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Full Length Research Paper

Evaluation of the reaction of durum wheat genotypes (*Triticum durum* Desf.) to drought conditions using various stress tolerance indices

Majid Khayatnezhad

Young Researchers Club, Ardabil Branch, Islamic Azad University, Ardabil, Iran. E-mail: Khayatneghad@yahoo.com.

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In this study, 40 genotypes of durum wheat (*Triticum durum*) originating from Iran and Azerbaijan Republic were evaluated in both water-stressed and well-watered environments in 3 years 2008 to 2011 cropping years. In each environment, the genotypes were evaluated using a randomized complete block design with three replications. From the grain yield data, drought tolerance indices comprising of stability tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), stress susceptibility index (SSI), tolerance index (TOL), yield index (YI) and yield stability index (YSI) were calculated for every genotype. The resulting data were analyzed as obtained from a randomized complete block design. Significant differences among genotypes were observed for all drought tolerance indices. High yield value in non-stress and stress environments was exhibited by genotypes '40 (4411.22 kg ha $^{-1}$) and '32' (4256.34 kg ha $^{-1}$) respectively. The maximum value of STI (1.07), MP (3642.11) and GMP (3590.85) indices was by genotype '35'. The highest value for YI (1.24) was from genotypes '39' and '21'. Correlation coefficients revealed that TOL, MP, GMP, STI, HM, and YI indices could effectively be used for screening of drought tolerant genotypes. Using MP, GMP, TOL, YI and STI indices, genotypes UPGMA classification was done and three clusters were established that is paralleled to biplot analysis results. According to results in this study, G10 and G35 were the most drought tolerant genotypes which were clustered as group A. We suggest that tolerance indices including MP, GMP and STI are suitable for durum wheat drought tolerant genotypes selection.

Key words: Biplot, *Triticum durum* Desf., multivariate analysis, water-stressed condition, yield stability.

INTRODUCTION

At present, durum wheat is grown mostly in rainfed areas of the Mediterranean region under stressful and variable environmental conditions (Nouri et al., 2011). Developing high-yielding wheat cultivars under drought conditions in arid and semi-arid regions is an important objective of breeding programs (Leilah and Khateeb, 2005). Drought stress may reduce all yield components, but particularly the number of fertile spikes per unit area and the number of grains per spike (Giunta et al., 1993; Simon et al., 1993; Abayomi and Wright, 1999), while kernel weight is negatively influenced by high temperatures and drought during ripening (Chmielewski and Kohn, 2000). Wheat production in Mediterranean region is often limited by sub-optimal moisture conditions. Visible syndromes of plant exposure to drought in the vegetative phase are leaf wilting, a decrease in plant height, number and area of leaves, and delay in accuracy of buds and flowers (Khayatnezhad et al., 2010). In addition, genetic divergence correlated to environmental differences has been found for emmer wheat [*Triticum turgidum* sp. Dicoccum (Schrank) Thell] (Li et al., 2000). Understanding

Abbreviations: STI, Stability tolerance index; **MP,** mean productivity; **GMP,** geometric mean productivity; **SSI,** stress susceptibility index; **TOL,** tolerance index; **YI,** yield index; **YSI,** yield stability index; **PCA,** principal component analysis; **CV,** coefficient of variation; **YP,** yield in non-stress condition; **YS,** yield in stress condition.

Table 1. Origin and taxonomy of durum wheat landraces tasted.

Code	Genotype	Region	Code	Genotype	Region
1	Hordeiforme (Miyaneh)	Iran	21	Africanum (Naxcivan)	Azerbaijan
2	Africanum (Sanandaj)	Iran	22	Leucurum (Qax)	Azerbaijan
3	(Omrabi15)	Iran	23	Hordeiforme (Naxcivan)	Azerbaijan
4	Leucurum (Kermanshah)	Iran	24	leucumelan(Naxcivan)	Azerbaijan
5	Melanopus (Ahar)	Iran	25	Niloticum (Naxcivan)	Azerbaijan
6	Hordeiforme (Maragheh)	Iran	26	Africanum (Naxcivan)	Azerbaijan
7	Leucurum (Sarab)	Iran	27	Boeuffi (Naxcivan)	Azerbaijan
8	Leucurum (Tabriz)	Iran	28	Leucumelan (lerik)	Azerbaijan
9	Melanopus (Cheiltoxm)	Azerbaijan	29	Apulicum (Shamaxi)	Azerbaijan
10	Leucurum (Germi)	Iran	30	Erythromelan (Shamaxi)	Azerbaijan
11	Reichenbachi (11077)	Iran	31	Barakatly-95	Iran
12	Saiymareh	Iran	32	Sharq	Iran
13	Hordeiforme (shamxi)	Azerbaijan	33	Hordeiforme (Ahar)	Iran
14	Apulicum (xanlar)	Azerbaijan	34	Apulicum (11010)	Iran
15	Boeuffi (shaxi)	Azerbaijan	35	Apulicum (11017)	Iran
16	Leucumelan (Naxcivn)	Azerbaijan	36	Africanum (Langan)	Azerbaijan
17	Melanopus (Naxcivan)	Azerbaijan	37	Melanopus (hasanbarouq)	Iran
18	Albiprovinciale (Qu)	Azerbaijan	38	Boeuffi (Langan)	Azerbaijan
19	Murceinse (Naxcivan)	Azerbaijan	39	Melanopus (Goliblag)	Azerbaijan
20	Leucurum (Lerik)	Azerbaijan	40	Apulicum (Langan)	Azerbaijan

