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Investigation and Selection Index for Drought Stress

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Abstract: Considering the special position of durum wheat in terms of resistance to environmental stress and diseases and lack of water resources for cultivation of this plant so valuable study on drought resistance in plants is important. The objective of this study was to evaluate the ability of several selection indices to identify drought resistance cultivars under a variety of environmental conditions. Twenty two durum wheat lines and cultivars were evaluated under both moisture stress (E1) and non-stress (E2) field environments using a randomized complete block design for each environment. Seven drought tolerance indices including stress susceptibility index, stress tolerance index, tolerance, yield index, yield stability index, mean productivity and geometric mean productivity were used. The indices were adjusted based on grain yield under drought and normal conditions. The significant and positive correlation of Yp and MP, GMP and STI showed that these indices were more effective in identifying high yielding cultivars under different moisture conditions. The results of calculated gain from indirect selection from 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 in choosing an index.

Key words: durum wheat, drought tolerance index, moisture stress.

INTRODUCTION

Dryness of the most important factor limiting production of crops including wheat in the world and Iran. This Topic is more important in dry and semi-arid regions of the world (Kirigwi, 2004). Importance of this subject is determined when we know which more than 1/4 part ground is dry and estimated that about 1/3 of the world's cultivable land under water shortage conditions are in range (Kirigwi, 2004). 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 (Talebi, 2009). Drought tolerance consists of ability of crop to growth and production under water deficit conditions. A long term drought stress effects on plant metabolic reactions associates with, plant growth stage, water storage capacity of soil and physiological aspects of plant. Drought tolerance in crop plants is different from wild plants. In case crop plant encounters severe water deficit, it dies or seriously loses yield while in wild plants their surviving under this conditions but no yield loss, is taken into consideration. However, because of water deficit in most arid regions, crop plants resistance against drought, has always been of great importance and has taken into account as one of the breeding factors (Talebi, 2009). Achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in yield grain has been much higher in favorable environments (Richards *et al*, 2002). Thus, drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). These indices are either based on drought resistance or susceptibility of genotypes (Fernandez, 1992). Drought resistance is 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 as a function of the reduction in yield under drought stress (Blaum, 1988) whilst the values are confounded with differential yield potential of genotypes (Ramirez and Kelly, 1998). Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress (Yp) environments and mean

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productivity (MP) as the average yield of Ys and Yp. Fischer and Maurer (1978) proposed a stress susceptibility index (SSI) of the cultivar. Fernandez (1992) defined a new advanced index (STI = stress tolerance index), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. Other yield based estimates of drought resistance are geometric mean (GM), mean productivity (MP) and TOL. The geometric mean is often used by breeders interested in relative performance since drought stress can vary in severity in field environment over years (Ramirez and Kelly, 1998). Clark *et al*. (1992) used SSI for evaluation of drought tolerance in wheat genotypes and found year-to-year variation in SSI for genotypes and their ranking pattern. In spring wheat cultivars, Guttieri *et al*. (2001) using SSI criterion suggested that SSI more than 1 indicated above-average susceptibility to drought stress. Golabadi *et al*. (2006) and Sio-Se Mardeh *et al*. (2006) suggested that selection for drought tolerance in wheat could be conducted for high MP, GMP and STI under stressed and non-stressed environments. Selection of different genotypes under environmental stress conditions is one of the main tasks of plant breeders for exploiting the genetic variations to improve the stress-tolerant cultivars (Clark *et al*., 1984). Until now different research has been done about stress on wheat. Zaeifizadeh studied the relationship between genotype and environmental conditions (dry and normal) on the amount of chlorophyll content and the amount of super oxide Dismutase reported that drought-resistant cultivars increase Dismutase Super oxide stress increases but in susceptible cultivars decrease chlorophyll Super oxide Dismutase showed (Zaeifizadeh, 2009). Also a good variety between the native masses of durum wheat in North-West Iran and Azerbaijan in terms of drought resistance and SRAP (Sequence related amplified polymorphism) but did not found any Significant relationship between Coefficient of drought tolerance and SRAP(Zaeifizadeh, 2009). The present study was undertaken to assess the selection criteria for identifying drought tolerance in durum wheat genotypes, so that suitable genotypes can be recommended for cultivation in the drought prone area of Iran and Ardabil.

