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Evaluation of drought tolerance in bread wheat genotypes under dryland and supplemental irrigation conditions

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Abstract

Drought is a wide spread problem seriously influencing wheat (*Triticum aestivum* L.) production, mostly in dryland regions. This study was conducted to determine drought tolerance genotypes with superiority in different stressed environments. Eighteen bread wheat genotypes were tested in a randomized complete block design with four replications in two years (2006- 2007 and 2007-2008). Stress intensity in the first and second year were low (SI=0.336) and high (SI=0.604), respectively. Five drought resistance indices include mean productivity (MP), geometric mean productivity (GMP), stress tolerance index (TOL), susceptible stress index (SSI) and stress tolerance index (STI) were applied on the basis of grain yield in dryland and supplemental irrigation conditions. Based on different drought indices, genotypes G1, G3 and G4 had the best rank with low standard deviation. The results indicated they have stable yield performance. Bi-plot display and cluster analysis cleared superiority of these genotypes in both years. Synthetic-derived materials had 2.6 to 18% higher yield than the best local check cultivars. The synthetic derived cultivars could perform well across all environments with better agronomic performance, especially for thousand kernel weight. Results showed MP, GMP and STI indices were more effective in identifying high yielding cultivars in diverse water scarcity.

Keywords: Bread wheat, Cluster analysis, Drought stress, Principal component analysis, Tolerance indices.
Abbreviations: SSI_stress susceptibility index, STI_stress tolerance index, TOL_ stress tolerance, MP_mean productivity, GMP_geometric mean productivity, YS_ grain yield under drought condition, YP_grain yield under normal conditions.

Introduction

In arid and semiarid regions with Mediterranean climate, wheat crops usually encounter drought stress during the anthesis and grain filling periods (Ehdaie and Waines, 1993). Bread wheat is the most important crop in dryland of Iran. Due to insufficient rainfall in the recent years, noticeable yield loss has happened that affect the total wheat production in country. For example, despite the 3.2 million hectares of wheat under cultivation in 2000, only about 2.5 million hectares had been harvested (Keshavarz et al., 2002). Risk management is very crucial in the investment and financing decisions for farmers in developing countries and in transition economies. Basic risk management in agriculture includes choosing plant varieties against adverse weather events (Robert, 2005). The optimum variety should have superiority in environments with different stress intensities. Some genotypes are only favorable in one specific environment, like landraces which have been adapted for sever local stresses or bred cultivars which genetically modified for high yield in full irrigation conditions. The introduction of improved varieties is one of the most powerful and cost-efficient means of enhancing crop productivity and farmers income. The Plant performance in diverse environments depends on efficiency of developed varieties which should be matched to the production areas. It also implies on understanding of cropping systems in a targeted production zone. Multi-location testing is the main tool for understanding varietal responses to environments, but the process is time-consuming and expensive. The efficiency of this analytical process can be enhanced using recently developed statistical methods (Annicchiarico, 2002). Understanding the plant response in dry environments has great importance and also a fundamental part of producing stress tolerant crops (Reddy et al., 2004; Zhao et al., 2008). Drought tolerance was defined by Hall (1993) as the relative yield of a genotype compared to other genotypes, subjected to the same drought stress. Drought susceptibility of a genotype is often measured by reduction in yield under drought stress (Blum, 1988) whilst the values are confounded with differential yield potential of genotypes (Ramirez and Kelly, 1998). A basic approach is to asses the drought tolerance indices. Several indices have been utilized to evaluate genotypes for drought tolerance based on grain yield in different environments. Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress (Yp) environments and mean productivity (MP) as the average yield of Ys and Yp. Fischer and Maurer (1978) proposed a stress susceptibility index (SSI) for cultivars. Fernandez (1992) defined an advanced index (STI= stress tolerance index), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. The other yield based estimate for drought resistance is geometric mean productivity (GMP). The geometric mean is often used by breeders interested in relative performance, since drought

Table 1. Name and pedigree of genotypes used for drought tolerance assessment.