plant responses to drought is of great importance and also a fundamental part of making crops stress tolerant (Reddy et al., 2004; Zhao et al., 2008). The relative yield performance of genotypes in drought-stressed and favorable environments seems to be a common starting point in the identification of desirable genotypes for unpredictable rainfed conditions (Mohammadi et al., 2010). Some researchers believe in selection under favorable conditions (Betran et al., 2003), others in a target stress condition (Rathjen, 1994) while others yet have chosen a mid-point and believe in selection under both favorable and stress conditions (Byrne et al., 1995; Rajaram and van Ginkel, 2001). Generally, different strategies have been proposed for the selection of relative drought tolerant and resistant genotypes, as Fisher and Maurer (1978) reported that achene yield in drought environment could be considered as drought-resistance index. While Blum (1988) men-tioned that selection of genotypes for drought resistance must be associated with selection for high yield in non-stress environments. Hence, by calculation of genotypes yield in drought and well-watered environments, one could select resistant genotypes to drought. There are several selection indices for screening drought resistance genotypes such as geometric mean productivity (GMP) (Fernández , 1992), mean productivity (MP) (Rosielle and Hamblin, 1981), harmonic mean (HM) (Jafari et al., 2009), stress susceptibility index (SSI) (Fischer and Maurer, 1978), yield stability index (YSI) (Bouslama and Schapaugh, 1984), yield index (YI) (Gavuzzi et al., 1997), stress tolerance index (STI) (Fernández, 1992) and tolerance index (TOL) (Rosielle and Hamblin, 1981) that identify susceptible and resistance genotypes based on their yields in stress and non-stress environments. The best selection index must be able to distinguish genotypes that have uniform superiority in both stress and nonstress environment. Fernández (1992) reported that mungbean (*Vigna radiata* L.) genotypes selection based on STI and GMP indices resulted in genotypes that have high tolerance and high yield. Clarke et al. (1992) used SSI index to distinguish between wheat (*Triticum aestivum* L.) genotypes. According to Sio-Se Mardeh et al. (2006), MP, GMP and STI were best indices under moderate stress in wheat. The objectives of present study were evaluation of several drought tolerance indices as well as to identify drought- tolerant genotypes in durum wheat genotypes.

MATERIALS AND METHODS

Plant material and experimental setup

Forty durum wheat (*Triticum turgidum* var. *durum* Desf.) breeding lines which were selected from the Iran and Azerbaijan republic regions were chosen for the study based on their reputed differences in yield performance under irrigated and non-irrigated conditions (Table 1). Experiments were conducted at experimental field of Islamic Azad University of Ardabil, in Ardabil province (Northwest of Iran), Iran in from 2008 to 2011 (three cropping years). The experimental layout was a randomized complete block design with three replications. Sowing was done by an experimental drill in 1.5 m × 4 m plots, consisting of five rows 20 cm apart at 400 seeds m^{-2} for each plot. Fertilizer was applied at 41 kg ha^{-1}

Table 2. Soil analysis results.

Soil type	Soil texture			Absorbent potassium (ppm)	Absorbent phosphorus (ppm)	Total nitrogen (%)	Organic carbon (%)	Neutral-reacting material (%)	(PH)	Electrical conductivity (ds / m)	Saturation	Depth (cm)
	Sand	Silt	Clay									
Clay loam	31	41	28	460	4/8	0/103	0/97	4/8	7/8	2/66	48	0 to 30
Clay	40	36	24	290	2	0/056	0/47	7	8/2	2/4	45	30 to 60

N and 46 kg ha^{-1} P_2O_5 and planting was according to the provincial soil test recommendations before sowing. Irrigation was performed in the non-stressed site at the flowering stage. To determine physical and chemical properties of soil tests, soil sampling before land preparation operations were performed. Samples 0 to 30 and 30 to 60 cm depths were selected after laboratory analysis of soil and water in the Islamic Azad University of Ardebil; the results are shown in Table 2 (this test was performed only for soil uniformity and to avoid errors in 60 cm wheat root penetration is not required to review), and the results of rainfall for 2008 to 2010 years, are shown in Figure 1 (IMO, 2011).

Drought resistance indices were calculated using the following relationships:

Stress intensity

Stress intensity was (SI=0.2).

Drought indices

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

1. Stress Susceptibility Index (SSI)= $\left[1-\left(Ysi-Ypi\right)\right]/SI$ (Fischer and Maurer, 1978)
2. Stress Tolerance Index (STI)= $\left[Ypi\times Ysi\right]/\left(Yp\right)^2$ (Fernandez, 1992)
3. Tolerance Index (TOL)= $Ypi-Ysi$ (Hossain et al., 1990)
4. Geometric Mean Productivity (GMP)= $\sqrt{\left(Ypi\times Ysi\right)}$ (Fernandez, 1992)
5. Mean Productivity (MP)= $\left(Ypi+Ysi\right)/2$ (Rosielle and Hambling, 1981)
6. yield index (YI)= Ysi/Ys (Gavuzzi et al., 1997)
7. Yield stability index (YSI)= Ysi/Ypi (Bouslama and Schapaugh, 1984).