MATERIAL AND METHODS

Twenty two durum wheat cultivars (Triticum durum Desf.)with Iran and Azerbaijan republic region were chosen for the study based on their reputed differences in yield performance under irrigated and non-irrigated conditions (Table 1).

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

no	name	Landraces	origin	no	name	Landraces	origin
1	Hordeiforme	Miyane	Iran	12	leucumelan	Naxcivan	Azerbijan
2	Africanum	Sanandaj	Iran	13	albiprovinciale	Qu	Azerbijan
3	leucurum	kermanshah	Iran	14	murceinse	Naxcivan	Azerbijan
4	melanopus	Ahar	Iran	15	leucurum	Lerik	Azerbijan
5	hordeiforme	Maragheh	Iran	16	leucumelan	Naxcivan	Azerbijan
6	leucurum	Sarab	Iran	17	apulicum	11010	Iran
7	leucurum	Tabriz	Iran	18	melanopus	hasanbaruq	Azerbijan
8	melanopus	Cheiltoxm	Azerbijan	19	hordeiforme	Langan	Azerbijan
9	hordeiforme	shamxi	Azerbijan	20	apulicum	Ardabi	Iran
10	apulicum	xanlar	Azerbijan	21	boeuffi	Ardabi	Iran
11	boeuffi	shaxi	Azerbijan	22	aboscurum	Ardabi	Iran

Experiments were conducted at the experimental field of Islamic Azad University of Ardabil, in Ardabil province (Northwest of Iran) in 2008-2009. Seeds were hand drilled and each genotype was sown in five rows of 1.5 m, with row to row distance of 0.2 0 m. The experiment was laid out in randomized complete block design (RCBD) with two replications. Two levels of stress treatments including:

1- Full irrigation (100 percent water based on plant needs wheat cultivars at different growth stages).
2- Limited irrigation (Supply plant water needs until pollination stage and then Format water until the end of wheat growth and development).

Every line in 5 rows and 20 cm intervals and 150 cm in width were planted. Immediately after planting the field was irrigated to soil moisture profiles in root development and saturated and identical for all treatments in addition to the germination easily be done. Irrigation was done with leaking method. After harvest to evaluate the factors affecting the performance traits, plant height, tiller number total , fertile tillers, number of internode, peduncle length, length of main spike, spike original weight, awn length, total dry weight , number of seeds per main spike and main spike grain weight were measured.

Drought resistance indices were calculated using the following relationships:

1. Stress Susceptibility Index (SSI):

SSI=(1-(Ysi/Ypi))/SI

(Fischer and Maurer, 1978);

2. Stress Tolerance Index (STI):
STI= $(Ypi*Ysi)/Yp^2$
(Fernandez, 1992);

3. Tolerance Index (TOL):
TOL=Ypi-Ysi
(Hossain *et al*., 1990);

4. Geometric Mean Productivity (GMP):
GMP= $\sqrt{Ypi*Ysi}$
(Fernandez, 1992);

5. Mean Productivity (MP):
MP=(Ypi+Ysi)/2
(Hossain *et al*., 1990);

6. Yield Index (YI):
YI=Ysi/Ys
(Gavuzzi *et al*., 1997; Lin *et al*., 1986);

7. Yield Stability Index (YSI):
YSI=Ysi/Ypi
Where:
Ysi= yield of cultivar in stress condition,
Ypi= yield of cultivar in normal condition
And SI that is stress intensity, where:
SI= 1- (Ys/Yp)
Ys= total yield mean in stress condition,
Yp= total yield mean in normal condition

Data were analyzed using SPSS16 for analysis of variance and Duncan's multiple range tests was employed for the mean comparisons.

Results:

The results of analyses of variance for grain yield and other related traits in both stress and non-stress environments are given in Table 2. There was a significant difference among stress conditions for grain yield and other traits. Except as total number of tillers and fertile tillers remaining traits were Significant in 0.01 percent probability level. The genotypes showed significant differences in grain yield and other traits. Traits of total number of tillers, total plant weight and seed number per main spike were non-significant, traits of fertile tillers and harvest index 0.05 percent level, and other traits were significant in 0.01 percent level. Thus, indirect selection for a drought-prone environment based on the results of optimum conditions will not be efficient. These results are in agreement with those of Sio-Se Mardeh *et al*. (2006) and Bruckner and Frohberg (1987). For drought tolerance genotypes and select the best value performance indicators based on tolerance for the genotypes studied and calculated in Table 3 is. Accordingly, high levels indicators sti, mp, and GMP values and low index of tol and SSI indicator of resistance to stress conditions has figures.

