.

Table 2. Analysis of variance for studied traits under stress and non-stress conditions.

S.O.V.	d.f.	Mean Squares					
		Plant Height		Peduncle Length		Peduncle/Plant Height	
		Non-stress	Stress	Non-stress	Stress	Non-stress	Stress
Replication	2	184.37130*	200.27648*	2.599575	46.158318*	0.00360136*	0.00092347**
Genotype	79	260.80882**	276.01837**	62.880040**	61.474586**	0.00407724**	0.00432042**
Error	158	59.87938	61.89178	12.151422	11.763369	0.00108922	0.00109918
C.V %	-	10.23	10.53	12.16	12.23	8.71	8.83

Table 2. Continued.

S.O.V.	d.f.	Mean Squares					
		Spike Length		Awn Length		Grain Yield	
		Non-stress	Stress	Non-stress	Stress	Non-stress	Stress
Replication	2	0.5797129	9.9255050**	0.379878	2.048900**	12450131.8*	4363472.5
Genotype	79	2.5511516**	2.5443843**	18.090619**	17.593719**	5224359.3**	3148554.2*
Error	158	0.8821543	0.7083923	0.339692	0.422241	3216520.2	2103065.2
C.V %	-	9.13	8.39	8.57	9.80	27.00	28.54

* and **: Significant at the 5% and 1% probability levels, respectively.

Table 3. Analysis of variance for studied traits under non-stress conditions.

S.O.V.	d.f.	Mean Squares		
		Flag Leaf Width	Flag Leaf Length	Flag Leaf Area
Replication	2	0.03674292	10.4015962	48.210500*
Genotype	79	0.08309493**	9.1625173**	42.481916**
Error	158	0.01307034	3.724133	13.176925
C.V %	-	6.46	8.28	12.52

* and **: Significant at the 5% and 1% probability levels, respectively.

Mean comparison

Mean comparison of grain yield and morphological traits were calculated for all genotypes and are presented in Table 4. In this experiment, stress intensity (SI) was 0.23 which is mild. Results showed that drought stress reduced the grain yield of all genotypes and the mean of grain yield in non-stress and stress conditions were 6641.26 and 5081.72 Kg/ha, respectively. In normal conditions, Genotypes 72, 54, 8, 33, 55, 22, 69 and 23 gave the highest performance and Genotypes 80, 42, 45 and 26 showed the lowest grain yield. In stressed conditions, Genotypes 5, 52, 72, 6 and 8 had the highest grain yield and Genotypes 80, 63, 28, 26 and 1 showed the lowest grain yield. Therefore, in both conditions, Genotypes 72 and 8 gave the best performance and Genotypes 80 and 26 showed the worst performance. Genotypes 50, 43, 11, 5 and 18 with 0.12, 0.20, 0.46, 0.51 and 0.65% reduction in grain yield were the most stable genotypes and 80, 70, 63, 30 and 75 with 54, 49, 48, 48 and 46% reduction in grain yield were the least stable genotypes. Genotypes 5 (Ghods) and 80 (Norstar) were known as the best and worst genotypes, respectively.

Plant height ranged from 55.17 (Gascogne) to 105.76 cm (Shahpasand) under non-stress and 54.63 (Gascogne) to 101.99 cm (Roshan) under stress conditions. The highest plant height was recorded for

