World Applied Sciences Journal 22 (4): 594-600, 2013
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2013.22.04.1915

Assessment of Drought Tolerance in Genotypes of Wheat by Multivariate Analysis

[1]Reza Ashrafi Parchin, [2]Abdollah Najaphy, [3]Ezatollah Farshadfar and [1]Saied Hokmalipour

[1]Ardabil Branch, Islamic Azad University, Ardabil, Iran
[2]Department of Agronomy and Plant Breeding,
Faculty of Agriculture, Razi University, Kermanshah, Iran
[3]Department of Biotechnology for Drought Resistance, Razi University, Kermanshah, Iran

Abstract: Drought is a factor that limits the agricultural crops. Improving resistant genotypes is a method to control the drought effects. The research was carried out at Agriculture College, Pardis Branch within 2008-2009 growing season. The thirty genotypes applied in this experiment were received from Rain-fed Research Sub-Institute of Sararood, Kermanshah. The genotypes were assessed using a completely randomized block design with three replications. Most drought resistant indices and the multivariate statistical analyses concerned the data which were obtained from stress and normal site. The results analysis of variances indicated the genotypes difference in their reaction to the drought. Moreover the resistant, susceptible genotypes were identified according to the indices. By means of the results of component analysis, two factors were identified and were named drought resistance and drought susceptibility factors. These factors justify 99.1 percent of the total changes. The results of main components analysis and by plot analysis indicated that genotypes 1, 2, 15, 7, 9, 19, 30 and 20 are introduced as the best genotypes; on the yield figure these genotypes are seen among normal condition, stress condition and the indices of MP, GMP, HARM and STI. Based on the results of the cluster analysis, the genotypes are placed in three separate groups. the genotypes placed in the first cluster, were drought resistant, those of the second group were intermediate and those of the third group were drought susceptible.

Key words: Drought tolerance % Multivariate analysis and wheat genotypes

INTRODUCTION

Bread wheat, regular wheat, is scientifically called *Triticum aestivum* and contains Genome Hexoploid (AABBDD). This plant is annual and self-pollinator. Wheat is cultivated in the realm of 30-60 N° and 27-40 S° [1]. According to the statistics of the food and agriculture organization (FAO), during 2008-2009 growing season 678 million tons of wheat were produced and it is estimated that up to 682 million tons will be produced in 2009-2010 growing season. Meanwhile, more than 250 million ha of the world soil is cultivated with wheat [2]. As the world population increases, so does the demand noticeably for wheat: the experts contend that the amount of the annual wheat production must be 2% higher than the annual demand. The world does not have enough potential for increasing the soil level cultivated with wheat; therefore in order to increase the wheat production, we have to increase the productivity of the fields which have been cultivated with wheat. Developing new genotypes should be for the sake of increasing the grain yield and quality and its resistance to biological stresses and other kinds of stress [3]. Drought is a non-biologic stress which limits the production of crops in regions with water shortage [4]. Drought stress is attributed to the condition wherein the swelling of cells and tissues is not in a perfect state; this problem may vary from a minor decrease in water potential to the plant’s permanent withering. To put simply, the water shortage occurs when transpiration is more than the amount of absorbed water [5].

Five terms which have been used more often to express the plant’s mechanisms for resistance to the drought, are escape from drought (e.g. premeditation), drought avoidance (e.g. stomata and cuticle resistance), drought tolerance (e.g. osmotic adjustment and swelling

Corresponding Author: Saied Hokmalipour, Ardabil Branch, Islamic Azad University, Ardabil, Iran.

increase), post- drought recovery (e.g. super-susceptibility) and drought resistance [6, 7, 8]. According to Fernandez, you can classify the genotypes into four groups by their yield response to stress conditions: group A) genotypes which yield highly in both the stress and non-stress conditions, group B) genotypes which yield highly in non-stress conditions, group C) stress, group D) genotypes with weak yield in both the stress and non-stress conditions [9]. Several selection indexes based on the mathematical relations between the stress condition and normal condition have been suggested for determining the drought resistant genotypes. The most suitable index, based on which you select the genotypes, must be one that causes the yield improvement in both the stress and non-stress conditions [10], in an experiment Mohammadi *et al*. [11] used principal components analysis to classify the genotypes of doroum wheat into three groups by their drought resistance. In this research, too, there appear three main groups of genotypes. The first group has much positive first component; has less positive second component; and has optimal yield and drought resistance in rain-fed conditions. The second group has positive amount of first component; has negative amount of second component; and is good at drought resistance. However they yield well only in irrigation conditions because these genotypes are closer to the irrigation yield and are more selected by use of TOL index. The third group is negative in terms of both components and is considered susceptible. This experiment was carried out with the aim of identifying the most drought-resistant genotype and selecting the best index for investigated genotypes by multivariate statistical methods.