Fernandez (1992) in study the yield of genotypes in two environments and without drought stress than plants in two environments appears to be divided into four groups:

1- The genotypes that have high yield in stress and non stress environments (group A).
2- The genotypes that have high yield only in non stress environments (group B).
3- The genotypes that have high yield in stress environments (group C).
4- The genotypes that have weak yield in stress and non stress environments (group D).

Fernandez opinion appropriate selection criterion for stress group A criterion that can recognize from other groups. How much higher STI value represents higher drought tolerance of specific genotypes that cause this rise in yield potential is higher than its genotype. This index genotypes of group A group B and C are separated. Selected based on selection index SSI caused some genotypes with low yield but high yield under normal environmental conditions are stressful. The major drawback of this index is able to identify group A,

Table 2: Results of Analysis of variance for studied traits

		MS					
S.O.V	df	Plant height	Total tillers	Fertile tillers	Peduncle length	Main spike length	Main spike weight
Rep	1	739.96**	2.13	0.031	649.80**	1.77*	0.012
Condition	1	7040.78**	0.13	1.65	2465.03**	10.09**	3.64**
Genotype	21	713.54**	3.041	4.15*	179.01**	1.71**	0.406**
C*G	21	278.74**	3.78*	2.906	150.54**	0.36	0.07
Error	43	113.36	2.205	2.46	37.63	0.61	0.15

		MS					
S.O.V	df	Total plant weight	grains per main spike	Grain weight per main spike	1000 grain weight	yield	Harvest index
Rep	1	77.4	1.11	0.013	50.16	15.72	64.96
Condition	1	747.17**	120.11**	4.11**	217.54**	1216.901**	647.09**
Genotype	21	71.84	15.44	0.23**	32.41**	1516.86**	45.35*
C*G	21	58.17	12.72	0.05	23.13	953.4*	46.48*
Error	43	64.36	17.16	0.07	18.63	474.41	27.84

** And * significant at the 0.01 and 0.05 levels, respectively

group C is not. Any differences between the YP and YS is more TOL value increases and this represents the most susceptible to drought and whatever values of this index is lower, will be more favorable. Selection index based on these selected causes some genotypes with low yield potential under stress and high yield under stress is. The index also able to isolate the group A of C is not. GMP less sensitive to the values of YS and YP is very different, whereas the MP index is based on an arithmetic average, when the relative difference between YS and YP is great with unbiasedness will be upwards. Therefore, GMP index compared with the MP index higher separation power than other groups, Group A and on this basis that Fernandez STI index to put on the GMP.(Sio-Se Mardeh *et al*. (2006) Relationship between grain yield of irrigated and non irrigated durum wheat cultivars in Figure 1 has been shown.Thus, grouping genotypes based on Index Fernandez took.

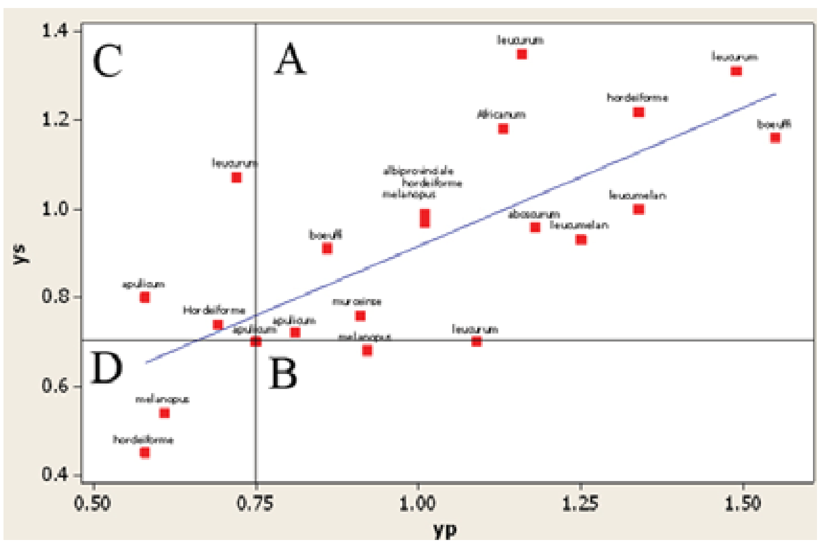

Fig. 1: Relationship between grain yield of irrigated and non-irrigated durum wheat genotypes.