Genotype 63 (Shahpasand) followed by Genotypes 80 (Norstar), 66 (Tabassi), 64 (Omid), 65 (Roshan), 41 (Kaveh), 73 (Cross of Shahi) and 70 (Sabalan) under non-stress conditions. Genotypes 26 (Gascogne) and 27 (Soisson) had the shortest height. Under stress conditions, Genotypes 65 (Roshan), 64 (Omid), 66 (Tabassi), 67 (Sholleh), 70 (Sabalan) and 50 (Chenab) were the highest and 26 (Gascogne), 32 (Oroom) and 58 (Dez) were the shortest genotypes, respectively. So, Genotypes 64 (Omid), 65 (Roshan), 66 (Tabassi) and 70 (Sabalan) had the highest and Genotype 26 (Gascogne) were the shortest genotypes in both non-stress and stress conditions. Terminal drought stress caused reduction in plant height by average of 1.23% and Genotype 80 (Norstar) had the highest reduction (23.58%). Genotypes 50 (Chenab) and 27 (Soisson) showed the highest increase in plant height by 12.74% and 12.64% due to terminal drought stress. In this study half of the genotypes (Genotypes 65, 66 and 50) which had the higher plant height under terminal drought stress conditions, produced high grain yield but another half (Genotypes 64, 67 and 70) produced rather low grain yield. The plant height has a contribution in the increase of the competitiveness to weeds, but, on the other hand, it also increased the tendency to the lodging. Innes et al. (1985) reported that genotypes with more height produced further grain yield in comparison with dwarf genotypes under terminal drought stress. This could be due to their wider and deeper roots which caused optimal utilization of water. Moreover, existence more reserves of assimilates in stem at grain filling period stage caused further performance (Austin, 1989). Adversely, several studies indicated that semi-dwarf stature is preferred in terminal drought conditions (Fischer and Maurer, 1978; Richards, 1996).

Peduncle length ranged from 20.81 (Mughan-2) to 44.74 cm (Norstar) under non-stress and 18.19 (Navid) to 39.27 cm (Roshan) under stress conditions. The highest peduncle length were recorded for Genotypes 80 (Norstar), 65 (Roshan), 73 (Cross of Shahi), 63 (Shahpasand), 47 (Morvarid) and 70 (Sabalan) under non-stress and Genotypes 65 (Roshan), 50 (Chenab), 67 (Sholleh), 70 (Sabalan), 66 (Tabassi), 64 (Omid) and 47 (Morvarid) under stress conditions. The shortest peduncle length was found for Genotypes 37 (Mughan-2) and 62 (Baaz) under non-stress and Genotypes 20 (Navid), 26 (Gascogne) and 62 (Baaz) under stress conditions. Terminal drought stress caused reduction in peduncle length by average of 2.17%. Genotype 80 (Norstar) had the highest reduction (39.41%) and Genotype 50 (Chenab) had the highest increase (20.43%) due to terminal drought stress. The maximum ratio of peduncle length to plant height was recorded for Genotypes 80 (Norstar) and 11 (Sepahan) under non-stress and stress conditions, respectively. The minimum ratio of this trait was found for Genotypes 37 (Mughan-2) and 20 (Navid) under non-stress and stress conditions. Terminal drought stress caused reduction in the ratio of peduncle length to plant height by average of 0.97%. Genotype 80 (Norstar), 26 (Gascogne) and 3 (Karaj-3) had the highest reduction and Genotype 42 (Rassoul) had the highest increase (20.43%) due to terminal drought stress.

Spike length varied from 7.84 (Soisson) to 13.17 cm (Omid) and 8.13 (Sorkhtokhm) to 12.77 cm (Omid) under non-stress and stress conditions, respectively. Highest spike length was observed for Genotypes 64 (Omid) and 6 (Mahdavi) under non-stress and Genotypes 64 (Omid) and 3 (Karaj-3) under stress conditions. The shortest spike length was found for Genotype 27 (Soisson) under non-stress and Genotypes 26 (Gascogne) and 68 (Sorkhtokhm) under stress conditions. Terminal drought stress caused reduction in spike length by average of 2.58%. Genotype 68 (Sorkhtokhm) had the highest reduction (17.88%) and Genotype 27 (Soisson) had the highest increase (25.65%) because of terminal drought stress.

The maximum awn length was recorded for Genotype 80 (Norstar) under both conditions. Genotypes 3 (Karaj-3), 19 (Bezostaya), 24 (MV-17), 25 (Gaspard), 26 (Gascogne), 65 (Roshan), 68 (Sorkhtokhm) and 73 (Cross of Shahi) were genetically awnless. Terminal drought stress caused reduction in awn length by average of 2.55% which Genotype 67 (Sholleh) had the highest reduction (22.76%) which is in agreement with Zare et al. (2011). Awn length of Genotype 38 (Mughan-3) had the highest increase by 13.68% because of terminal drought stress.

