Identification of sources for drought tolerance in local bread wheat landraces

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Abstract

In order to identify drought tolerant germplasm, 97 bread wheat landraces, mostly Iranian genotypes, were evaluated in two separate experiments of normal and drought stress conditions in the field of Agriculture and Natural Resources Research Center of Varamin. The experiments were performed in lattice statistical design with three replications. Drought conditions in the stress experiment was exerted by irrigation stoppage at the spike emerging stage. Agronomic traits were measured and drought tolerance indices were calculated. The results of combined ANOVA indicated significant differences among genotypes and between conditions as well as genotype × conditions interaction for all the evaluated traits. STI, GMP, HM and MP were known as the best indices for the selection of drought tolerant genotypes. Thirty genotypes, located in A region of Fernandez grouping method, had a higher grain yield in both stress and normal conditions. Four principal components explained 71.44% of the total variation. The first component differentiated drought tolerant genotypes with early spike emerging and the second one emphasized on later spike emergence, larger harvest index and shorter plant height. The results of this research identified a large number of superior drought tolerant genotypes which could be exploited in wheat drought breeding programs.

Key words: Diversity, Gene Bank, Genetic resources, Germplasm.

INTRODUCTION

Adverse environmental conditions have decreased wheat production below average in many regions of the world (El-Maghraby *et al.,* 2005). Water shortage is a threatening limitation for wheat productivity, especially in the arid and semiarid regions of the world (Chaves *et al.,* 2003; Kumar *et al.,* 2012). Drought occurs in nearly 32 percent of the wheat growing areas in developing countries (Morris *et al.,* 1991). Food security for the hundreds of millions of rural poor necessitates improved crop productivity through breeding for enhanced drought tolerance (Ortiz *et al.,* 2008). However, progress in breeding drought-tolerant wheat varieties has been slow (Kumar *et al.,* 2012). Low heritability resulting from variations in the intensity of the stress throughout the field has made the selection for grain yield under drought stress conditions difficult (Blum, 1988; Ludlow and Muchow, 1990). In addition, the responses of plants to water stress depend on plant species, plant age, phase of growth and development, level and duration of drought and physical parameters (Marcinska *et al.,* 2013) which make the study of the traits identified as responsible for drought tolerance, more complicated. Differences in resistance to drought stress are known to exist amongst wheat genotypes (Winter *et al.,* 1988). Aghaee-Sarbarzeh *et al.* (2008) evaluated some important traits related to drought tolerance in 17 genotypes of bread wheat in field and laboratory conditions. Four genotypes were selected based on relative water content, proline content, cell membrane stability, chlorophyll content and stress tolerance index in the field conditions. Using 22 bread

Table 1. Origin of bread wheat germplasm used for drought tolerance evaluation in this study.

No.	Accession	Origin	No.	Accession	Origin	No.	Accession	Origin
1	Kavir	Commercial	35	4127	Izeh	69	4215	Mashad
2	Mahooti	Commercial	36	2179	Ardebil	70	4228	Mashad
3	Roushan	Commercial	37	2524	Bam	71	4238	Mashad
4	1354	Iran*	38	2533	Chabahar	72	4239	Mashad
5	1392	Iran	39	2563	Iranshahr	73	4244	Mashad
6	1399	Iran	40	2578	Zabol	74	4251	Torbet-e-jam
7	1400	Iran	41	2581	Zabol	75	4268	Neishabour
8	1423	Esfahan	42	2810	Iran	76	4056	Rafsanjan
9	1469	Behbahan	43	2853	Iran	77	4327	Bojnord
10	1473	Iran	44	2855	Iran	78	4331	Esfahan
11	1476	Iran	45	2892	Iran	79	4370	Esfahan
12	1488	Varamin	46	3053	Iran	80	4339	Esfahan
13	4402	Esfahan	47	3373	Mashad	81	4344	Esfahan
14	1708	Sabzevar	48	3428	Mashad	82	4355	Esfahan
15	1716	Iran	49	3474	Mashad	83	4357	Esfahan
16	1816	Iran	50	3505	Mashad	84	4337	Esfahan
17	1975	Iran	51	3506	Mashad	85	4371	Esfahan
18	1980	Iran	52	3566	Khorram Abad	86	4379	Esfahan
19	1981	Iran	53	3583	Iran	87	4384	Esfahan
20	1985	Iran	54	3684	Iran	88	4385	Esfahan
21	1986	Iran	55	3699	Iran	89	4401	Esfahan
22	1990	Iran	56	3716	Neishabour	90	1503	Shahr-e-kord
23	1998	Iran	57	4172	Iran	91	4407	Esfahan
24	2010	Iran	58	3737	Iran	92	4424	Bam
25	2011	Iran	59	3989	Iran	93	4448	Mexico
26	2155	Ardebil	60	4034	Yazd	94	4557	USA
27	2033	Iran	61	4052	Taft	95	4707	Czech Republic
28	2056	Iran	62	4283	Mashad	96	5078	Portugal
29	2132	Tabriz	63	4083	Marand	97	5320	Argentina
30	2146	Ardebil	64	2172	Shiraz	98	5327	Argentina
31	2023	Iran	65	4132	Esfahan	99	5329	Australia
32	2157	Ardebil	66	4155	Boyer Ahamd	100	5386	Iran
33	2162	Shiraz	67	3729	Iran			
34	2168	Shiraz	68	4174	Iran			