No	Parentage	Origin
1	HAMAM-4	ICARDA
2	ZEMAMRA-8	ICARDA
3	CHEN/AEGILOPSSQUARROSA(TAUS)//BCN/3/VEE#7/BOW/4/PASTOR	CIMMYT
4	CHEN/AEGILOPSSQUARROSA(TAUS)//BCN/3/VEE#7/BOW/4/PASTOR	CIMMYT
5	SERI/RAYON	CIMMYT
6	TJN//GHK”S”/BOW”S”/3/SHIR	Iran
7	SITTA/CHIL/IRENA	CIMMYT
8	PIGO/PASTOR	CIMMYT
9	BERKUT	CIMMYT
10	SERI*3//RL6010/4*YR/3/PASTOR/4/BAV92	CIMMYT
11	PASTOR/ /HXL7573/2*BAU	CIMMYT
12	CROC_1/AE.SQUARROSA(213)//PGO/3/BABAX	CIMMYT
13	BAVIACORA M 92	CIMMYT
14	GHK”S”BOW”S”//90 -ZHONG87	CIMMYT
15	KATILA-11	CIMMYT
16	NESTOR/3/HE1/3*CNO79//2*SERI	CIMMYT
17	SERI82/SHUHA ”S”	ICARDA
18	KOUHDASHT(national check)	Iran

Table2. Rainfall and mean temperature in 2006-2008 at Gachsaran dryland agricultural research station in different months during growth season.

Climatic parameters	Year	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Total
Rain fall	2006-07	0.0	31.3	133.1	66.4	84.1	29.0	167.3	2.0	511.2
	2007-08	0.0	0.0	53.7	105.4	23.0	1.6	0.8	0.0	184.9
Mean Temp.(C^o)	2006-07	26.2	20.7	12.8	10.5	10.5	15.6	18.2	25.4	
	2007-08	26.5	18.8	14.3	8.1	10.2	15.3	21.2	26.4	

Table 3. Analysis of variance of Yp, Ys, and drought tolerance indices for 18 bread wheat genotypes

SOV	DF	YP	YS	TOL	MP	GMP	SSI	STI
First year								
Rep	3	2908395.5	17567.0	3167443.7	846117.6	359910.5	0.117	0.041
Genotype	17	738845.3*	379825.6**	986045.7*	180324.0*	300184.8**	0. 112**	0.032**
Error	51	372417.7	67585.0	529144.4	87715.1	63650.4	0.063	0.007
Second year								
Rep	3	1023480.6	8389384.9	6959177.8	2966637.7	5683484.2	1.320	3.452
Genotype	17	633493.6**	382733.5**	421819.8*	402658.6**	437249.1**	0.117**	0.128**
Error	51	154675.7	54675.8	215398.1	50825.9	38791.9	0.0166	0.038

*and **: Significant at 0.05 and 0.01 probability levels, respectively.

stress can vary in severity in field environments over years (Ramirez and Kelly, 1998). The optimal selection criterion should distinguish genotypes that express uniform superiority in both stressed and non-stressed environments from the genotypes that are favorable only in one environment. Guttieri et al., (2001) suggested that SSI more and less than 1 indicates above and below-average susceptibility to drought stress, respectively. The main objectives of this study were to identify the high yielding genotypes, suitable for dryland regions of Iran using drought tolerance indices, biplot and cluster analysis and to compare synthetic derived lines with the other genotypes in different drought stress intensities.

Materials and methods

Site of experiments

The field experiments were conducted at Gachsaran Dryland Agricultural Research Station, located in Southwest of Iran (30° 20´ N and 50° 50´ E, 710 m altitude) during two cropping seasons (2006-2007 and 2007-2008). Some climatic parameters during this research are given in Table 2. The soil texture was silty-clay loam, with pH= 7.3-7.8, and less than 1% organic matters. The fertilizer was applied completely before sowing (90 kg N ha^{-1} and 75 kg P2O5 ha^{-1}).