The positive correlation between TOL and irrigated yield (Yp) and the negative correlation between TOL and yield under stress (Ys) (Table 4) suggest that selection based on TOL will result in reduced yield under well-watered conditions. Similar results were reported by Clark *et al*. (1992) and Sio-Se Mardeh *et al*. (2006). SSI showed a negative correlation 0.01with yield under stress (Table 4). SSI has been widely used by researchers to identify sensitive and tolerant genotypes (Clark *et al*., 1992; Sio-Se Mardeh *et al*., 2006; Golabadi *et al*., 2006).There was a significant correlation between STI or GMP and yield under stress (Table 4). In this study, a general linear model regression of grain yield under drought stress on STI revealed a positive correlation between this criteria with a similar coefficient of determination (R^2= 0.61) (Fig. 2). The connection between STI and y_s was positive and significant.

Table 3: Resistance indices of 22 durum genotypes under stress and non-stress environment

YI	YSI	GMP	MP	TOL	STI	SSI	Yp	Ys	genotype no
0.69	0.74	70.59	112.57	21.75	0.53	2.69	82.3	60.55	1
1.13	1.18	91.42	133.75	-15.5	0.88	-1.88	84	99.5	2
1.16	1.35	87.51	126.14	-26.53	0.81	-3.59	75.25	101.78	3
1.01	0.97	89.91	135.53	2.55	0.86	0.28	91.2	88.65	4
0.58	0.45	75.69	138.7	62.95	0.61	5.65	113.45	50.5	5
1.09	0.7	114.75	185.35	41.65	1.39	3.09	137.45	95.8	6
0.72	1.07	60.68	90	-4.35	0.39	-0.76	58.55	62.9	7
0.92	0.68	98.06	159.18	37.6	1.02	3.23	118.65	81.05	8
1.01	0.99	89.24	134.13	1	0.84	0.11	89.75	88.75	9
0.81	0.72	83.31	133.45	27.25	0.73	2.83	98.05	70.8	10
1.55	1.16	125.73	184.38	-19.1	1.67	-1.67	116.55	135.65	11
1.34	1	117.24	175.95	0.3	1.45	0.03	117.4	117.1	12
1.01	0.98	89.47	134.6	1.55	0.85	0.17	90.25	88.7	13
0.91	0.76	92.14	146.05	25.9	0.9	2.49	106	80.1	14
1.49	1.31	113.72	164.4	-31.05	1.37	-3.19	99.25	130.3	15
1.25	0.93	113.92	173.03	8.1	1.37	0.7	118.05	109.95	16
0.75	0.7	78.73	127.2	28.65	0.66	3.09	94.35	65.7	17
0.61	0.54	72.78	125.65	45.25	0.56	4.66	98.85	53.6	18
1.34	1.22	106.3	154.88	-21.6	1.2	-2.29	96.05	117.65	19
0.58	0.8	56.62	88.63	12.65	0.34	2.03	63.3	50.65	20
0.86	0.91	79.02	120.43	7.1	0.66	0.87	82.65	75.55	21
1.18	0.96	105.75	159.68	4.05	1.18	0.38	107.8	103.75	22

Table 4: Correlation coefficients between Yp, Ys and drought tolerance indices.

	Y_P	Y_S	SSI	STI	TOL	MP	GMP	YSI	YI
Y_P	1								
Y_S	0.399	1							
SSI	0.301	-0.74**	1						
STI	0.735**	0.905**	-0.397	1					
TOL	0.364*	-0.70**	0.985**	-0.354	1				
MP	0.902**	0.765**	-0.435*	0.951**	-0.074	1			
GMP	0.749**	0.904**	-0.393	0.994**	-0.343	0.961**	1		
YSI	-0.298	0.744**	-1.00**	0.400	-0.98**	0.138	0.395	1	
YI	0.398	1.000**	-0.743	0.905**	-0.71**	0.755**	0.904**	0.744**	1