* Iran is mentioned as origin for genotypes with unknown province.

wheat genotypes, Amirifar *et al.* (2011) identified high yielding drought tolerant genotypes with yield stability and good bread making quality in Sararood (Kernamshah) and Karaj (moderate cold areas). Based on the results of different characteristics, the genotypes 1, 11, and 19 were selected for drought tolerance, yield and yield stability and genotypes 10 and 12 were selected for drought tolerance and quality characteristics. Drought tolerance of twenty one advanced bread wheat genotypes was studied by Moslemi *et al.* (2012) at Maragheh research station. The combined analysis of variance showed significant differences among the genotypes over the environments. Significant differences were also found among the environments and GE interaction effects. The large magnitude of the GE interaction related to genotypic effect, suggested the possible existence of sub-environmental groups for the genotypes. AlaviSini *et al.* (2013) measured physiological traits of twenty bread wheat genotypes in rainfed conditions. The results showed that genotypes having lower internal CO_2 concentration and higher thousand grain weight, produced higher yield. Decrease in photosynthesis was mainly due to non-stomatal limitations, and high grain yield was not related to leaf relative water content. Naderi *et al.* (2013) evaluated six bread wheat advanced lines and nine selected lines in optimum irrigation and terminal drought stress. Results showed that simple and multiple effects of experimental factors were significantly different under well-watered and terminal drought stress conditions. They concluded that high yielding genotypes selected under optimum condition, will also produce higher grain yield under terminal drought stress conditions.

Landraces are regarded as valuable resistance resources to biotic and abiotic stresses. This research was performed with the purpose of identifying drought tolerant genotypes within bread wheat germplasm in the National Plant Gene Bank of Iran.

Table 2. Meteorological data of the experimental site during cropping period.

Month (2010-2011)	Temperature			Relative humidity			Precipitation (mm)
	Maximum	Minimum	Average	Maximum	Minimum	Average	
November	23.2	-2.0	10.9	86	54	70	55.3
December	15.4	-2.4	5.3	84	49	66	24.7
January	15.0	-4.2	5.6	79	39	59	2.0
February	15.8	-6.4	4.5	78	42	60	28.4
March	22.4	-4.0	7.4	65	26	46	1.7
April	30.8	5.4	16.4	60	22	41	6.9
May	36.0	9.2	21.8	66	26	46	13.4
June	42.4	12.6	28.4	44	14	29	0.0
July	44.8	17.6	31.9	43	14	29	0.0
Annual	44.8	-6.4	17.6	64	28	46	147.5

Table 3. Soil characteristics in area under experiment.

Soil type	Bulk density (g/cm^3)	EC dS/m	Organic carbon (%)	Available phosphorus*	Available potassium*	Fe*	Mn*	Zn*	Br*
loam-clay	1.2	3	0.52	9.4	332	3.4	1.6	0.9	0.6