Plant material and drought treatments

Eighteen spring bread wheat genotypes (Kouhdasht as check) were evaluated in a randomized complete block design with four replications in two separate experiments under dryland and supplemental irrigation (Table 1). The irrigated experiment was considered to be a favorable condition in order to have a better estimation of the optimum environment. Supplemental irrigation was performed in stem elongation and grain filling period each year. Planting time was in 10th and 15th December in two years, respectively. Each genotype was sown in six rows of 6 m, with row to row distance of 17.5 cm.

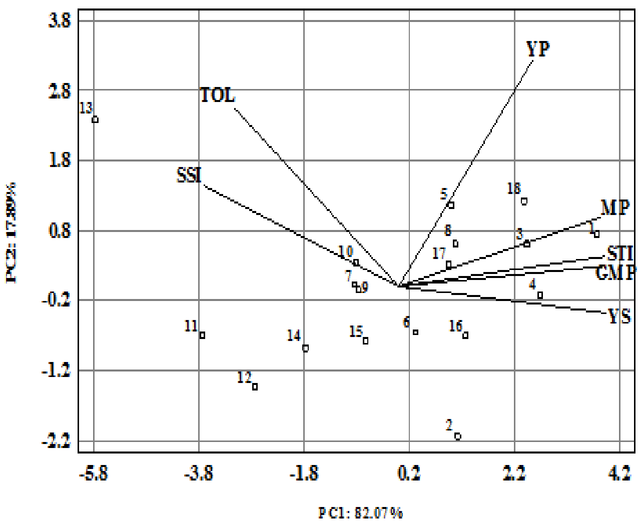

Fig 1. Drawing bi-plot based on first and second components for 18 bread wheat genotypes on first year

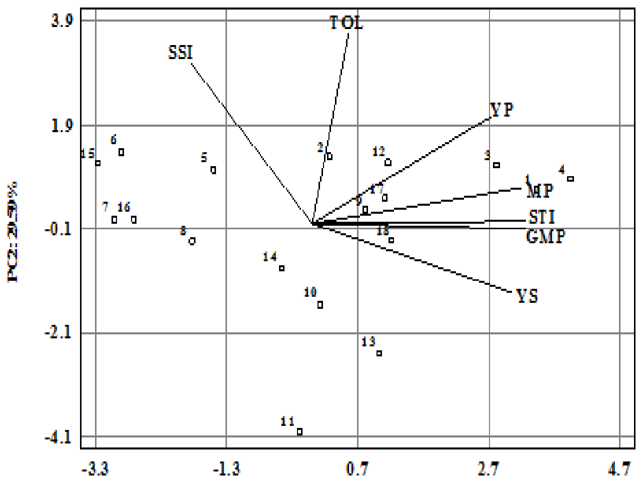

Fig 2. Drawing bi-plot based on first and second omponents for 18 bread wheat genotypes and different indices in the second years

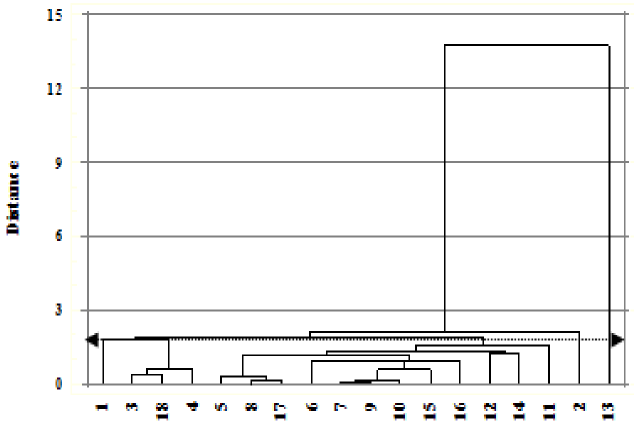

Fig 3. Dendrogram of measured traits mean for 18 wheat genotypes by using of the UPGMA method in first year