MATERIALS AND METHODS

Thirty genotypes of bread wheat (*Triticum aestivum* L.) listed in Table 1 were received from Dryland Agriculture Research Sub-Institute (Sararood Station). They were assessed using a completely randomized block design with three replications under two different water environments (irrigated and rain-fed) during 2008-2009

Table 1: Pedigree of investigated wheat genotypes

Genotype	Genotype pedigree
1	F103-L-1-12//PONY/OPATA
2	OR F1.158/FDL//BLO/3/SH14414/CROW/4/C ICWH99381-0AP-0AP-OMAR-6MAR
3	PYN/BAU//VORONA/HD2402
4	KATILA-13
5	SARDARI-HD35/5/DMN//SUT/AG(ES86-7)/3/ ICWH99-0552-0AP-0AP-OMAR-3MAR
6	Zarin
7	CA8055//KS82W409/STEPHENS
8	Bolani
9	Shahriar
10	WS-82-9
11	SABALAN/4/VRZ/3/OR F1.148/TDL//BLO
12	HAMAM-4
13	Atila2/PBW65
14	KAUZ’S’/MACHETE
15	M-79-7
16	Pishtase
17	KAR-1//RMNF12-71/JUP’S’
18	QAFZAH-25
19	Marvdasht
20	Chamran
21	M-81-13
22	TEVEE’S’//CROW/VEE’S’
23	M-83-17
24	M-83-6
25	M-82-6
26	Jcam/Emu”s”//dove”S”/3/Alvd/4/MV17/Attila
27	Shiraz
28	STAR/SHUHA-4
29	KATILA-1
30	Pishgam (Bkt/Zhong)

Table 2: Yield in Stress, non Stress and drought stress indicators

Genotype	Yp	s	STI	GMP	SSI	MP	TOL	HARM	YSI	YI
1	8.17	3.82	0.62	5.59	1.02	5.99	4.35	5.20	0.47	1.13
2	7.51	3.66	0.55	5.25	0.98	5.59	3.85	4.93	0.49	1.08
3	5.89	3.05	0.36	4.24	0.92	4.47	2.84	4.02	0.52	0.90
4	6.60	2.67	0.35	4.20	1.14	4.63	3.93	3.80	0.40	0.79
5	7.28	2.78	0.40	4.50	1.18	5.03	4.50	4.03	0.38	0.82
6	8.82	3.17	0.56	5.29	1.22	5.99	5.65	4.66	0.36	0.94
7	6.65	4.29	0.57	5.34	0.68	5.47	2.36	5.21	0.65	1.27
8	6.26	3.64	0.45	4.78	0.80	4.95	2.62	4.61	0.58	1.08
9	7.26	3.61	0.52	5.12	0.96	5.43	3.65	4.82	0.50	1.07
10	6.71	3.01	0.40	4.49	1.05	4.86	3.70	4.15	0.45	0.89
11	6.70	3.24	0.43	4.66	0.99	4.97	3.46	4.37	0.48	0.96
12	4.22	4.04	0.34	4.13	0.08	4.13	0.18	4.13	0.96	1.20
13	5.91	3.90	0.46	4.80	0.65	4.91	2.01	4.70	0.66	1.15
14	6.95	4.00	0.55	5.27	0.81	5.47	2.95	5.07	0.58	1.18
15	8.92	4.08	0.72	6.03	1.04	6.50	4.84	5.60	0.46	1.21
16	8.05	2.99	0.48	4.90	1.20	5.52	5.07	4.36	0.37	0.88
17	5.81	3.39	0.39	4.44	0.80	4.60	2.43	4.28	0.58	1.00
18	6.04	3.58	0.43	4.65	0.78	4.81	2.46	4.50	0.59	1.06
19	8.39	3.58	0.60	5.48	1.10	5.98	4.81	5.02	0.43	1.06
20	8.19	4.62	0.75	6.15	0.83	6.40	3.57	5.91	0.56	1.37
21	6.99	2.76	0.38	4.39	1.15	4.87	4.22	3.96	0.40	0.82
22	5.08	2.72	0.28	3.72	0.89	3.90	2.35	3.55	0.54	0.81
23	8.22	2.92	0.48	4.90	1.23	5.57	5.30	4.31	0.36	0.86
24	4.93	2.99	0.29	3.84	0.75	3.96	1.94	3.72	0.61	0.88
25	6.49	3.08	0.40	4.47	1.00	4.79	3.40	4.18	0.48	0.91
26	8.51	3.50	0.59	5.46	1.12	6.00	5.00	4.96	0.41	1.04
27	8.14	2.57	0.42	4.58	1.31	5.36	5.57	3.91	0.32	0.76
28	7.83	3.07	0.48	4.90	1.16	5.45	4.77	4.41	0.39	0.91
29	6.15	2.85	0.35	4.19	1.03	4.50	3.31	3.90	0.46	0.84
30	10.13	3.86	0.78	6.25	1.18	6.99	6.27	5.58	0.38	1.14