Where, Ysi, is the yield of cultivar in stress condition, Ypi, the yield of cultivar in normal condition, SI that is stress intensity, where:

SI= $1-\left(Ys/Yp\right)$;

Ys, is total yield mean in stress condition, Yp, the total yield mean in normal condition. 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 MStatC and SPSS16 package (SPSS, 2007). Principal component analysis (PCA) was used to classify the screening methods as well as the genotypes. The biplot display was also used to identify tolerant and high yielding genotypes using Minitab16 software, based on principal component analysis.

RESULTS

There were significant differences among genotypes for yield under stress and non-stress conditions (Table 3). Significant differences among genotypes were observed for all drought tolerance indices at 0.01 probability level (Table 3). These results indicate that there is high genetic variation among genotypes, which could be a useful resource for selection of drought-tolerant germplasm. The experimental coefficient of variation (CV) varied from 3.48 to 23.18. However, for the majority of traits the values were less than 6% (Table 2). Resistance indices were calculated on the basis of GY of genotypes (Table 4). High yield value in non-stress and stress environments was exhibited by genotypes ‘G40 (4411.22 kg ha^{-1}) and ‘G32’ (4256.34 kg ha^{-1}) respectively (Table 4). The maximum value of STI (1.07), MP (3642.11) and GMP (3590.85) indices was by genotype ‘G35’. The highest value for YI (1.24) was from genotypes ‘G39’ and ‘G21’ (Table 4).

In this study, a general linear model regression of GY under drought stress on YSI revealed a positive correlation between this criterion with a similar coefficient of determination (R^2= 0.83) (Figure 2). Selection based on a combination of indices may provide a more useful criterion for improving drought resistance of wheat although correlation coefficients are useful to find the degree of overall linear association between any

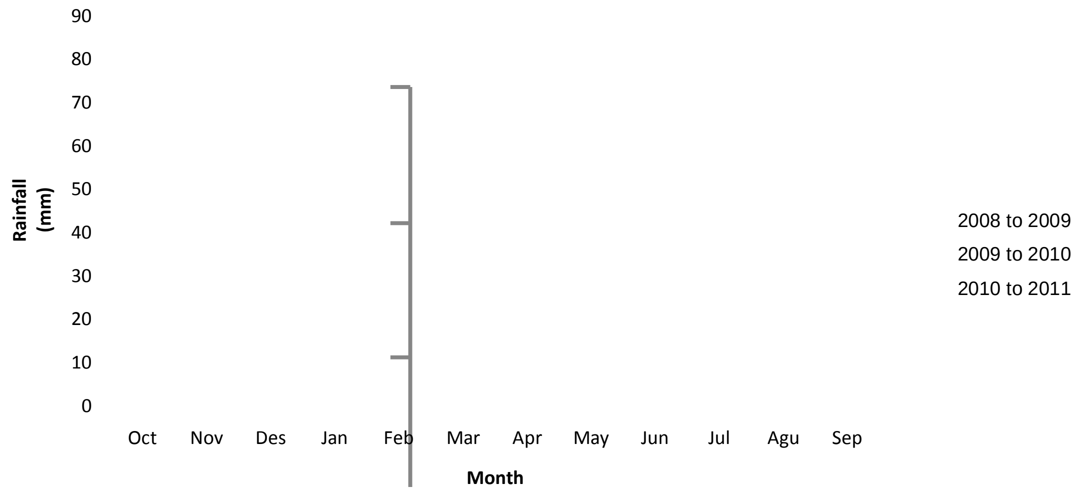

Figure 1. Statistics of Ardabil Rainfall for 2008 to 2011 cropping years.

Table 3. The mean squares of grain yield of durum wheat genotypes under optimal and stress conditions, and calculated different drought tolerance indices.

Source of variation	df[1]	Mean Square								
		YP [2]	YS [3]	SSI [4]	TOL [5]	MP [6]	GMP [7]	STI [8]	YI [9]	YSI [10]
Year	2	8247.09**	1314.1**	1.22*	1097.05**	2291.3**	1810.89**	0.46**	0.003**	0.47**
Genotypes	39	6427.02**	4462.2**	0.95**	5588.17**	4047.5**	4115.67**	0.103**	0.067**	0.045**
Error	78	1.42	1.52	0.06	4.17	2.01	2.02	0.002	0.0004	0.001
CV (%)[11]	-	3.94	4.51	23.18	6.90	3.48	5.51	5.33	5.11	4.55

[1]df, degrees of freedom; [2]YP, yield of a given genotype in optimal (potential) conditions; [3]YS, yield of a given genotype in stress conditions; [4]SSI, stress susceptibility index; [5]TOL, tolerance index. [6]MP: mean productivity. [7]GMP, geometric mean productivity; [8]STI, stress tolerance index; [9]YI, yield index; [10]YSI, yield stability index; [11]CV, coefficient of variation; **, significant at 0.05 and 0.01 probability level.