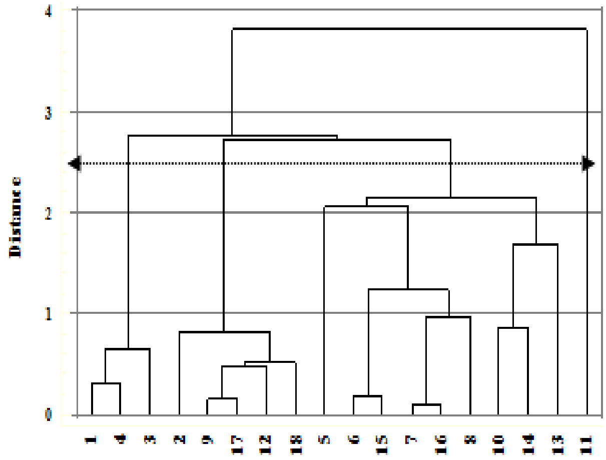

Fig 4. Dendrogram of measured traits mean for 18 wheat genotypes by using of the UPGMA method in second year

Stress intensity

Stress intensity in the first and second year were low (SI=0.336) and high (SI=0.604), respectively.

Drought indices

Drought tolerance/susceptibility indices were calculated for each genotype using the following relationships:

-Stress Susceptibility Index $(SSI) = \left[1 - \left(Ys / Yp\right)\right] / SI$ [1]

-Stress Intensity $(SI) = 1 - \left(\bar{Ys} \big/ \bar{Yp}\right)$

-Mean Productivity $(MP) = \left(Yp + Ys\right) / 2$ [2]

-Tolerance $(TOL) = Yp - YS$ [3]

-Geometric Mean Productivity $(GMP) = \sqrt{\left(Yp \times YS\right)}$ [4]

-Stress Tolerance Index $(STI) = \left[Ys \times Yp\right] / \left(\bar{Yp}\right)^2$ [5]

Where, Ys, is the grain yield of genotype under stress, Yp, the grain yield of cultivar under irrigated condition, $\bar{Ys}$ and $\bar{Yp}$ are the mean yields of all genotypes under stress and non-stress conditions, respectively. Among the stress tolerance indices, a larger value of TOL and SSI represent relatively more sensitivity to stress, thus a smaller value of TOL and SSI are favorable. Selection based on these two criteria favors genotypes with low yield potential under non-stress conditions and high yield under stress conditions. On the other hand, selection based on STI and GMP will be resulted in genotypes with higher stress tolerance and yield potential will be selected (Fernandez, 1992).

Statistical analysis

Analysis of variance, mean comparison, correlation between different treatments and cluster analysis of genotypes based on Euclidean distance was computed by SAS package. The bi-plot display was also used to identify tolerant and high yielding genotypes using StatGraphics software, based on principal component analysis.