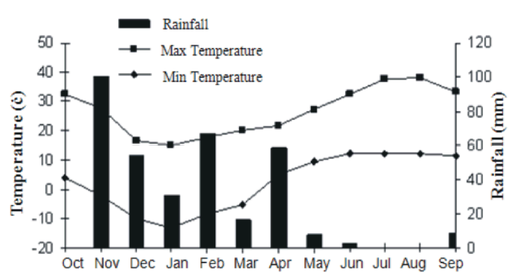

Fig. 1: Precipitation rate, maximum and minimum temperature of the studied region

growing season in the experimental field of the college of Agriculture, Razi University of Kermanshah, Iran (34°19'N, 47°03'E, 1322 m above sea level, Koppen climate classification; CS3). Mean precipitation in 2008-2009 growing season was 455 mm. The soil of experimental field was clay loam with pH 7.1. Sowing was done by hand in plots with four rows 2 m in length and 20 cm apart. The seeding rate was 400 seeds per m^2 for all plots. At the rain-fed experiment, water stress was imposed after anthesis. Non stressed plots were irrigated three times after anthesis, while stressed plots received no water.

Grain yield and Stress at maturity, after separation of border effects from each plot, yield potential (Yp) and stress yield (Ys) were measured. Stress tolerance index (STI) was calculated using the following formula: *STI* ~ (*Yp*)~(*Ys*) /(*Yp*)2., Tolerance index was calculated using the following formula: *TOL* ~ [(*Yp* ~ *Ys*)], Mean productivity (MP) was calculated using the following formula: *MP* =[(*Yp* + *Ys*) / 2], Stress susceptibility index was calculated using the following formula: SSI = [1- (Ys) /(Yp)] / SI; SI is the stress intensity and calculated as: SI = [1- (Ys) /(Yp)], Yield stability index was calculated using the following formula: [(Ys) /(Yp)] [12], Yield index was calculated using the following formula: [(Ys) /(mean Ys)], [13], Geometric mean productivity was calculated using the following formula: [v(*Yp*)~(*Ys*)] and Harmonic mean was calculated using the following formula: Harm = [2(*Yp*× *Ys*)/ (*Yp*+ *Ys*)] [14] where Yp and Ys are the yield of a given genotype in a non stress and stress environment, respectively and Yp is the mean yield for all genotypes in non stress condition. Statistical analysis was performed using *SPSS*, *STATGRAPHICS Cent.* and *SAS* packages.

RESULTS AND DISCUSSION

After normalizing the data and testing the variances monotony (Bartlet), the results of variances analysis regarding the wheat genotypes were presented for the stress condition, normal condition and compound condition respectively. The effects of environments and genotypes on the grain yield were meaningful at 1% probability and the interaction effect between genotypes and environments were meaningful at 5% probability; this indicates that there is a noticeable difference between genotypes and either environments. The various indices of “drought resistance” were calculated by means of the yield in stress and normal conditions. Genotype 30 had the largest STI rate and genotype 22 the smallest rate (a high STI rate for the genotype represents its high drought resistance and its high yielding potential). Genotypes 22 and 30 displayed the least and the most GMP rate respectively (a high GMP rate for the genotype represents its high drought resistance, which is very useful for distinguishing group A from other groups) [15]. Genotype 27 had the largest extent (susceptible) of SSI index while genotype 12 had the least (resistant) extent (a large extent of this index indicates the genotype susceptibility to drought; this index does not distinguish group A from group C) [16] Genotype 22 and genotype 30 displayed the smallest and the largest extent of MP respectively (selecting based on this index will cause the increase in the average amount of yield in both stress and normal conditions; this index cannot separate genotypes of group B from group A).