Table 4. Average yield durum wheat genotypes under optimal and stress conditions, and calculated different drought tolerance indices[1].

Genotypes	YS	YP	GMP	MP	TOL	SSI	STI	YI	YSI
1	3063.08	3768.83	3393.94	3415.96	705.75	0.75	0.95	1.19	0.82
2	2494.36	2942.64	2706.25	2718.51	448.28	0.6	0.61	0.97	0.85
3	2339.81	3046.58	2663.03	2693.2	706.78	0.9	0.58	0.91	0.78
4	2487.56	3302.26	2859.45	2894.92	814.7	0.98	0.67	0.97	0.76
5	2409.16	3211.39	2775.37	2810.28	802.23	0.99	0.63	0.94	0.76
6	2857.8	3707.39	3248.95	3282.6	849.58	0.92	0.87	1.11	0.78
7	2291.72	3052.22	2639.29	2671.97	760.5	1	0.58	0.89	0.76
8	2436.52	3155.38	2765.7	2795.96	718.86	0.88	0.63	0.95	0.78
9	1668.52	2856.83	2176.71	2262.68	1188.3	1.74	0.39	0.65	0.6
10	3097.8	4174.59	3586.61	3636.2	1076.78	1.07	1.07	1.2	0.75
11	2364.17	3449.46	2847.13	2906.82	1085.29	1.28	0.67	0.92	0.7
12	2356.52	3158.78	2723.99	2757.66	802.26	1.04	0.62	0.92	0.75
13	2142.92	3214.58	2618.26	2678.76	1071.66	1.38	0.56	0.83	0.68
14	2308.52	3172.99	2699.68	2740.76	864.47	1.09	0.6	0.9	0.74
15	2308.04	3170.94	2701.17	2739.5	862.9	1.13	0.61	0.9	0.73
16	2809.8	3496.98	3128.07	3153.4	687.18	0.76	0.81	1.09	0.81
17	3104.2	3905.79	3476.16	3505	801.58	0.81	1	1.21	0.8
18	2643.72	3812.19	3169.12	3227.96	1168.47	1.28	0.83	1.03	0.7
19	2847.08	3513.46	3156.22	3180.27	666.38	0.73	0.82	1.11	0.82

Table 4. Contd.

20	2265.8	3539.06	2826.1	2902.43	1273.26	1.52	0.66	0.88	0.65
21	3193.8	3864.19	3507	3529	670.39	0.67	1.02	1.24	0.83
22	3172.52	3751.54	3443.6	3462.04	579.02	0.57	0.98	1.23	0.85
23	2593.96	4152.51	3277.21	3373.24	1558.54	1.61	0.89	1.01	0.63
24	2249.16	3240.98	2693.45	2745.07	991.82	1.25	0.6	0.87	0.7
25	2909.32	3796.19	3317.42	3352.76	886.87	0.94	0.91	1.13	0.77
26	2248.04	3422.1	2767.7	2835.08	1174.06	1.44	0.63	0.87	0.67
27	2402.92	3237.79	2782.57	2820.36	834.86	1.03	0.64	0.93	0.75
28	2233.8	3924.19	2955.95	3079	1690.39	1.86	0.72	0.87	0.57
29	2248.84	3156.23	2658.91	2702.54	907.38	1.18	0.58	0.87	0.72
30	2716.36	3351.06	3010.22	3033.71	634.7	0.71	0.75	1.06	0.82
31	1796.52	4032.5	2687.58	2914.52	2235.98	2.43	0.6	0.7	0.45
32	2846.6	4256.34	3478.18	3551.48	1409.73	1.43	1.01	1.11	0.67
33	2864.04	3541.46	3178.3	3202.75	677.42	0.73	0.83	1.11	0.82
34	2901.32	2308.19	2575.28	2604.76	-593.14	-1.52	0.54	1.13	1.3
35	3038.12	4246.1	3590.85	3642.11	1207.97	1.19	1.07	1.18	0.72
36	2751.56	3988.19	3307.39	3369.88	1236.62	1.3	0.9	1.07	0.7
37	2392.52	3101.14	2716.72	2746.84	708.62	0.88	0.61	0.93	0.78
38	1993.16	2924.19	2407.16	2458.68	931.02	1.29	0.48	0.78	0.69
39	3188.84	3912.63	3528.12	3550.74	723.78	0.75	1.03	1.24	0.82
40	2818.76	4411.22	3521.65	3615	1592.46	1.55	1.03	1.1	0.64