Results

Analysis of variance for grain yield showed significant differences between genotypes for grain yield in dryland and supplemental irrigation conditions (Table 3) under different stress intensity (SI) in two years (SI=0.34 and 0.60 in the first and second years, respectively). Based on ranking of MP, GMP and STI indices, G1, G4 and G3 had the best performance in the first year and showed the highest value. Ranking changed among these genotypes in the second year but still showed the best performance compared to other genotypes. The lowest value of SSI and TOL assigned to G2, followed by G1, G4 and G3 in the first year. In consideration to all indices, G1, G4 and G3 showed the best mean rank and low standard deviation of ranks in both years. On the other hand, G1 and G4 had stable yield under different intensity of drought stresses. Check cultivar (G18) which has been cultivating by farmers since ten past years, had the forth rank with medium standard deviation (Tables 4 and 5). Grain yield under supplementary irrigation showed positive significant correlation with the yield in dry conditions in both years. The correlation between yield under dryland condition and supplementary irrigation with SSI index was negative in both years. Whereas, MP, GMP and STI indices had positive significant correlation at 1% probability level with each other and grain yield in both conditions in two years (Tables 6 and 7). Bi-plot display through principal component analysis technique was divided into four components. The first two components in total, explained more than 99 percent of the variation between the data in the both years (Table 8). Thus, bi-plot was drawn based on the first two components. The first component in the first and second years justified 82.1 and 70.3 percent of variation in the matrix of the data and showed highly coordination with yield in both environments, MP, GMP and STI indices. Therefore, it was named as high yield and stress tolerance component. This component separates drought tolerant genotypes with high yield in both environments. The second component justified, 17.9 and 29.6 percent of total variation in the first and second years, respectively. This component had negative correlation with yield in dry condition and high positive correlation with the TOL, SSI indices and yield in supplemental irrigation. Thus, it was called as stress susceptibility component. This component separated genotypes with low and high difference yield in different environments. Regarding the results of principal components analysis of indices (Table 8) and bi-plot display based on two first components, G1, G3, G4 and G18, in the vicinity of drought tolerance indices were identified as stable high yielding genotypes in both years. It was mainly due to yield potential and drought tolerance region (Fig 1 and 2: top right). Genotype No. 13 in the first year (Fig 1) and G5, G6, G7, G8, G15 and G16 in the second year (Fig 2) were identified as drought sensitive genotypes, due to location in sensitive to drought stress and low yield region (Fig 1 and 2 top left). Genotype grouping by cluster analysis (UPGMA method), using MP, GMP and STI indices and yield in dryland and supplemental irrigation conditions are shown in the Figures 3 and 4, for each year. Dendrogram in the first year showed that G1, G3, G4 and G18 were located in the same group that was already classified in bi-plot. These genotypes, in terms of yield in supplementary irrigation and dryland conditions were superior compared to other genotypes, according to MP, GMP and STI indices. Other genotypes except G2 and G13 were located in the second group. These two genotypes were separately classified in the third and fourth groups and in the stress susceptible region, according to bi-plot analysis. In the second year, G1, G3 and G4 were in the first group. These genotypes were located in the potential yield and drought tolerance region in bi-plot (top right) in the vicinity of drought tolerance indices. The other genotypes, except G11 (a susceptible genotype), locate in the second and third groups. In view of days to heading, G1 and G4 are 2 and 1 day earlier than check (G18) in dryland and supplemental irrigation conditions, respectively. The number of days to maturity for these genotypes was similar. The tallest plant height was observed for G3 and G4, meanwhile, G1 was 2 centimeter taller than local check. The highest value of TKW, assigned to G1 followed by G3, in both environments. It is interesting to note that G3 and G4 are synthetic-derivative lines. The grain yields of synthetic derived materials were 80 to 246 Kg/ha more than the best local check cultivar (Tables 4 and 5). Synthetic derivatives had early maturity, higher 1000-kernel weight and favorable plant height (Table 9). These synthetic derivatives developed in Mexico by CIMMYT under managed terminal drought stress.