Flag leaf width, flag leaf length and flag leaf area were recorded for all genotypes in only non-stress condition. Genotypes 48 (N-85-5), 42 (Rassoul) and 63 (Shahpasand) had the maximum flag leaf width, flag leaf length and flag leaf area, respectively. Genotype 80 (Norstar) had the minimum flag leaf width and Genotype 59 (Vee/Nac) had the lowest both flag leaf length and flag leaf area.

Correlation analysis

According to the results of the correlation coefficients, no significant correlation was found between grain yield and other traits under both conditions (Table 5 and 6). Niari Khamssi and Najaphy (2012) indicated that there is no significant correlation between awn length and grain yield under non stress condition. Plant height was positively correlated with peduncle length under both non-stress ($r=0.796^{**}$) and stress ($r=0.806^{**}$) conditions. This finding is in agreement with results of Bogale et al. (2011) and Niari Khamssi and Najaphy (2012). So, it is logical that Genotypes 80 (Norstar), 65 (Roshan), 73 (Cross of Shahi) and 70 (Sabalan) under non-stress and Genotypes 65 (Roshan), 64 (Omid), 66 (Tabassi), 67 (Sholleh), 70 (Sabalan) and 50 (Chenab) under stress conditions had the highest plant height and peduncle length. Similarly a high significant positive correlation was found between peduncle length and the ratio of peduncle length to plant height under non-

stress (r=0.621**) and stress (r=0.595**) conditions. Spike length showed positive and significant correlation with plant height, peduncle length, flag leaf length and flag leaf area under non-stress and with plant height and peduncle length under stress conditions. A positive and significant correlation of flag leaf length with plant height and peduncle length was found under non-stress conditions. Whereas, flag leaf width showed negative significant correlation with peduncle length (r= -0.266*) and the ratio of peduncle length to plant height (r= -0.258*). In this study, it has been shown that there is a non-significant positive correlation between grain yield and flag leaf area. There are several reports in relation to flag leaf area and its effect on grain yield. An investigation indicated that higher flag leaf area caused higher levels of photosynthesis (Pecetti et al., 1993). Flag leaf is of utmost importance in cereals like wheat, because it provides the maximum amount of photosynthesis assimilates to be stored in the grains. A greater flag leaf area will eventually help to increase photosynthetic efficiency by increasing the production of photosynthesis, which is then translocated into grains and finally cause an increase in their weight. Therefore, flag leaf area has a direct relationship to grain yield (Riaz and Chowdhry, 2003). On the other hand, some reports have stated that lower flag leaf area is associated with higher grain yield because they will be roll faster (Cedola et al., 1994; Amawate and Behl, 1995).

Results of this study indicated that terminal drought stress had the significant effect on all studied traits specially grain yield. Therefore, in regions which are subjected to terminal drought stress, using genotypes that are drought tolerant and compatible to circumstances of region can be valuable. In general it can be concluded that there is a high genetic diversity in the gene pool of Iranian wheat that could be used as a rich genetic resource for breeders.

Table 4. Mean comparison of studied traits under stress and non-stress conditions.