Genotype 22 and genotype 30 displayed the least and the most amount of TOL index (a high amount of TOL is a sign of genotype susceptibility to stress; also this index cannot separate group C from group A [17]. In terms of Harm, genotype 22 had the smallest rate and genotype 20 the largest amount. In terms of YSI, genotype 27 and genotype 12 had the smallest and the largest rate respectively (genotypes with high YSI are expected to yield highly in stress conditions [11]. Genotype 4 displayed the least extent of YI, while genotype 20 displayed the highest extent. The results of analyzing the correlation between the yield in stress or normal condition and “stress resistance” indexes are presented in Table 3. Whereas the yielding in normal condition had a very positive, meaningful correlation with the indices of STI, TMOL, P, Harm, SSI and GMP, it had a very negative correlation with indices containing YSI. The yielding in stress condition had positive, meaningful correlation with STI’ Harm’ YSI indices; however it correlated negatively meaningfully with SSI index. MP, YI.

With regard to the positive correlation among STI, MP, Harm, GMP and their positive correlation with yield, these indices are introduced as the best common indices for selection in both the stress and normal conditions.

Our findings correspond to the findings of Farshadfar *et al*. [18]; Sio-se Mardeh *et al*. [19] Golabadi *et al*. [20].

Factor Analysis and Principal Component Analysis: “Factor Analysis” is generally utilized to reduce a large number of dependent variables to a small number of main factors [19]. “Factor analysis” of the data was carried out by means of the methods of “principal components” and “Varimax rotation”. Two factors which constituted 99/1 percent of the total data variety were selected. The special value of these two factors was more than four (Table 4). The first factor mainly emphasized the grain yield in stress and normal conditions of YI, HARM, MP, GMP and STI with positive factor loads. This factor which constitutes 55/3 percent of the total changes is called “resistance factor”. The second factor, entitled “susceptibility factor”, mostly emphasized the grain yield in normal condition of YI, YSI with positive factor loads and of TOL, SSI indexes

Table 3: correlation between drought stress indicators

	Yp	Ys	STI	GMP	SSI	MP	TOL	HARM	YSI
Yp	1								
Ys	0.15	1							
STI	.808**	.695**	1						
GMP	.816**	.690**	.997**	1					
SSI	.713**	-.539**	0.211	0.224	1				
MP	.936**	.489**	.960**	.966**	.438*	1			
TOL	.921**	-0.248	.517**	.528**	.912**	.724**	1		
HARM	.626**	.854**	.961**	.961**	-0.026	.857**	0.276	1	
YSI	-.713**	.539**	-0.211	-0.224	-1.000**	-.438*	-.912**	0.026	1
YI	0.15	1.000**	.695**	.690**	-.539**	.489**	-0.248	.854**	.539**

Yp: yield in non stress, Ys: yield in stress and drought stress indicators

Table 4: Principal Component Analysis and Factor Analysis (Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization)

	Factor Analysis		Principal Component Analysis	
	Factor 1	Factor 2	Component 1	Component 2
Yp	0.61	0.79	0.90	-0.42
Ys	0.88	-0.48	0.56	0.83
STI	0.95	0.29	0.98	0.18
GMP	0.95	0.30	0.99	0.17
SSI	-0.08	0.99	0.38	-0.91
MP	0.85	0.52	0.99	-0.08
TOL	0.25	0.96	0.66	-0.74
HARM	0.99	0.04	0.90	0.42
YSI	0.08	-0.99	-0.38	0.91
YI	0.88	-0.48	0.56	0.83
Eigen value	5.90	4.01	5.50	4.41
Cumulative variance (%)	59.01	99.10	55.03	99.10