Discussion

Wheat breeders have made significant improvements in adaptation of wheat to stress-prone environments (Trethowan et al., 2002 and Lantican et al., 2003). This success has largely been achieved through field-based empirical selection for stress tolerance. Significant difference between grain yield in dryland and supplemental irrigation conditions indicates existence of genetic variation and possibility of selection for favorable genotypes in both environments (Table 3). On the other hand, MP, GMP and STI indices which highly correlated with grain yield in both environments are introduced as the best indices. They are suitable to screen drought-tolerant, high yielding genotypes (e.g. G1, G3 and G4) in both dryland and supplemental irrigation conditions. Similar results were reported by Fernandez, (1992); Zeynali et al., (2004); Sio Se-Mardeh, (2006); Talebi et al., (2009); Sanjari pirevatlou et al., (2008); Nouri et al., (2010); Mohammadi et al., (2010) and Karimizadeh and Mohammadi, (2011). All of whom found these parameters to be suitable for discriminating the best genotypes under stress and irrigated conditions.Cluster analysis has been widely used for description of genetic diversity and grouping based on similar characteristics (Souri et al., 2005; Golestani et al., 2007; Malek shahi et al., 2009 and Golabadi et al., 2006). This result is consistent with results obtained by other researchers (Ahmadi et al., 2000; Souri et al., 2005; Youssefi Azar and Rezaei, (2007); Golestani et al., (2007), Abdipur et al., 2008; Malek shahi et al., 2009 and Golabadi et al., 2006). The results of bi-plot is in agreement with cluster analysis in this study.Optimum yield and agronomic traits of G3 and G4 (synthetic derivatives lines) is very interesting. The primary synthetics were agronomically poor, difficult to thresh, generally tall, low yielding and frequently poor quality. However, they do carry useful and often new variation for a range of economically important characters (Mujeeb-Kazi et al., 2008). These materials are normally derived from crossing between tetraploid durum wheat (Chen) with the diploid wild species *T. tauschii* (D genome). Crosses between elite wheat cultivars

Table 4. Estimation of stress tolerance indices from the potential yield and the stress yield data for18 bread wheat genotypes in the first year**.**

No Gen	Yp (kg.ha^{-1})	Ys (kg.ha^{-1})	TOL	MP	GMP	SSI	STI	Mean Rank	SDR Indices
1	4409^{ns}	3222 ^{ns}	1187[3]	3815 [1]	3769 [1]	0.80 [2]	0.82 [1]	1	0.894
2	3958*	2959 ^{ns}	999[1]	3459 [9]	3423 [9]	0.75 [1]	0.68 [9]	5	4.382
3	4336 ^{ns}	3055 ^{ns}	1281 [6]	3695 [3]	3639 [4]	0.88 [5]	0.77 [2]	3	1.581
4	4262 ^{ns}	3109 ^{ns}	1153 [2]	3685 [4]	3640 [3]	0.81 [3]	0.77 [3]	2	0.707
5	4339 ^{ns}	2854 ^{ns}	1484 [15]	3596 [5]	3519 [5]	1.02 [11]	0.72 [5]	9	4.604
6	4096 ^{ns}	2816 ^{ns}	1280 [2]	3456 [19]	3397 [10]	0.93 [6]	0.67 [10]	10	2.490
7	4124 ^{ns}	2652*	1472 [14]	3388[13]	3307 [13]	1.06 [13]	0.63[12]	14	0.707
8	4276 ^{ns}	2879 ^{ns}	1397 [10]	3578 [6]	3509 [6]	0.97 [9]	0.71 [6]	7	1.949
9	4118 ^{ns}	2662*	1456 [13]	3390[12]	3311[12]	1.05 [12]	0.63[13]	12	0.548
10	4163 ^{ns}	2647**	1515 [16]	3405 [11]	3320[11]	1.08 [15]	0.64 [11]	13	2.490
11	3907*	2304**	1604 [17]	3105[17]	3000[17]	1.22[17]	0.52[17]	17	0.000
12	3866*	2449**	1418 [11]	3157[16]	3077[16]	1.09[16]	0.55[16]	16	2.236
13	4190 ^{ns}	1970**	2220[18]	3080[18]	2873[18]	1.58[18]	0.48[18]	18	0.000
14	3975*	2555**	1420 [12]	3266[15]	3187[15]	1.06 [14]	0.59[15]	15	1.304
15	4039 ^{ns}	2699*	1340 [7]	3369[14]	3302[14]	0.99 [10]	0.63[14]	11	3.194
16	4132 ^{ns}	2942 ^{ns}	1191 4]	3537 [8]	3486 [8]	0.86 [4]	0.70 [6]	6	2.049
17	4236 ^{ns}	2871 ^{ns}	1365 [8]	3554 [7]	3487 [7]	0.96 8]	0.70 [8]	8	0.548
18	4406 ^{ns}	3029 ^{ns}	1376 [9]	3718 [2]	3653 [2]	0.93 [7]	0.77 [4]	4	3.114

Table 5. Estimation of stress tolerance indices from the potential yield and the stress yield data for18 bread wheat genotypes in the Second year.