Genotype	Plant Height (cm)		Peduncle Length (cm)		Peduncle Length / Plant Height		Grain Yield (kg/ha)	
	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress
1	86.64	85.07	34.07	32.97	0.393	0.387	5134.33	3687.47
2	84.06	83.48	32.98	29.57	0.392	0.354	4825.33	4091.00
3	75.58	75.04	30.96	25.29	0.411	0.337	7024.07	4591.13
4	74.84	80.73	27.89	31.39	0.373	0.389	6849.80	5880.00
5	80.11	85.66	30.25	31.87	0.378	0.372	8206.47	8164.80
6	81.73	82.11	29.06	30.03	0.356	0.365	7214.33	6703.00
7	70.17	67.35	29.48	29.10	0.421	0.439	5707.13	5032.07
8	71.69	73.61	26.49	24.67	0.370	0.331	9430.53	6643.20
9	76.69	74.35	30.35	31.33	0.396	0.421	6002.00	5822.93
10	71.52	73.26	28.67	28.77	0.402	0.393	6812.53	4828.13
11	72.30	64.44	31.91	30.77	0.440	0.493	6137.40	6108.87
12	78.90	75.73	29.41	28.95	0.372	0.383	6510.07	6377.20
13	68.56	67.31	24.47	25.73	0.358	0.382	6671.87	6257.33
14	71.80	76.24	23.79	21.64	0.331	0.284	5891.00	4819.40
15	68.82	76.03	25.51	29.43	0.368	0.385	5318.13	4966.07
16	80.02	81.51	31.09	33.01	0.386	0.404	6786.40	5901.73
17	69.07	63.05	28.33	23.21	0.409	0.368	6862.33	5573.53
18	82.04	76.49	29.15	27.89	0.355	0.368	6404.27	6362.80
19	79.46	86.27	31.23	32.47	0.396	0.376	5906.33	5476.00
20	76.39	67.98	24.36	18.19	0.319	0.267	7040.53	6254.47
21	69.92	75.06	24.46	28.10	0.350	0.372	5916.53	4345.00
22	76.04	78.57	29.29	27.43	0.385	0.349	8784.20	5815.67
23	79.21	74.45	24.94	23.03	0.315	0.309	8643.60	5198.20
24	66.33	63.19	22.55	21.14	0.342	0.334	7478.20	4583.53
25	67.62	64.19	21.67	22.01	0.322	0.347	5710.60	4281.13
26	55.17	54.63	22.55	18.30	0.411	0.333	4641.20	3663.20
27	55.21	62.19	23.64	22.54	0.432	0.362	5577.60	4410.40
28	73.93	70.46	28.37	26.18	0.382	0.373	6237.40	3519.07
29	79.29	79.91	28.07	29.22	0.351	0.366	6893.33	5498.87
30	65.49	66.58	26.46	27.61	0.401	0.414	8208.60	4264.27
31	62.39	62.30	24.77	27.59	0.398	0.443	7163.47	4645.87
32	61.18	56.06	26.27	24.87	0.430	0.443	4738.47	3753.40
33	74.79	74.51	32.43	32.56	0.433	0.437	9424.93	5664.47
34	78.21	79.05	30.37	29.35	0.389	0.371	6934.40	5055.00
35	72.24	79.29	31.10	30.85	0.441	0.390	5238.07	4936.47
36	66.29	61.84	25.32	24.87	0.382	0.401	7193.87	4372.00
37	69.49	66.85	20.81	22.35	0.299	0.337	7357.60	4414.73
38	77.37	80.11	27.03	27.09	0.349	0.338	5213.07	4925.00
39	71.33	68.85	27.70	29.15	0.389	0.425	6926.53	4493.13
40	70.21	72.58	24.53	25.19	0.351	0.347	5673.33	5205.53

Table 4. Continued.