1 Indices: see Table 3.

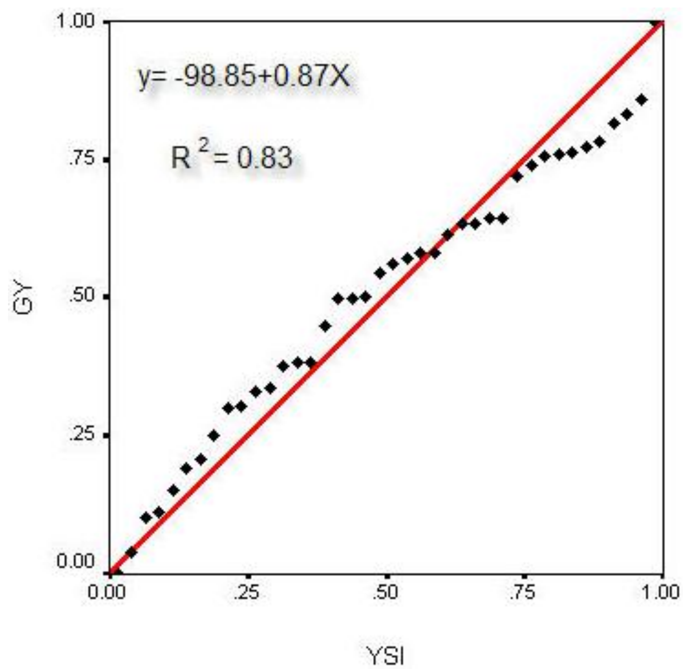

Figure 2. Relationship between drought stress grain yield and YSI.

both stressed and non-stressed environments.

To identify the best index of selection for drought-resistant genotypes, correlation coefficient between these indices and yield in non-stress condition (YP) as well as yield in stress condition (YS) was determined (Table 5). Correlation coefficients matrix (Table 5) revealed that TOL, MP, GMP, STI, and YI indices could effectively be used for screening of drought resistant genotypes. The

Table 5. Correlation between different drought tolerance indices[1] and mean yield of durum wheat genotypes under optimal and stress conditions.

	YS	YP	GMP	MP	TOL	SSI	STI	YI	YSI
YS	1								
YP	0.495**	1							
GMP	0.88**	0.846**	1						
MP	0.837**	0.890**	0.995**	1					
TOL	-0.363*	0.63**	0.121	0.207	1				
SSI	-0.514*	0.455**	-0.054	0.017	0.947**	1			
STI	0.873**	0.849**	0.998**	0.994**	0.130	-0.043	1		
YI	1.00**	0.495**	0.88**	0.837**	-0.362**	-0.515**	0.873**	1	
YSI	0.252**	-0.444**	0.067	-0.004	-0.945**	-1.00**	0.056	0.525**	1

1 Indices: see Table 3. ** And *, significant at 0.01 and 0.05 probability levels.

Table 6. Eigen value and vectors of principal component analysis for potential yield (YP), stress yield (YS) and drought tolerance indices[1].

Principal component	1	2
Percentage of variance	59.3	39.9
Cumulative percentage	59.3	99.2
YS	0.41	-0.16
YP	0.32	0.35
GMP	0.42	0.09
MP	0.41	0.13
TOL	-0.02	0.52
SSI	-0.10	0.50
STI	0.42	0.10
YI	0.41	-0.16
YSI	0.10	-0.50

[1] Indices: see Table 2.

results indicate that there were positive, significant correlations among Yp and (MP, GMP, TOL, SSI, YI and STI) and Ys and (YP, GMP, MP, STI, YI and YSI). SSI and TOL under rainfed condition was negatively and highly significantly (P<0.05) correlated with Ys (Table 5).

PCA result revealed that the first PCA explained 59.3% of the total data variation and had positive correlation with the performance under both stress and non-stress environments (Table 6). Thus the first dimension represents the yield potential and drought tolerance. In other words, this component was able to separate the genotypes with higher yield under both stress and non-stress conditions. The second PCA explained 39.9 % of total data variation (Table 6). The first two PCAs accounted for about 99.2% of total variation. PCA indicated that the indices could discriminate the wheat genotypes.

Biplot presentation depicted genotypes NO‘ 1, 22, 17, 21, 39, 6, 25, 16, 19, 33, 30, 10, 35, 32, 40, 18, 36 and 23’ located adjacent to important drought resistance indices that confirm these genotypes being drought resistant (Figure 3). Genotype NO‘ 2, 3, 7, 8, 37, 12, 14, 15, 4, 5, 27, 11, 20, 26, 13, 24, 29 and 28 was near to SSI and has high YP (seed yield in non-stress condition) value (Figure 3). Therefore, this genotype had specific adaptability to non-stress environment. Genotype No. 34, belong to low yield and high drought sensitivity region in the biplot space (Figure 3). On the other hand, there was genetic variability among genotypes based on their drought resistance. Using important resistance indices comprising of MP, GMP, HM, TOL, YI and STI genotypes UPGMA classification was done and three clusters were established that paralleled the biplot analysis results (Figure 4). And results of cluster Dendrogram confirmed the principle component analysis results.