* mg/kg

MATERIALS AND METHODS

A total of 97 bread wheat accessions were investigated for drought tolerance (Table 1). The accessions had been selected and multiplied as pure lines from previous experiments. Eight genotypes out of the studied germplasm had exotic origin and were received from Mexico, USA, Czech Republic, Portugal, Argentina and Australia. Among 89 remaining accessions with Iranian origin, 63 accessions had been collected from certain regions, while the collection site of the rest (34 genotypes) was unknown within the country. The accessions along with three drought tolerant genotypes Kavir, Roshan and Mahooti (Saidi *et al.,* 2005) as checks, were evaluated in two separate experiments under drought stress and normal conditions in the research field of Agriculture and Natural Resources Research Center of Varamin (35° 31′ N, 51° 67′E, 918 m alt.), during 2010-2011 growing season. The mean air temperature and total rainfall received over the cropping period were 12.5 °C and 132.4 mm (Table 2). Soil composition was determined by the samples taken from 0-30 cm depth on the experimental field (Table 3). Both experiments were conducted in lattice statistical design with three replications. The seeds of each genotype were sown in one plot of four 2m paired-rows, 0.6 m apart. The experiment of normal condition was irrigated regularly, while drought condition in the stress experiment was exerted through irrigation stoppage at the spike emerging stage. The traits spike length, plant height, number of seeds per spike, 100 grain weight, days to spike emergence, days to full maturity, grain filling duration, grain yield and harvest index were measured. To eliminate the marginal effect, the traits were measured on the middle 1.5-m of each row, leaving 0.25m of each side of the rows in experimental plots which led to the harvest area of 1.8 m^2 on each row. Average grain yield of genotypes in normal and stress conditions were computed as $\bar{Y}_p$ and $\bar{Y}_s$, respectively. Stress intensity was calculated as $SI = 1 - \bar{Y}_s / \bar{Y}_p$. Stress susceptibility index (Fischer and Maurer, 1978) was estimated as $SSI = \left(1 - \left(Y_s / Y_p\right)\right) / SI$, where Y_s and Y_p were grain yield of each genotype in normal and stress conditions, respectively. Tolerance index (Rosielle and Hamblin, 1981), mean productivity (Rosielle and Hamblin, 1981), geometric mean productivity (Fernandez, 1992) and harmonic mean were calculated as $TOL = Y_p - Y_s$, $MP = Y_s + Y_p / 2$, $GMP = \sqrt{(Y_s)(Y_p)}$ and $HM = 2\left(Y_p . Y_s\right) / Y_p + Y_s$, respectively. Correlation coefficients between indices were calculated. The genotypes were separated in four classes of A, B, C and D, according to Fernandez (1992) method of grouping. In order to reduce the dimensions of the data, principal component analysis was performed. The studied genotypes were also grouped through K means clustering method. The statistical analyses were conducted by SPSS 16.0 software.

RESULTS

The results of ANOVA for lattice design indicated no significant differences among replications for both normal and drought stress experiments. Hence, analysis of variance was performed as randomized complete block design (RCBD). The result of combined ANOVA indicated significant differences among genotypes and between irrigation levels as well as genotype × condition interaction for all evaluated traits at confidence level of 1% (Table 4). Results of descriptive statistics showed that under both normal and stress conditions, grain yield had the highest coefficient of variation (Table 5). The plant height, number of seeds per spike, days to full maturity and grain yield had a wider range in normal condition than in the stress. However, the range for the days to spike emergence and harvest index in the stress condition was larger than that of the normal one. The spike length, 100 grain weight and grain filling duration had approximately equal ranges in both environments. Mean of all traits decreased in stress condition compared to normal one. Coefficient of variation (CV) of the traits spike length, 100 grain weight, plant height, grain filling duration, grain yield and harvest index increased in stress condition, while CV of the traits number of seeds per spike, days to spike emergence and grain filling duration appeared to decline.

Genotypes 4337 and 1399 had the highest amount of grain yield in normal condition (830.07 g and 816.23 g, respectively), while the highest grain yield in stress condition belonged to genotypes 3684 and 3506 (615.0 g and 610.0g, respectively). Genotypes 2853 and 3373 had the highest values for STI, GMP, HM and MP (Table 6). Grain yield of 44 genotypes was higher than that of all three check genotypes in normal condition while there were eight genotypes 3684, 3506, 2853, 1998, 3373, 4407, 4228, and 4172 with higher yield compared to the check genotypes in stress condition. In addition, compared to the three checks, a total of seven, six and two genotypes had higher spike length, 100 grain weight, number of seeds per spike, and genotypes 2, 1 and 51 had a shorter duration to full maturity, spike emergence and grain filling in stress condition, respectively.

The results of correlation analysis showed that grain yield in stress condition (Ys) had the highest coefficient of correlation (r=0.907**) with HM, while the highest coefficient of correlation with grain

Table 4. The results of combined ANOVA in the evaluation of bread wheat landraces under normal and drought stress condition.

Source of variations	df	Mean of Square (MS)								
		Spike length	100grain weight	Plant height	Number of seeds per spike	Days to full maturity	Days to spike emergence	Grain filling duration	Grain yield	Harvest index
Condition	1	451.53**	48.95**	5667.23**	2612.51**	24257.04**	7942.48**	4439.04**	4426469.99**	78.25**
Condition×Replication	4	1.16	1.25	132.71	6.36	1.61	2.92	0.41	1794.99**	1.40
Genotype	99	12.57**	0.85**	685.27**	20.56**	104.85**	358.22**	272.82**	32326.84**	57.46**
Genotype× Condition	99	5.63**	0.65**	145.20**	13.46**	11.67**	23.39**	36.25**	16947.05**	35.94**
Error	396	0.31	0.01	7.65	1.70	0.26	0.29	0.57	347.34**	0.80

Table 5. Descriptive statistics of bread wheat landraces under normal and drought stress conditions.