No Gen	Yp (kg.ha^{-1})	Ys (kg.ha^{-1})	TOL	MP	GMP	SSI	STI	Mean Rank	SDR Indices
1	3600 ^{ns}	1566 ^{ns}	2034[13]	0.94 [6]	2583 [2]	2374 [2]	0.62 [2]	2	4.796
2	3252 ^{ns}	1128 ^{ns}	2124 [17]	1.08 [13]	2190 [8]	1915 [10]	0.41 [9]	12	3.647
3	3589 ^{ns}	1450 ^{ns}	2139 [18]	0.99 [8]	2520 [3]	2282 [3]	0.58 [3]	5	6.519
4	3700*	1611 ^{ns}	2090 [15]	0.93 [4]	2656 [1]	2442 [1]	0.66 [1]	1	6.066
5	2952 ^{ns}	932*	2021 [12]	1.13 [15]	1942 [12]	1659 [13]	0.30 [13]	14	1.225
6	2791 ^{ns}	741**	2050 [14]	1.22[17]	1766 [15]	1438[17]	0.23[16]	17	1.304
7	2566*	818**	1748 [6]	1.13[16]	1692[18]	1448[16]	0.23[17]	16	4.879
8	2684 ^{ns}	990*	1694 [5]	1.04 [11]	1837[14]	1630 [14]	0.29[14]	13	3.912
9	3169 ^{ns}	1271 ^{ns}	1897 [9]	0.99 [9]	2220 [7]	2007 [8]	0.44 [8]	9	0.837
10	2794 ^{ns}	1321 ^{ns}	1473 [3]	0.87 [3]	2057 [10]	1921 [9]	0.41 [10]	6	3.674
11	2402**	1443 ^{ns}	959[1]	0.66[1]	1923 [13]	1862 [11]	0.38 [11]	7	5.899
12	3363 ^{ns}	1245 ^{ns}	2118 [16]	1.04 [12]	2304 [4]	2046 [6]	0.46 [5]	10	5.177
13	2788 ^{ns}	1500 ^{ns}	1288[2]	0.76 [2]	2144 [9]	2045 [7]	0.46 [6]	3	3.114
14	2812 ^{ns}	1196 ^{ns}	1616 [4]	0.95 [7]	2004 [11]	183412]	0.37 [12]	11	3.564
15	2697 ^{ns}	713**	1984 [11]	1.22[18]	1705 [17]	1387[18]	0.21[18]	18	3.050
16	2613 ^{ns}	854**	1760 [7]	1.11 [14]	1734 [16]	1494[15]	0.25 [15]	15	3.647
17	3249 ^{ns}	1293 ^{ns}	1956 [10]	1.00 [10]	2271 [5]	2050 [5]	0.46 [7]	8	2.510
18	3137 ^{ns}	1365 ^{ns}	1771 [8]	0.93 [5]	2252 [6]	2070 [4]	0.47 [4]	4	1.673

Table 6. The correlation coefficients between Yp, Ys and drought tolerance indices during the first year.

	YP	YS	TOL	MP	GMP	SSI	STI
YP	1.000						
YS	0.639**	1.000					
TOL	-0.139	-0.810**	1.000				
MP	0.810**	0.934**	-0.589*	1.000			
GMP	0.794**	0.944**	-0.620**	0.994**	1.000		
SSI	-0.463	-0.961**	0.895**	-0.841**	-0.853**	1.000	
STI	0.794**	0.944**	-0.620**	0.994**	1.000**	-0.853**	1.000

* and **: Significant at 0.05 and 0.01 probability levels, respectively

Table 7. The correlation coefficients between Yp, Ys and drought tolerance indices during the second year.