DISCUSSION

The CV values for YP and YS were 3.94 and 4.51, respectively. As regard calculating indices, the values varied from 3.48 to 23.18 (Table 2). In general, CV value

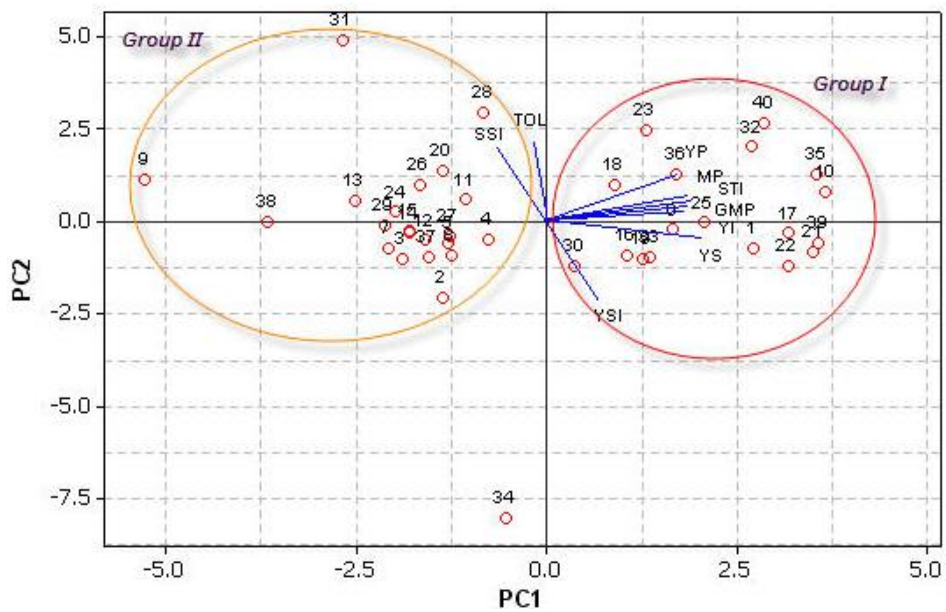

Figure 3. The genotype by trait biplots of durum wheats for resistance to drought stress trial. The traits are spelled out in lowercase letters, and each genotype is represented by numbers. [1] Indices: see Table 2.

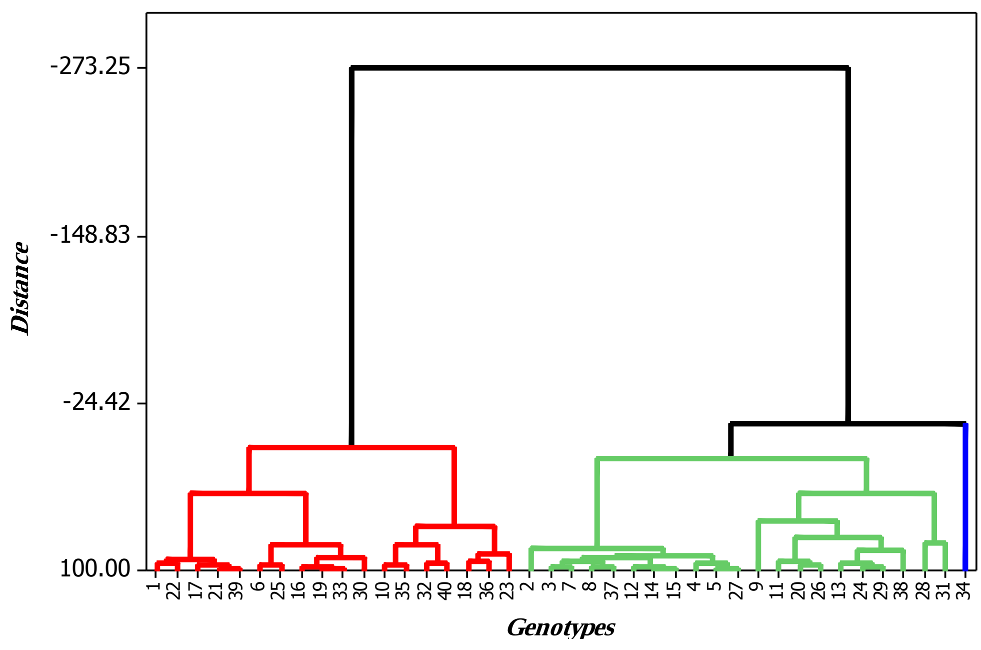

Figure 4. Dendrogrph from cluster analysis of genotypes based on drought tolerance indices and grain yield of durum wheat genotypes, in both normal and stress environment. Genotype codes: see Tabe 2.

higher than 20% is considered to be high; however, may be possible to ignore from approximately high CV values when F test are significant and this item is found in several published research works (Takemoto et al., 1988; Xu et al., 2000; Aliyu and Awopetu, 2005; Zarei et al., 2007; Okwuagwu et al., 2008; Kandiç et al., 2009; Sabu et al., 2009). This however indicates that effect of genotypes was more pronounced on studied characters under two irrigation regimes (Aliyu and Awopetu, 2005). The inconsistent CV values reported in many studies as our one might be due to physio-genetic characteristics and degree of compatibility of the plant material, low number of individual per genotype in plot, low number of replication per genotype and/or variable environments in which the trial was carried out (Okwuagwu et al., 2008).

Variation due to genotypes was significant for all characters in two conditions (rainfed and poorlyirrigated). This suggested that the magnitude of differences in genotypes was sufficient to provide some scope for selecting genotypes to improve drought tolerance. The mean comparison showed that G40 had the highest GY value.