Genotype	Plant Height (cm)		Peduncle Length (cm)		Peduncle Length / Plant Height		Grain Yield (kg/ha)	
	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress
41	92.93	89.05	29.59	28.08	0.317	0.314	7548.87	5374.80
42	71.42	70.88	22.18	25.67	0.310	0.361	4589.67	4524.27
43	69.63	70.21	22.84	25.02	0.329	0.357	6107.87	6095.67
44	63.75	70.69	23.87	25.67	0.374	0.363	6539.73	6304.20
45	73.60	70.04	26.81	24.30	0.363	0.348	4621.60	4538.60
46	70.13	70.04	27.33	27.04	0.389	0.386	6646.73	6182.13
47	81.83	82.54	35.51	35.48	0.434	0.430	5152.60	4298.73
48	69.18	75.63	22.93	24.93	0.332	0.330	6334.80	6244.00
49	84.36	83.84	31.99	30.80	0.379	0.366	8286.67	5783.47
50	79.98	90.17	31.58	38.03	0.396	0.421	5465.80	5459.07
51	75.25	75.36	26.39	25.62	0.352	0.341	7895.07	5125.27
52	72.83	69.42	26.90	26.53	0.370	0.384	7587.60	6889.87
53	80.24	75.03	32.78	30.36	0.408	0.405	6893.27	5126.80
54	82.81	73.66	30.72	28.44	0.370	0.386	9493.67	5407.73
55	69.30	62.60	25.07	22.71	0.361	0.356	8888.00	6385.60
56	71.67	69.10	27.20	23.84	0.379	0.346	6893.33	5672.87
57	71.74	66.48	26.57	25.04	0.371	0.377	5661.53	3977.53
58	64.92	59.04	23.32	20.53	0.358	0.349	6866.87	5110.40
59	63.34	63.61	21.68	21.98	0.344	0.346	6149.40	5616.53
60	73.24	69.86	24.71	25.65	0.336	0.367	5022.53	4154.80
61	73.57	76.01	31.81	32.71	0.432	0.428	7367.80	5942.93
62	66.73	64.07	20.91	19.38	0.313	0.306	5348.33	4311.00
63	105.76	88.07	36.10	30.43	0.343	0.345	5306.07	2722.80
64	93.51	100.85	34.66	35.81	0.373	0.357	5606.27	4850.73
65	93.34	101.99	38.58	39.27	0.413	0.386	8016.00	5905.67
66	93.89	96.96	34.09	36.34	0.363	0.376	6296.20	5527.93
67	87.20	92.64	31.29	36.88	0.358	0.399	4839.20	4208.53
68	84.01	70.46	32.10	28.07	0.382	0.398	5502.53	4423.47
69	87.69	81.15	33.55	31.68	0.383	0.392	8670.47	5034.00
70	91.06	90.43	35.48	36.52	0.394	0.405	7927.53	4013.73
71	83.05	76.55	33.70	29.51	0.407	0.386	7448.80	4870.67
72	83.89	80.59	30.54	29.06	0.365	0.361	9535.20	6703.33
73	91.82	89.37	37.66	33.95	0.410	0.379	6044.80	4800.00
74	71.17	69.36	25.28	25.72	0.358	0.368	5588.87	3796.53
75	70.83	71.45	28.37	29.19	0.403	0.408	7859.40	4237.67
76	66.06	72.95	23.95	27.28	0.367	0.376	7154.60	5143.07
77	73.61	70.48	32.21	29.23	0.438	0.415	7543.00	4221.33
78	74.12	76.28	32.41	33.51	0.438	0.439	6511.47	4709.33
79	73.18	73.24	33.22	29.63	0.454	0.406	8226.80	4806.33
80	94.83	72.47	44.74	27.11	0.473	0.376	3171.87	1449.93
Mean	75.67	74.74	28.66	28.03	0.379	0.375	6641.26	5081.72
Std. Deviation	9.32	9.59	4.58	4.53	0.04	0.04	1319.66	1024.46
LSD 5%	12.479	12.687	5.6215	5.531	0.0532	0.0535	2892.2	2338.7
LSD 1%	16.473	16.748	7.421	7.3015	0.0703	0.0706	3818	3087.3

Table 4. Continued.