Trait	Range		Mean		CV	
	Normal	Stress	Normal	Stress	Normal	Stress
Spike length (cm)	6.83	6.83	10.85	8.73	16.61	17.14
100 grain weight (g)	2.67	2.25	4.68	3.97	10.43	11.16
Plat height (cm)	60.00	49.67	114.55	105.19	9.94	10.49
Number of seeds per spike	11.33	9.33	36.31	31.85	6.93	6.09
Days to full maturity	21.33	18.00	198.53	185.82	2.50	2.03
Days to spike emergence	32.03	34.74	151.54	144.42	5.43	5.39
Grain filling duration	43.29	43.00	47.18	41.21	15.15	17.62
Grain yield/plot (g)	453.88	438.33	598.76	425.36	16.77	18.41
Harvest index	19.26	24.14	28.98	28.19	12.31	15.14

Table 6. Values of grain yield under normal (Yp) and drought (Ys) conditions and stress tolerance indices for 20 superior genotypes of bread wheat landraces.

Genotype	Yp	Ys	TOL	STI	GMP	SSI	HM	MP
2853	778.30	576.67	201.63	1.25	669.94	0.89	662.48	677.48
3373	778.47	553.33	225.14	1.20	656.32	1.00	646.87	665.90
3506	651.62	610.00	41.62	1.11	630.47	0.22	630.12	630.81
1392	776.41	506.67	269.74	1.10	627.20	1.20	613.18	641.54
3684	634.81	615.00	19.81	1.09	624.83	0.11	624.75	624.91
4127	763.35	476.67	286.68	1.01	603.21	1.30	586.87	620.01
4228	666.74	543.33	123.41	1.01	601.88	0.64	598.74	605.04
1998	633.42	570.00	63.42	1.01	600.87	0.35	600.04	601.71
4056	733.31	490.00	243.31	1.00	599.44	1.15	587.46	611.66
1423	710.26	498.33	211.93	0.99	594.93	1.03	585.72	604.30
3737	702.95	503.33	199.62	0.99	594.83	0.98	586.62	603.14
4402	700.20	493.33	206.86	0.96	587.73	1.02	578.84	596.77
4337	830.07	415.00	415.07	0.96	586.92	1.73	553.35	622.53
3729	657.03	520.00	137.03	0.95	584.51	0.72	580.54	588.51
1399	816.23	418.33	397.89	0.95	584.34	1.68	553.16	617.28
1354	676.48	500.00	176.48	0.94	581.58	0.90	575.00	588.24
2023	758.58	440.00	318.58	0.93	577.73	1.45	556.95	599.29
1476	650.02	511.67	138.36	0.93	576.71	0.73	572.61	580.84
4172	601.67	541.72	59.95	0.91	570.91	0.34	570.12	571.70
4034	635.25	511.67	123.58	0.91	570.12	0.67	566.80	573.46
Roushan	610.24	528.33	81.91	0.90	567.81	0.46	566.34	569.29
Kavir	584.48	511.67	72.82	0.83	546.86	0.43	545.66	548.08
Mahooti	567.01	423.33	143.68	0.67	489.93	0.87	484.75	495.17

Table 7. Coefficient of correlation among the studied traits under drought condition and stress tolerance indices in evaluation of bread wheat genotypes.

	Ys	STI	TOL	GMP	SSI	HM	MP	SL	GW	PH	NS	DFM	DSE	GFD	HI
Yp	0.349**	0.785**	0.706**	0.789**	0.516**	0.702**	0.867**	-0.171	0.122	0.003	-0.032	-0.133	-0.260**	0.211*	0.155
Ys		0.846**	-0.418**	0.849**	-0.605**	0.907**	0.769**	-0.15	0.162	-0.055	-0.021	-0.015	-0.173	0.19	0.671**
STI			0.121	0.995**	-0.099	0.986**	0.985**	-0.19	0.18	-0.052	-0.024	-0.084	-0.255*	0.239*	0.532**
TOL				0.123	0.957**	-0.005	0.259**	-0.052	-0.004	0.045	-0.015	-0.117	-0.121	0.061	-0.357**
GMP					-0.102	0.991**	0.989**	-0.193	0.166	-0.031	-0.034	-0.082	-0.259**	0.244*	0.535**
SSI						-0.222*	0.03	0.004	-0.048	0.035	0.011	-0.084	-0.066	0.016	-0.474**
HM							0.961**	-0.187	0.16	-0.035	-0.034	-0.066	-0.245*	0.238*	0.591**
MP								-0.197	0.17	-0.027	-0.033	-0.099	-0.269**	0.245*	.463**
S33									-0.189	-0.285**	-0.11	.274**	0.314**	-0.210*	0.079
S310										-0.135	0.345**	0.027	-0.08	0.117	0.083
P312											-.259**	-.234*	-0.149	0.04	-0.285**
N316												-0.018	0.083	-0.089	0.001
D318													0.410**	0.089	-0.012
D320														-0.865**	-0.065
D322															0.073