Yield and yield-related traits under stress were independent of yield and yield-related traits under non-stress conditions, but this was not the case in less severe stress conditions. As STI, GMP and MP were able to identify cultivars producing high yield in both conditions. When the stress was severe, TOL, YSI and SSI were found to be more useful indices discriminating resistant cultivars, although none of the indicators could clearly identify cultivars with high yield under both stress and non-stress conditions (group A cultivars). It is concluded that the effectiveness of selection indices depends on the stress severity supporting the idea that only under moderate stress conditions, potential yield greatly influences yield under stress (Blum, 1996). Two primary schools of thought have influenced plant breeders who target their germplasm to drought-prone areas. The first of these philosophies states that, high input responsiveness and inherently high yielding potential, combined with stress-adaptive traits will improve performance in drought-affected environments (Richards, 1996; Van Ginkel et al., 1998; Rajaram and Van Ginkle, 2001; Betran et al., 2003). The breeders who advocate selection in favorable environments follow this philo--sophy. Producers, therefore, prefer cultivars that produce high yields when water is not so limiting, but suffer a minimum loss during drought seasons (Nasir Ud-Din et al., 1992). The second is the belief that progress in yield and adaptation in drought-affected environments can be achieved only by selection under the prevailing conditions found in target environments (Ceccarelli, 1987; Ceccarelli and Grando, 1991; Rathjen, 1994). The theoretical framework to this issue has been provided by Falconer (1952) who wrote, ‘‘yield in low and high yielding environments can be considered as separate traits which are not necessarily maximized by identical sets of alleles’’. Over all, drought stress reduced significantly the yield of some genotypes and some of them revealed tolerance to drought, which suggested the genetic variability for drought tolerance in this material. Therefore, based on this limited sample and environments, testing and selection under non-stress and stress conditions alone may not be the most effective for increasing yield under drought stress. The significant and positive correlation of Yp and MP, GMP and STI showed that these criteria indices were more effective in identifying high yielding cultivars under different moisture conditions. The results of calculated gain from indirect selection in moisture stress environment would improve yield in moisture stress environment better than selection from non-moisture stress environment. Wheat breeders should, therefore, take into account the stress severity of the environment when choosing an index. Finally it was found that Genotypes No. 10 and 35 based on STI, Mp and GMP indices were tolerant genotypes and these genotypes are useful to selection for drought resistance.

REFERENCES

Abayomi Y, Wright D (1999). Effects of water stress on growth and yield of spring wheat (*Triticum aestivum L.*) cultivars. Trop. Agric., 76: 120-125.

Aliyu OM, Awopetu JA (2005). *In vitro* regeneration of hybrid plantlets of cashew (*Anacardium occidentale* L.) through embryo culture. Afr. J. Biotechnol., 4: 548-553.

Betran FJ, Beck D, Banziger M, Edmeades GO (2003). Genetic analysis of inbred and hybrid grain yield under stress and non stress environments in tropical maize. Crop Sci. J., 43: 807-817.

Betran FJ, Beck D, Banziger M, EdmeadeS GO (2003). Genetic analysis of inbred and hybrid grain yield under stress and nonstress environments in tropical maize. Crop Sci., 43: 807-817.

Blum A (1988). Plant Breeding for Stress environments. CRC Press Florida, pp. 212.

Blum A (1996). Crop responses to drought and the interpretation of adaptation. Plant Growth Regul., 20: 135-148.

Bouslama M, Schapaugh WT (1984). Stress tolerance in soybean. Part 1: evaluation of three screening techniques for heat and drought tolerance. Crop Sci. J., 24: 933-937.

Bouslama M, Schapaugh WT (1984). Stress tolerance in soybean. Part 1: evaluation of three screening techniques for heat and drought tolerance. Crop Sci. J., 24: 933-937.

Byrne PF, Bolanos J, Edmeades GO, Eaton DL (1995). Gains from selection under drought versus multilocation testing in related tropical maize populations. Crop Sci. J., 35: 63-69.

Ceccarelli S (1987). Yield potential and drought tolerance of segregating populations of barley in contrasting environments. Euphytica, 40:197-205.

Ceccarelli S, Grando S (1991). Selection environment and environmental sensitivity in barley. Euphytica., 57: 157-167.

Chmielewski F, Kohn W (2000) Impact of weather on yield components of winter rye over 30 years. Agric. Forest Meteorol. .102: 253-261.

Clarke JM, De Pauw RM, Townley-Smith TM (1992). Evaluation of methods for quantification of drought tolerance in wheat. Crop Sci. J., 32: 728-732.

Falconer DS (1952). The problem of environment and selection. Am Nat., 86: 293-298.

Fernandez GCJ (1992). Effective selection criteria for assessing stress tolerance. In: Kuo CG (ed) Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress, Publication, Tainan, Taiwan.

Fischer RA, Maurer R (1978). Drought resistance in spring wheat cultivars. I. Grain yield response. Aust. J. Agric. Res. 29: 897-907.

Gavuzzi P, Rizza F, Palumbo M, Campaline RG, Ricciardi GL, Borghi B (1997). Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Plant Sci., 77: 523-531.