Genotype	Spike Length (cm)		Awn Length (cm)		Flag Leaf Width (cm)	Flag Leaf Length (cm)	Flag Leaf Area (cm2)
	Non-stress	Stress	Non-stress	Stress	Non-stress	Non-stress	Non-stress
1	10.61	10.32	5.68	5.73	1.63	22.87	26.50
2	10.49	9.79	7.39	7.47	1.87	22.52	29.51
3	11.47	12.30	0.00	0.00	1.85	23.11	29.96
4	11.31	10.91	7.70	8.11	1.59	24.01	26.69
5	11.59	11.54	8.17	8.03	1.64	25.13	28.85
6	12.08	11.19	8.11	7.82	1.86	25.96	33.77
7	10.31	9.26	7.19	7.03	1.64	25.05	28.75
8	9.88	9.41	8.13	7.94	2.03	22.83	32.39
9	9.93	9.94	8.76	8.50	1.66	20.85	24.20
10	11.10	10.90	8.30	8.33	1.81	23.45	29.77
11	9.30	9.29	6.97	7.45	1.67	22.23	25.92
12	11.53	10.51	8.15	7.61	1.83	22.42	28.67
13	10.80	9.89	8.97	8.38	1.94	23.45	31.94
14	10.31	9.72	8.34	8.02	1.67	23.56	27.60
15	11.25	11.57	6.99	6.86	1.90	22.27	29.65
16	10.43	11.16	7.03	7.23	1.67	24.27	28.35
17	9.79	9.51	7.11	6.49	1.53	21.11	22.58
18	9.77	9.91	7.39	7.01	1.67	22.55	26.37
19	10.09	9.94	0.00	0.00	1.85	23.65	30.76
20	9.33	8.85	7.39	7.10	2.02	21.77	30.94
21	9.74	10.11	8.35	8.33	1.66	23.23	26.99
22	10.64	11.04	9.06	8.74	1.74	23.10	28.15
23	11.85	11.43	8.19	8.05	1.96	23.23	31.87
24	9.75	9.12	0.00	0.00	2.19	23.81	36.57
25	8.63	8.64	0.00	0.00	2.03	22.63	32.09
26	8.39	8.13	0.00	0.00	1.91	19.79	26.58
27	7.84	9.85	6.10	6.47	1.67	20.44	23.80
28	9.97	10.85	8.27	7.79	1.76	23.05	28.46
29	10.14	9.84	7.76	8.11	1.71	21.77	25.93
30	9.38	9.73	8.49	8.45	2.11	25.81	38.17
31	9.93	9.27	8.84	8.85	2.01	25.07	35.41
32	8.88	8.24	8.64	8.09	1.71	21.28	25.61
33	11.36	11.01	7.93	8.01	1.73	23.43	28.52
34	9.90	9.67	7.22	7.46	1.63	21.97	25.03
35	10.09	11.33	7.56	7.36	1.91	25.05	33.47
36	9.76	9.44	7.22	7.08	1.74	23.97	29.32
37	9.75	9.76	7.37	7.43	1.91	23.69	31.59
38	10.20	10.63	7.04	8.01	1.73	23.02	27.95
39	10.48	9.94	8.23	7.33	1.76	23.17	28.61
40	9.83	10.26	6.17	5.43	1.55	19.70	21.81

Table 4. Continued.