SL, GW, PH, NS, DFM, DSE, GFD, HI represent spike length, 100grain weight , Plat height, Number of seeds per spike, Days to full maturity, Days to spike emergence, Grain filling duration and Harvest index, respectively.

yield in normal condition (Yp) was obtained for MP (r=0.867**) (Table 7). In total, STI, GMP, HM and MP had a high coefficient of correlation with grain yield in both drought stress and normal conditions. TOL and SSI were negatively correlated with Ys indicating an inverse relation between these indices and grain yield in stress condition. TOL and SSI also had a non-significant or low coefficient of correlation with other indices. Days to spike emergence under drought condition showed a significant negative correlation with potential grain yield, STI, GMP, HM and MP. Harvest index under drought condition was positively correlated with grain yield under drought condition, STI, GMP, HM, MP and negatively correlated with TOL, SSI and plant height under drought condition.

The genotypes were categorized based on the grain yield under two stress and normal conditions according to Fernandez (1992) definition (Figure 1). Thirty genotypes having higher grain yield in both normal and stress conditions along with Roshan genotype, were placed in group A. Genotypes 2853, 3373, 3506, 1392, 3684, 4127, 4228, 1998 and 4056 were located in group A, with the highest STI. Genotypes 1392 and 2023, which were located in group A, had the highest 100 grain weight and plant height under stress conditions, respectively. A total of 20 genotypes with higher grain yield in normal condition (Yp) and lower grain yield in stress condition (Ys) were placed in region B of biplot. Region C comprised genotype Kavir along with 17 genotypes having higher Ys and lower Yps. Thirty genotypes along with genotype Mahooti possessing lower Ys and Yp were located in region D. Group A had the highest average for 100 grain weight, grain filling duration and harvest index in both normal and stress conditions, while the highest average for plant height in both normal and stress conditions belonged to group B. Group C also possessed the highest average for the number of seeds per spike in both normal and stress conditions.

The results of principal component analysis in drought stress condition showed that the first four PCs comprised 71.45% of total variation (Table 8). In the first component, the STI, Yp and Ys variables had the largest positive coefficients and days to spike emergence with a high negative coefficient. Hence, the first component distinguished drought tolerant genotypes with early spike emergence. Genotypes 2853, 1998, 1392, 3684, 3373 and 1354 had the highest value for the first PC. The second PC emphasized on later spike emergence, larger harvest index and shorter plant height. The highest numerical amount of PC2 belonged to 4407, 4379, 4371 and 4337 genotypes. The third PC

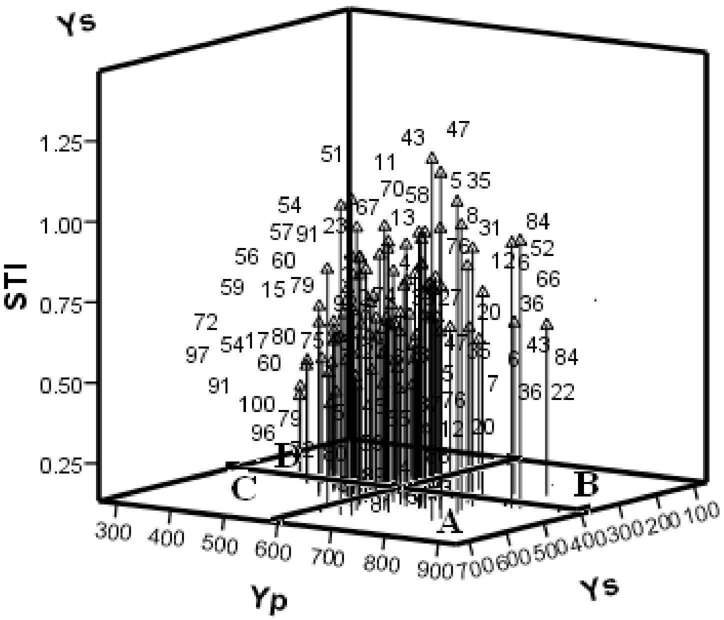

Figure 1. Distinction of genotypes of bread wheat genotypes based on grain yield in drought stress (Ys) and Normal (Yp) conditions and STI.