Giunta F, Motzo R, Deidda M (1993) Effect of drought on yield and yield components of durum wheat and triticale in a Mediterranean environment. Field Crops Res., 33: 399-409.

Hossain ABS, Sears AG, Cox TS, Paulsen GM (1990). Desiccation tolerance and its relationship to assimilate partitioning in winter wheat. Crop Sci., 30: 622-627.

Iran Meteorological Organization (2011). http://www.irimo.ir/

Jafari A, Paknejad F, Jami M, Ahmadi AL (2009). Evaluaton of selection indices for drought tolerance of corn (*Zea mays* L.) hybrids. Int. J. Plant Prod, pp. 3-4.

Kandic´ V, Dodig D, Jovic´ M, Nikolic´ B, Prodanovic´ S (2009). The importance of physiological traits in wheat breeding under irrigation and drought stress. Genetika 41, 11-20.

Khayatnezhad M, Zaefizadeh M, Gholamin R (2010). Investigation and selection index for drought stress, Aust. J. Basic Appl. Sci., 4(10): 4815-4822.

Leilah AA, AL Khateeb SA (2005) Statistical analysis of wheat yield under drought conditions. J. Arid Environ., 61: 483-496.

LI Y, Fahima T, Korol AB, Peng J, Roder MS, Kizhner V, Beiles A, Nevo E (2000). Microsatellites diversity correlated with ecological and genetics factors in three micro sites of wild emmer wheat in north Israel Mol. Biol. J., 17: 851-862

Mohammadi R, Armion M, Kahrizi D, Amri A (2010). Efficiency of screening techniques for evaluating durum wheat genotypes under mild drought conditions. Journal of Plant Production 4(1): 11-24.

Nasir Ud-Din, Carver BF, Clutte AC (1992). Genetic analysis and selection for wheat yield in drought-stressed and irrigated environments. Euphytica, 62, 89-96.

Nouri A, Etminan A, Silva JAT, Mohammadi R (2011). Assessment of yield, yield-related traits and drought tolerance of durum wheat genotypes (*Triticum turjidum* var. *durum* Desf.), Aust J. Crop Sci., 5(1):8-16.

Okwuagwu CO, Okoye MN, Okolo EC, Ataga CD, Uguru MI (2008). Genetic variability of fresh fruit bunch yield in Deli/*dura. tenera* breeding populations of oil palm (*Elaeis guineensis* Jacq.) in Nigeria. J. Trop. Agr., 46: 52-57.

Rajaram S, VAN Ginkle M (2001) Mexico, 50 years of international wheat breeding. In The world Wheat Book, A History of Wheat Breeding, Bonjean AP, and Angus WJ (eds) Paris, France. Lavoisier Publishing, 579-604.

Rathjen AJ (1994). The biological basis of genotype environment interaction: its definition and management. In: Proceedings of the Seventh Assembly of the Wheat Breeding Society of Australia, Adelaide, Australia.

Reddy AR, Chaitanya KV, Vivekananda M (2004). Drought induced responses of photosynthesis and antioxidant metabolism in higher plants. Plant Physiol. J., 161: 1189-1202.

Richards RA (1996). Defining selection criteria to improve yield under drought. Plant Growth Regul., 20: 157-166.

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

Sabu KK, Abdullah MZ, Lim LS, Wickneswari R (2009) Analysis of heritability and genetic variability of agronomically important traits in *Oryza sativa. O. rufipogon* cross. Agron. Res., 7: 97-102.

Simon BS, Geresh S (1993). Polysaccharide degrading activities extracted during growth of a dinoflagellate that preys on *Porphyridium sp.,* Plant Physiol. Biochem., 31: 387 - 393.

Sio-se Mardeh A, Ahmadi A, Poustini K, Mohammadi V (2006). Evaluation of drought resistance indices under various environmental conditions. Field Crop Res. J., 98: 222-229.

Takemoto BK, Bytnerowicz A, Olszyk DM (1988). Depression of photosynthesis, growth, and yield in field-grown green pepper (*Capsicum annuum* L.) exposed to acidic fog and ambient ozone. Plant Physiol., 88: 477-482.

van Ginkel M, Calhoun DS, Gebeyehu G, Miranda A, Tian-you C, PARGAS Lara R, Trethowan RM, Sayre K, Crossa L, Rajaram S (1998). Plant traits related to yield of wheat in early, late, or continuous drought conditions. Euphytica, 100: 109-121.

Xu W, Subudhi PK, Crasta OR, Rosenow DT, Mullet JE, Nguyen HT (2000). Molecular mapping of QTLs conferring stay-green in grain sorghum (*Sorghum bicolor* L. Moench). Genome, 43: 461-469.

Zarei L, Farshadfar E, Haghparast R, Rajabi R, Mohammadi-sarab Badieh M (2007). Evaluation of some indirect traits and indices to identify drought tolerance in bread wheat (*Triticum aestivum* L.). Asian J Plant Sci., 6: 1204-1210.

Zhao CX, Guo LY, Jaleel CA, Shao HB, Yang HB (2008). Prospects for dissecting plant-adaptive molecular mechanisms to improve wheat cultivars in drought environments. Compt. Rend Biol. J., 331: 579-586.