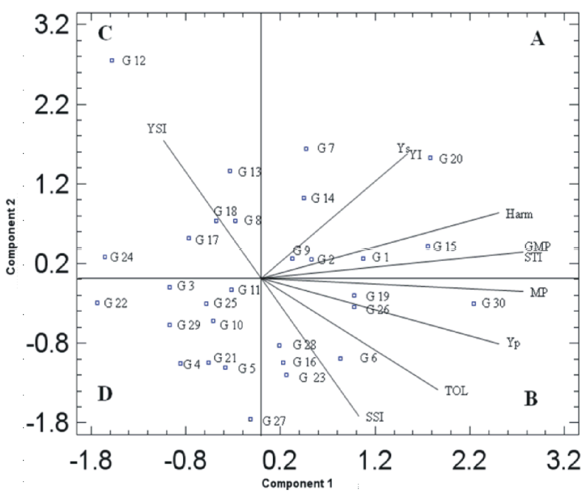

Fig. 2: The results of by plot

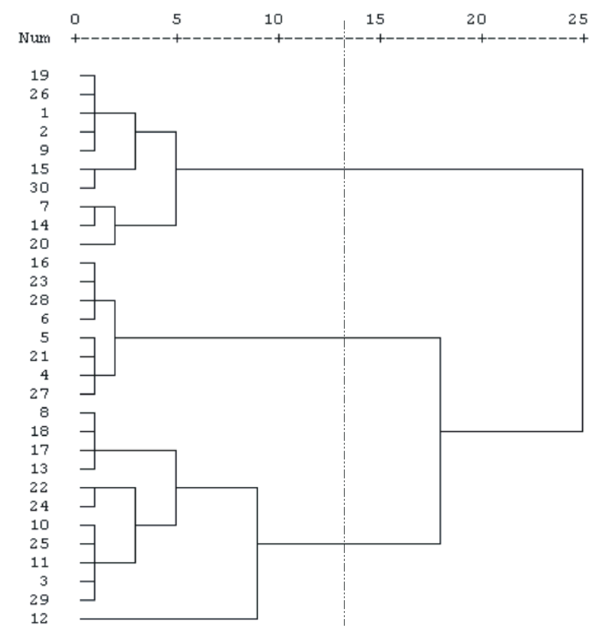

Fig. 3: Cluster analysis based on Factor analysis using Ward method and squared Euclidean distance

with negative factor loads. This factor justifies 43/8 percent of the total variations. The results of "principal components" analysis (Table 4) and the {by plot} accrued on (Figure 2) indicated that the first two components justify 99/1 percent of all the variations and that the maximum (2/24) and minimum (1/73) value of the first component concern respectively genotypes 22 and 30. Moreover genotype 30 displayed maximum yield in normal condition while genotype 22 had lesser yield in both normal and stress conditions; that is why genotype 30 was placed in group B and genotype 22 was in group D. With regard to the above-mentioned Fernandez classification, genotypes encoded with numbers 1, 2, 15, 7, 9, 14 and 20 in group A, are drought resistant and have optimal yielding in either stress and normal conditions.

Genotypes encoded with numbers 30, 19, 26, 6, 23 and 28 in group B, yield well in normal condition. Genotypes of group C, encoded 13, 8, 17, 18, 24 and 12, yield highly in stress condition. Finally genotypes of group D, encoded with numbers 3, 4, 5, 10, 21, 22, 25 and 27, have low extent of yield in either stress or normal conditions. Furthermore, regarding {by plot} of Figure 2, you could say that such genotypes as number 1, 2, 15, 7, 9, 19, 20, 30, which are located between the yield figure of stress - normal conditions and the indices of MP, GMP, HARM and STI, are introduced a s the superior genotypes. Such Genotypes as number 6, 23, 16, 28, which are close to SSI index, manifested excessive susceptibility to stress- their yield has considerably decreased as compared to their yield in normal condition.

Cluster Analysis: Cluster analysis was done based on Ward method and Euclidean distance was done based on factor analysis.

The genotypes were placed in three separate groups. The genetic distance between the groups which is presented in Figure 3- ranged 0-25 with an average of 13. The advantage of cluster analysis based on factor analysis over the one based on all the traits, is in the lesser used variable and in its better cluster form which is close to normal distribution. Regarding the cluster analysis, the more the cluster shape is sinilar to the normal distribution curve, the better it will be. The results of cluster analysis to a large extent correspond to the results of principal components analysis andFernandez classification. Totally, the genotypes of the first cluster can be called "drought resistant", the genotypes of the second group can be called "medium" and those of the third group can de called "drought susceptible".