Table 8. Eigen values and vectors in principal component analysis of bread wheat genotypes under drought stress condition.

Trait	Component			
	1	2	3	4
Yp	0.687	0.031	-0.089	-0.198
Ys	0.791	0.375	-0.165	-0.101
STI	0.902	0.274	-0.149	-0.174
Spike length	-0.363	0.473	-0.315	0.369
100 grain weight	0.278	0.134	0.716	-0.03
Plat height	-0.008	-0.614	-0.291	-0.39
Number of seeds per spike	-0.007	0.223	0.801	-0.14
Days to full maturity	-0.221	0.453	-0.024	0.524
Days to spike emergence	-0.598	0.646	-0.086	-0.374
Grain filling duration	0.543	-0.459	0.095	0.684
Harvest index	0.56	0.539	-0.166	0.056
Eigen value	3.14	2.01	1.44	1.27
Cumulative variance (%)	28.51	46.78	59.86	71.45

distinguished genotypes with a higher number of seeds per spike and 100 grain weight. Genotypes 4448 and 5386 had the highest value for PC3. The fourth component specified longer grain filling duration and later maturity. The highest amount for PC4 belonged to 4331, 4357 and 2157 genotypes.

Cluster analysis by K means method classified the studied genotypes in seven groups (Table 9). Group 1 consisting of 10 genotypes had the highest amounts of plant height, spike length and days to spike emergence in stress condition, highest amounts of spike length, number of seeds per spike and days to spike

Table 9. Average values of the traits of bread wheat genotypes in groups developed by K means clustering method in evaluation under normal and drought stress conditions.

Trait/index		Cluster						
		1	2	3	4	5	6	7
STI		0.46	0.74	0.45	0.80	0.92	0.65	1.06
Normal condition	Grain yield(g)	528.99	649.54	435.02	762.82	621.89	541.67	742.91
	Spike length (cm)	9.62	8.60	8.63	8.21	8.25	9.20	8.36
	100 grain weight (g)	3.88	3.93	3.91	4.02	4.09	3.93	4.12
	Plat height (cm)	105.83	104.56	105.72	108.54	104.98	104.28	105.00
	Number of seeds per spike	32.67	31.59	31.19	31.29	31.71	32.12	32.58
	Days to full maturity	187.03	184.97	184.78	184.04	185.25	187.70	186.00
	Days to spike emergence	150.86	143.23	146.46	143.08	142.17	145.26	140.28
	Grain filling duration	35.50	41.47	38.15	40.96	42.97	42.36	45.47
	Harvest index	24.05	27.40	27.03	25.21	31.69	28.81	31.08
Drought condition	Grain yield (g)	306.67	409.39	366.89	374.79	530.49	432.38	512.29
	Spike length (cm)	12.50	10.44	11.47	10.96	9.93	11.19	9.85
	100 grain weight (g)	4.52	4.66	4.69	4.59	4.77	4.66	4.90
	Plat height (cm)	116.90	114.70	115.86	113.42	115.41	112.77	114.00
	Number of seeds per spike	35.13	36.05	35.67	37.12	36.75	36.28	38.00
	Days to full maturity	200.53	197.18	197.83	196.29	197.73	200.54	199.00
	Days to spike emergence	159.06	149.98	154.66	148.97	148.30	152.63	148.04
	Grain filling duration	42.14	47.47	43.34	47.32	49.55	47.98	50.96
	Harvest index	28.26	30.08	24.61	31.68	29.77	28.35	30.78
	Number of member	10	22	12	8	17	23	8

emergence in normal condition, lowest amounts of grain yield, 100 grain weight, grain filling duration and harvest index in stress condition and lowest amounts of grain yield, 100 grain weight, number of seeds per spike and grain filling duration in normal condition. Group 3 having 12 genotypes possessed the lowest amounts of STI, grain yield and number of seeds per spike in normal condition. Group 4 consisting of eight genotypes, had the highest amount of harvest index in stress condition and the highest amounts of grain yield and plant height in normal condition, lowest amount of days to full maturity in stress condition and lowest amount of spike length and days to full maturity in normal condition. Group 5 consisting of 17 genotypes had the highest amounts of the traits grain yield and harvest index in stress condition. Group 6 composed of 23 genotypes had the highest values for days to full maturity and lowest values for plant height in both normal and stress conditions. Group 7 containing eight genotypes possessed the highest amounts of STI, 100 grain weight and grain filling duration in stress condition, the highest amount of 100 grain weight and grain filling duration in normal condition, the lowest amount of days to spike emergence in stress condition and the lowest amount of days to spike emergence in normal condition.