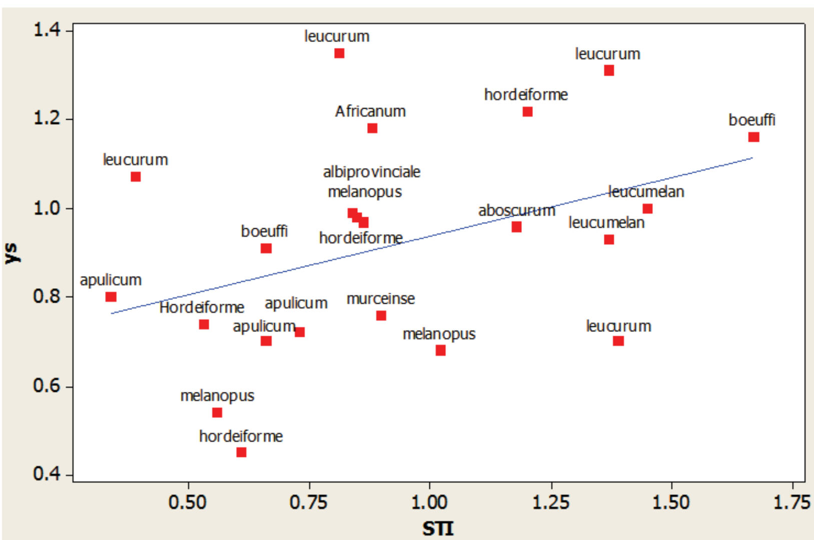

Fig. 2: Relationship between drought stress grain yield (g m-2) and stress tolerance index (STI).

Selection based on a combination of indices may provide a more useful criterion for improving drought resistance of wheat but study of correlation coefficients are useful in finding the degree of overall linear association between any two attributes. Thus, a better approach than a correlation analysis such as biplot is needed to identify the superior genotypes for both stress and non-stress environments. Principal component analysis (PCA) revealed that the first PCAs explained 1.69 of the variation with Ys, Ys, MP, STI and GMP (Fig 3).

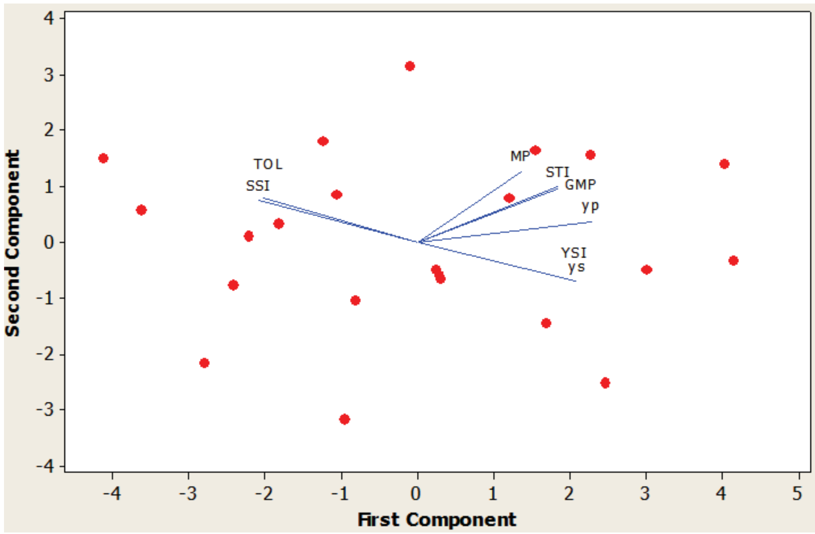

Fig. 3: Principal component analysis of drought resistance indices.

Analysis of principal components in Table 5 has been inserted in the first two components of total 99.53 percent of the data changes were justified. And the most positive relationship belongs Fernandez index and the lowest index was SSI.

Table 5: Results of factor analysis

Extraction Sums of squared Loadings		
Component	% Variance	Cumulative %
1	69.190	69.190
2	30.349	99.539
	Component	
	1	2
YI	0.996	0.0085
YSI	0.801	-0.595
GMP	0.865	0.500
MP	0.698	0.713
TOL	-0.765	0.637
STI	0.867	0.491
SSI	-0.799	0.597

Therefore, genotypes belonging to numbers 6, 11, 15 and 19 were superior genotypes for both environments with high PC1 and low PC2. Genotypes belonging to numbers 5, 7 and 18 with high PC2 were more suitable for non-moisture stress than for moisture-stress environment. Farshadfar and Sutka (2003), Sio-Se Mardeh *et al*. (2006) and Golabadi *et al*. (2006) obtained similar results in multivariate analysis of drought tolerance in different crops.

Discussion:

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; Panthuwan *et al*., 2002). 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 philosophy. 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.

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