REFERENCES

1. Mergoum, M., P.K. Singh, J.A. Anderson, R.J. Pena and R.P. Singh, 2009. Spring Wheat Breeding. In: Hand book of plant breeding (cereals). Carena, M.J., (Ed). Springer Science, pp: 127-156.
2. Royo, C., M.M. Miloudi, N. Di Fonze, J.L. Arraus, W.H. Pfeiffer and G.A. Slafer. 2005. Durum wheat breeding current approaches and future strategies. Vol1. Editors: Food Product Press.
3. Singh, R.P., J. Huerta-Espino, R. Sharma, A.K. Joshi and R.M. Trethowan, 2007. High yielding spring bread wheat germplasm for irrigated agro-ecosystems. Euphytica, 157: 351-363.
4. Jaleel, C.A., P.B. Manivannan, A. Sankar, R. Kishorekumar, R. Gopi, R. Somasundaram and R. Panneerselvam. 2007. Water deficit stress mitigation by calcium chloride in Catharanthus roseus; effects on oxidative stress, proline metabolism and indole alkaloid accumulation. Colloids Surf. B: Biointerfaces, 60: 110-116.
5. Abdul Jaleel, C., P. Manivannan, A.L.W.M. Farooq, H. Jasim AL-juburi, R. Somasundaram and R. Panneerselvam, 2008. Effect of drought stress on photosyntetic rate of four rapseed (Brassica napus). Journal of Applied Sciences, 8(23): 4460-4463.
6. Izanloo, A., A.G. Condon, P. Langridge, M. Tester and T. Schnurbusch, 2008. Different mechanisms of adaptation to cyclic water stress in two South Australian bread wheat cultivars. Journal of Experimental Botany, 59: 3327-3346.
7. Mohamed Mohamedi, N.E., 2008. Association mapping for drought stress related traits in a structured population with wild and cultivated barley. Ph.d thesis University of Bonn, Germany, pp: 1-117.
8. Skoric, D., 2010. Sunflower breeding for resistance to abiotic stresses. Helia, 32(50): 1-16.
9. Sio-Se Mardeh, A., A. Ahmadi, K. Poustini and V. Mohammadi. 2006. Evaluation of drought resistance indices under various environmental conditions. Field Crop Res., 98: 222-229.
10. Golabadi, M., A. Arzani and S.A.M. Mirmohammadi Maibody, 2006. Assessment of Drought Tolerance in Segregating Populations in Durum Wheat. African Journal of Agricultural Research, 1(5): 162-171.
11. Mohammadi, R., M. Armion, D. Kahrizi and A. Amri, 2010. Efficiency of screening techniques for evaluating durum wheat genotypes under mild drought conditions. International Journal of Plant Production, 4(1): 26-28.
12. Bouslama, M. and W.T. Schapaugh, 1984. Stress tolerance in soybean. Part 1: evaluation of three screening techniques for heat and drought tolerance. Crop Sci., 24: 933-937.
13. Gavuzzi, P., F. Rizza, M. Palumbo, R.G. Campaline, G.L. Ricciardi and B. Borghi, 1997. Evaluation of field and laboratory predictors of droght and heat tolerance in winter ceraeals. Can. J. Plant Sci., 77: 523- 531.
14. Azizi-Chakherchaman, S.H., H. Kazemi-Arbat, M. Yarnia, H. Mostafaei, D. Hassanpanah, M.R. Dadashi and R. Easazadeh, 2008. Study on Relations Between Relative Water Content, Cell Membrane Stability and Duration of Growth Period with Grain Yield of Lentil Genotypes under Drought Stress and Non-Stress Conditions. International Meeting on Soil Fertility Land Management and Agroclimatology. Turkey, pp: 749-755.
15. Naroui Rad, M.R., A. Ghasemi and A. Arjmandinejad, 2009. Study of Limit Irrigation on Yield of Lentil (Lens culinaris) Genotypes of National Plant Gene Bank of Iran by Drought Resistance Indices. American-Eurasian J. Agric. and Environ. Sci., 7(2): 238-241.
16. Jafari, A., F. Paknejad and M. Jami AL-Ahmadi, 2009. Evaluation of selection indices for drought tolerance of corn (Zea mays L.) hybrids. International Journal of Plant Production, 3(4): 1735-8043.

17. Rosiele, A.A. and H. Hamblin, 1981. Theoretical aspects of selection for yield in stress and non-stress environment. Crop Sci., 21: 943-946.
18. Farshadfar, E., R. Mohammadi, M. Aghaee and J. Sutka, 2003. Identification of QTLs involved in physiological and agronomic indicator of drought tolerance in rye using a multiple selection index. Acta Agronomica Hungarica, 51(4): 419-428.
19. Walton, P.D., 1972. Factor analysis of yield in spring wheat (*Triticum aestivum* L.). Crop Sci., 12: 731-733.