DISCUSSION

In this research the calculated stress index was equal to 0.29, indicting an approximate average of 30 percent decrease in grain yield of the genotypes under drought condition which can be regarded as a severe stress, admissible to screen the plant materials for tolerance. The estimated values for the coefficients of variation for the measured traits showed an acceptable diversity in the studied materials enabling the breeder to perform selection. According to van Ginkel *et al.* (1998) both yield potential and specific adaptation traits are useful criteria in breeding for drought environments, and should be combined to achieve optimum performance and adaptation to drought stress. Increase in the value of coefficient of variation of the traits spike length, 100 grain weight, plant height, grain filling duration, grain yield and harvest index in stress condition implies that these traits could make a better differentiation among the genotypes under stress. The largest increase in the coefficient of variation belonged to grain filling duration and grain yield inferring their importance to discriminate the genotypes.

Grain yield under normal (Yp) and drought stress (Ys) had a large coefficient of correlation with STI, GMP, HM and MP. Hence, these indices could be used as criteria to select genotypes with proper grain yield under both normal and drought stress conditions. This finding is consistent with the results of Aghaee-Sarbarzeh *et al.* (2008), Khezri Afrawi *et al.* (2010), Arshad and Zahravi (2012) and Naderi *et al.* (2013).

A total of twenty genotypes, all originated from Iran, had higher values of STI than three check genotypes, indicating a high potential of drought tolerance in Iranian beard wheat germplasm. The number of genotypes with grain yield above the check genotypes in normal condition (44 genotypes) was much higher than that of genotypes in drought condition (8 genotypes). This observation is reasonable since the check genotypes were drought tolerant so they were expected to have better performance in the stress condition. Among the eight mentioned genotypes, 3684, 3506, 2853, 1998, 3373, 4228, had the highest STI compared to other genotypes in the germplasm. The genotype 4172 ranked 19 yet above all three check genotypes in terms of STI. The genotype 4407 ranked 26 for STI, below Roshan and above Kavir and Mahooti. Therefore, these eight genotypes could be identified as superior drought tolerant landraces in this research.

The same genotypes with the highest STI had the largest values for the first principal component, hence, the results of two analyses were consistent as the first principal component emphasizes on drought tolerance. Genotypes with the highest values for the second principal component belonged to different regions of Fernandez grouping which is expected since Fernandez grouping is based on the sole grain weight while the second principal component emphasizes on other traits. In order to select the genotypes with higher grain yield in both drought stress and normal conditions, a higher number of seeds per spike and 100 grain weight, larger PC1 and PC3 should be considered, for instance, two genotypes, 2853 and 1392.

A total of 30 genotypes were located in region A of Fernandez grouping which could be recognized as genotypes having a higher grain yield potential as well as better performances in drought condition. Therefore, these genotypes are suitable for regions prone to occasional drought occurrence. These genotypes were situated in different groups through K means clustering method, providing a wide range of valuable germplasm for plant breeders to select among them according to their breeding objectives. Evaluating 17 local bread wheat genotypes in drought stress at different growth stages, Arshad and Zahravi (2012) also concluded that variation in genetic sources of tolerance provides a valuable tool at the hands of breeders to adopt different strategies. Twenty genotypes with higher grain yield in normal condition (Yp) and lower grain yield in stress condition (Ys) in region B of biplot are genotypes only suitable for favorable conditions. Seventeen genotypes, being placed in region C of Fernandez grouping, are likely to have specific adaptabilities to drought condition. Hence, these genotypes are suggested for the areas with constant drought occurrence in the growing season.

CONCLUSION

Iranian local wheat germplasm had a valuable potential for drought resistance. A large number of drought tolerant genotypes with high potential for yield and a diverse range of characteristics were identified. Since breeding for drought tolerance in different climatic regions relies on availability of diversity in attributes in the germplasm, the findings of this research will be useful for this purpose. On the other hand, the results of this research revealed that STI, GMP, HM and MP are suitable indices to distinguish superior drought tolerant genotypes. These findings could be very useful since the success of each breeding program depends on the adoption of appropriate criteria to differentiate among the germplasm under study.

REFERENCES

Aghaee-Sarbarzeh M., Rajabi R., Haghparast R., and Mohammadi R. (2008). Evaluation and selection of bread wheat genotypes using physiological traits and drought tolerance indices. *Seed and Plant*, 24: 579-599.

Alavi Sini S. M., Saba J., and Nasiri J. (2013). Evaluation of some physiological traits in drought tolerant lines of bread wheat in rainfed conditions. *Seed and Plant*, 29: 637-657.