Genotype	Spike Length (cm)		Awn Length (cm)		Flag Leaf Width (cm)	Flag Leaf Length (cm)	Flag Leaf Area (cm2)
	Non-stress	Stress	Non-stress	Stress	Non-stress	Non-stress	Non-stress
41	10.80	10.57	7.87	7.49	1.87	23.16	30.37
42	11.14	10.85	7.60	7.01	1.70	27.53	32.73
43	9.59	9.41	6.65	6.24	1.77	20.71	25.68
44	10.00	9.29	7.33	6.71	1.70	21.96	26.13
45	10.11	9.35	7.47	7.33	1.66	21.29	24.87
46	9.11	9.82	7.39	7.49	1.78	25.51	32.01
47	8.28	8.59	7.92	7.60	1.72	25.11	30.26
48	9.79	10.65	6.52	6.75	2.26	23.17	36.69
49	10.91	9.33	8.33	8.15	1.72	25.45	30.81
50	10.32	10.34	8.57	7.53	1.78	25.23	31.46
51	9.16	8.94	7.93	7.69	1.91	23.61	31.57
52	9.65	9.79	7.77	7.39	1.83	22.00	28.25
53	10.90	10.44	8.59	8.14	1.81	26.81	34.10
54	10.75	9.89	7.74	7.37	1.68	23.26	27.47
55	10.05	10.19	6.43	6.21	1.65	22.54	26.13
56	9.79	9.22	7.31	6.77	1.89	22.91	30.20
57	9.91	9.43	6.97	6.95	1.76	22.80	28.30
58	9.46	8.38	5.64	4.86	1.61	20.71	23.45
59	9.94	9.93	7.09	6.43	1.47	19.31	19.96
60	10.21	9.51	7.00	7.41	1.62	22.04	25.35
61	10.57	10.59	8.25	8.30	1.58	23.79	26.31
62	8.65	8.49	7.30	7.13	1.65	20.65	23.81
63	11.68	10.56	3.73	3.37	2.19	25.25	38.72
64	13.17	12.77	7.81	8.00	1.87	25.06	32.70
65	10.89	10.70	0.00	0.00	1.73	24.06	29.14
66	10.76	10.72	7.78	8.18	1.52	26.01	27.68
67	10.03	9.95	7.88	6.09	1.66	25.41	29.56
68	9.90	8.13	0.00	0.00	1.78	22.18	27.63
69	10.76	11.45	4.89	5.23	1.67	22.97	26.80
70	11.65	10.98	7.91	7.92	1.71	24.71	29.57
71	9.98	9.09	8.55	8.50	1.88	23.27	30.66
72	10.67	10.42	5.91	5.30	1.77	21.38	26.58
73	11.73	10.94	0.00	0.00	1.55	27.42	29.80
74	10.76	9.93	7.93	7.21	1.81	22.59	28.87
75	10.37	10.31	7.61	7.21	2.06	26.10	37.71
76	9.66	9.13	7.80	7.50	1.69	22.50	26.54
77	11.48	10.19	8.05	8.05	1.83	25.70	33.06
78	10.88	9.99	7.77	7.59	1.77	24.40	30.16
79	10.82	9.80	7.44	7.32	1.64	23.27	26.69
80	11.17	9.83	9.41	9.93	1.33	23.51	22.03
Mean	10.29	10.03	6.80	6.63	1.77	23.32	28.99
Std. Deviation	0.922	0.921	2.456	2.422	0.167	1.748	3.763
LSD 5%	1.5147	1.3573	0.9399	1.0479	0.1844	3.1121	5.8539
LSD 1%	1.9995	1.7918	1.2408	1.3833	0.2434	4.1083	7.7277

Table 5. Simple correlation coefficients between different traits under non-stress condition.

Trait	1	2	3	4	5	6	7	8	9
1. Grain Yield	1								
2. Spike Length	0.205	1							
3. Awn Length	0.101	0.101	1						
4. Plant Height	0.031	0.594**	-0.066	1					
5. Peduncle Length	0.000	0.489**	-0.037	0.796**	1				
6. Peduncle Length / Plant Height	-0.028	0.043	0.023	0.027	0.621**	1			
7. Flag Leaf Width	0.196	-0.041	-0.180	-0.106	-0.266*	-0.258*	1		
8. Flag Leaf Length	0.107	0.469**	0.096	0.414**	0.424**	0.172	0.191	1	
9. Flag Leaf Area	0.201	0.231*	-0.067	0.147	0.039	-0.090	0.835**	0.695**	1

* and **: Significant at the 5% and 1% probability levels, respectively.

Table 6. Simple correlation coefficients between different traits under drought stress condition.

Trait	1	2	3	4	5	6
1. Grain Yield	1					
2. Spike Length	0.178	1				
3. Awn Length	0.109	0.115	1			
4. Plant Height	0.131	0.589**	-0.017	1		
5. Peduncle Length	0.070	0.472**	0.087	0.806**	1	
6. Peduncle Length / Plant Height	-0.056	0.010	0.194	0.011	0.595**	1

* and **: Significant at the 5% and 1% probability levels, respectively.

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