	YP	YS	TOL	MP	GMP	SSI	STI
YP	1.000						
YS	0.529*	1.000					
TOL	0.738**	-0.015	1.000				
MP	0.911**	0.804**	0.480*	1.000			
GMP	0.794**	0.903**	0.302	0.965**	1.000		
SSI	-0.179	-0.882**	0.414	-0.525*	-0.672**	1.000	
STI	0.794**	0.903**	0.302	0.965**	1.000**	-0.672**	1.000

* and **: Significant at 0.05 and 0.01 probability levels, respectively

Table 8. Results of principal component analysis for Yp, Ys and drought tolerance indices on 18 bread wheat genotypes in two years.

	2006-2007		2007-2008	
Traits	Component 1	Component 2	Component 1	Component 2
YP	0.259	0.699	0.361	0.415
YS	0.415	-0.081	0.429	-0.209
TOL	-0.319	0.574	0.0138	0.694
MP	0.403	0.227	0.439	0.151
GMP	0.415	0.069	0.450	0.008
SSI	-0.388	0.327	-0.293	0.526
STI	0.414	0.102	0.449	0.030
Eigenvalue	5.744	1.252	4.918	2.846
Percent of variation	82.1	17. 9	70.26	29.59
Cumulative percentage	82.07	99.95	70.26	99.85

Component 1: high yield in both environments. Component 2: Susceptibility to drought stress

Table 9. Average of some important agronomic traits for 18 bread wheat genotypes in two years

Gen No	DHE(days)		DMA(days)		PLH(centimeter)		TKW(gram)	
	Dryland	Supplemental irrigation	Dryland	Supplemental irrigation	Dryland	Supplemental irrigation	Dryland	Supplemental irrigation
1	99	103	139	144	53	86	38	45
2	100	104	138	144	56	83	32	38
3	99	103	139	144	57	86	35	42
4	99	103	139	143	57	87	33	40
5	102	104	139	145	53	90	33	38
6	100	105	140	145	60	85	33	41
7	100	105	140	145	51	81	33	40
8	100	104	140	144	51	91	32	39
9	101	104	139	145	53	94	34	39
10	100	104	140	145	54	91	33	37
11	101	104	140	144	51	88	34	40
12	102	104	140	144	51	89	31	39
13	101	105	140	145	52	90	34	38
14	100	104	139	144	47	80	34	40
15	101	103	138	144	48	84	30	37
16	102	104	140	142	45	87	31	39
17	102	104	138	144	52	84	32	36
18	101	104	139	144	51	86	35	41

DHE: Days to heading DMA: Days to maturity PLH: Plant height TKW: Thousand kernel weight

and synthetic wheat have resulted in lines with optimum grain yield under different drought stress intensity.Exotic germplasm such those described, appear to have considerable potential to improve drought-adaptive mechanisms in wheat. The potential for increasing drought adaptation has been realized (Trethowan et al., 2003, 2005) although there is already evidence for impact in drier regions worldwide, based on data from recent international drought trials (Trethowan and Reynolds, 2007). Also, it was appeared to be a remarkable drought adaptation which probably explains their ability to extract more water from deeper of soil profile. Reynolds et al. (2007) reported that synthetic derivatives used more water in total (26 mm) compared to recurrent parents.

Conclusion

Considering the results of this study, it was observed that G1, G3 and G4 during two years in both dryland and supplementary irrigation conditions, in comparison with other genotypes, had higher yields. They were also desirable in terms of MP, GMP and STI indices. They showed considerable potential to improve drought tolerance in wheat breeding programs. So, they were identified as suitable genotypes for semitropical dryland of Iran. It was also showed that MP, GMP and STI indices had high correlation with yield under dryland and supplemental irrigation conditions and were recognized as optimum indices for identifying cultivar with high production and low sensitivity to drought stress.

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