Amirifar E., Aghaee Sarbarze M., Haghparast R., and Khosroushahli M. (2011). Yield Stability, Bread Making Quality and Drought Tolerance in Bread Wheat Genotypes. *Seed and Plant*, 27: 233-255.

Arshad Y., and Zahravi M. (2012). Identification of drought tolerant genotypes in selected wheat genetic resources in the National Plant Gene-Bank of Iran. *Iranian Journal of Crop Science*, 13: 157-177.

Blum A. (1988). Plant breeding for stress environments. CRC Press, pp. 223.

Chaves M. M., Maroco J. P., and Pereira J. S. (2003). Understanding plant responses to drought: from gene to the whole plant. *Functional Plant Biology*, 30: 239–264.

El-Maghraby M. A., Moussa M. E., Hana N. S., and Agrama H. A. (2005). Combining ability under drought stress relative to SSR diversity in common wheat. *Euphytica*, 141: 301–308.

Fernandez G. C. (1992). Effective selection criteria for assessing plant stress tolerance. Proceedings of the international symposium on adaptation of vegetables and other food crops in temperature and water stress, Tanian, Taiwan, 257-270.

Fischer R. A., and Maurer R. (1978). Drought resistance in spring wheat cultivars. I. Grain yield response. Australian *Jouranal of Agricultural Research*, 29: 897-912.

Khezri Afrawi M., Hoseinzadeh A., Mohammadi V., and Ahmadi A. (2010). Evaluation of Drought Resistance in some Iranian Landraces of Durum Wheat (Triticumturgidum). *Iranian Journal of Field Crop Science*, 41: 741-753.

Kumar S., Sehgal S. K., Kumar U., Prasad P. V. V., Joshi A. K., and Gill B. S. (2012). Genomic characterization of drought tolerance-related traits in spring wheat. *Euphytica*, 186: 265–276.

Ludlow M. M., and Muchow R. C. (1990). A critical evaluation of traits for improving crop yield in water-limited environments. *Advances in Agronomy*, 43: 107–153.

Marcinska I., Czyczyło-Mysza I., Skrzypek E., FilekM., Grzesiak S., Grzesiak M. T., Janowiak F., Hura T. Dziurka M., Dziurka K., Nowakowska A., and Quarrie S. A. (2013). Impact of osmotic stress on physiological and biochemical characteristics in drought-susceptible and drought-resistant wheat genotypes. *Acta Physiologiae Plantarum*, 35: 451-461.

Morris M. L., Belaid A., and Byerlee D. (1991). Wheat and barley production in rainfed marginal environments of the developing world. Part I of 1990-91, CIMMYT world wheat facts and trends, Prepared in collaboration with ICARAD, Mexico, Federal District Mexico City (D.F.), CIMMYT, pp. 51.

Moslemi, M., Roustaii, M., and Rashidi V. (2012). Evaluation of grain yield and yield components in bread wheat genotypes under different moisture regimes. *Seed and Plant,* 28: 611-630.

NaderiA., Akbari Moghaddam H., and Mahmoodi K. (2013). Evaluation of Bread Wheat Genotypes for Terminal Drought Stress Tolerance in South-Warm Regions of Iran. *Seed and Plant*, 29: 601-616.

Ortiz R., Braun H. J., Crossa J., Crouch J., Davenport G., Dixon J., Dreisigacker S., Duveiller E., He Z., Huerta J., and Joshi A. K. (2008). Wheat genetic resources enhancement by the International Maize and Wheat Improvement Center (CIMMYT). *Genetic Resources and Crop Evolution,* 55: 1140–1195.

Rosielle A. A, and Hamblin J. (1981). Theoretical aspects of selection for yield in stress and non - stress environments. *Crop Science*, 21: 943 - 946.

Saidi A., Haghighi, A. A., Bakhtiar, F., Mehravar, M. R., and Nategh, Z. (2005). Characteristics of improved bread wheat, durum wheat, barley, triticale and rye cultivars released during 1930-2003. Agricultural Research, Education and Extension Organization, 12-67.

Van Ginkel M., Calhoun D. S., Gebeyehu G., Miranda A., Tian-you C., Pargas Lara R., Trethowan R.M., Sayre K., Crossa J., and Rajaram S. (1998). Plant traits related to yield of wheat in early, late, or continuous drought conditions. *Euphytica*, 100: 109–121.

Winter S. R., Musick, J. T., and Porter K. B. (1988). Evaluation of screening techniques for breeding drought resistant winter wheat. *Crop Science*, 28: 512–516.