Middle-East Journal of Scientific Research 9 (2): 189-194, 2011
ISSN 1990-9233

Selection of Useful Index for Drought Stress Tolerance in Durum Wheat Genotypes

[1]Majid Khayatnezhad, [2]Mohammad Zaefizadeh and [2]Aliakbar Eimani

[1]Young Researchers Club, Ardabil Branch, Islamic Azad University, Ardabil, Iran
[2]Department of Agronomy and Plant Breeding, Ardabil Branch, Islamic Azad University, Ardabil, Iran

Abstract: In order to study the reaction of forty durum wheat genotypes drought stress an experiment was done in 3 farming years 2008- 2011 under both moisture stress (E1) and non-stress (E2) field environments in Ardabil region. Results of analysis of variance (Table1) showed that the effect of year, Conditions, Genotypes, Interaction between year and conditions and the interaction between genotype and conditions was significant. Based on MP, STI, GMP indexes, high rates of these indexes indicate endurance or tolerance of genotypes to tension. Based on this matter genotypes 10 and 35 were resistant. Among all genotypes, NO. 21 (3.18 t ha^{-1}) and NO. 39 (3.19 t ha^{-1}) had the highest and NO. 9 (1.79 ton/ha) and NO. 31 (1.66 t ha^{-1}) produced the lowest yields in stress condition And genotypes NO. 40 (4.41 t ha^{-1}) and NO. 32 (4.25 t ha^{-1}) had the highest and NO. 34 (23.08 ton/ha) and NO. 9 (2.15 t ha^{-1}) produced the lowest yields in optimal condition. Cluster analysis showed that the genotypes, based on TOL, MP, GMP, SSI and STI tended to group into three groups with 11, 9 and 20 genotypes, respectively. The first two PCAs accounted for about 99.6% of total variation. Finnaly, 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 and thMP, GMP and Mp were more useful that SSI and TOL in selection resistant genotypes.

Key words: Drought stress tolerance · Wheat · Stress index · Cluster analysis

INTRODUCTION

For thousands of years, durum wheat (Triticum turgidum, L.var.Durum Defs) has been cultivated both irrigated and rain-fed in the west of Iran. Tetraploid durum wheat (T.durum) or hard wheats mainly are used to produce semolina flour used in the food industries especially pasta spaghetti. However, under cultivated area of this plant is less than other hexaploid wheats, but their resistance against disease and environmental stresses such as common consistencies, is more and remarkable in drought conditions [1]. 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 [2]. 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 [2]. 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 [3]. Drought resistance is defined by Hall [4] 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 [5] whilst the values are confounded with differential yield potential of genotypes [6]. Rosielle and Hamblin [7] 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

Corresponding Author: Majid Khayatnezhad, Young Researchers Club,
Ardabil Branch, Islamic Azad University, Ardabil, Iran.

Maurer [8] proposed a stress susceptibility index (SSI) of the cultivar. Fernandez [9] 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 [6]. Clark *et al*. [10] 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*. [11] using SSI criterion suggested that SSI more than 1 indicated above-average susceptibility to drought stress. Golabadi *et al*. [12] and Sio-Se Mardeh *et al*. [13] 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 [10]. Until now different research has been done about stress on wheat. The present study was undertaken to assess the selection criteria for identifying drought tolerance in durum wheat genotypes in Ardabil region.

MATERIAL AND METHODS

Forty 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.

Experiments were conducted at the experimental field of Islamic Azad University of Ardabil, in Ardabil province (Northwest of Iran) in 2008-2011. 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. Two levels of stress treatments including:

- Full irrigation (100 percent water based on plant needs wheat cultivars at different growth stages).
- 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 internodes, 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:

Stress Susceptibility Index (SSI):

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

[8]

Stress Tolerance Index (STI):

$$STI= (Ypi*Ysi)/Yp^2$$

[9]

Tolerance Index (TOL):

$$TOL=Ypi-Ysi$$

[14]

Geometric Mean Productivity (GMP):

$$GMP= vYpi*Ysi$$

[9]

Mean Productivity (MP):

$$MP=(Ypi+Ysi)/2$$

[14]

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.

Table 1: Result of analysis of variance for yield

SOV	df	Yield
Year	2	9165373.18**
Condition	1	104983954.93**
YC	2	10097044.73**
Error	6	400834.58
Genotype	39	1619032.87**
GY	79	7880.13
GC	39	558818.12**
GCY	79	4170.25
Error	234	74336.75
CV (%)	-	8.97

** Significant at 0.01 percentage level

RESULTS

Analysis of Variance: Results of analysis of variance (Table1) showed that the effect of year, Conditions, Genotypes, Interaction between year and conditions and the interaction between genotype and conditions was significant on 0.01 percentage levels. Khayatnezhad *et al*. [15] reported similar results.

Indicators of Resistance to Stress: Results of drought resistance indexes (Table2) showed that base on TOL and SSI Genotypes 2 and 34 were resistant to drought stress.

Table 2: Resistance indices of 40 durum genotypes under stress and non-stress environment

NO.	GMP	MP	TOL	SSI	STI	Yp	Ys
1	3397.68	3415.96	705.75	0.7	0.94	1374.137	235.7967
2	2709.25	2718.51	448.28	0.57	0.6	1055.787	149.8167
3	2669.91	2693.2	706.78	0.87	0.58	1133.617	236.0767
4	2866.11	2894.91	814.7	0.93	0.67	1236.847	272.1
5	2781.5	2810.27	802.23	0.94	0.63	1204.48	267.9333
6	3254.99	3282.6	849.58	0.86	0.86	1377.68	283.7667
7	2644.77	2671.97	760.5	0.93	0.57	1144.467	254
8	2772.76	2795.96	718.86	0.85	0.63	1171.89	240.1133
9	2183.27	2262.68	1188.3	1.56	0.39	1150.847	396.75
10	3596.12	3636.2	1076.78	0.97	1.05	1571.317	359.6
11	2855.72	2906.82	1085.29	1.18	0.66	1331.097	362.3767
12	2728.32	2757.65	802.26	0.95	0.61	1186.953	267.94
13	2624.62	2678.76	1071.66	1.25	0.56	1250.557	357.8233
14	2706.46	2740.76	864.47	1.02	0.6	1202.083	288.6967
15	2705.31	2739.5	862.9	1.02	0.6	1201.14	288.1733
16	3134.62	3153.39	687.18	0.74	0.8	1280.437	229.5733
17	3482	3505	801.58	0.77	0.99	1435.783	267.78
18	3174.65	3227.96	1168.47	1.15	0.82	1465.86	390.1467
19	3162.77	3180.27	666.38	0.71	0.81	1282.453	222.6333
20	2831.75	2902.43	1273.26	1.35	0.65	1392.347	425.0867
21	3513.04	3529	670.39	0.65	1	1400.013	224.0133
22	3449.91	3462.03	579.02	0.58	0.97	1347.21	193.5233
23	3281.99	3373.23	1558.54	1.41	0.88	1644.393	520.2767
24	2699.91	2745.07	991.82	1.15	0.59	1246.013	331.1867
25	3323.3	3352.75	886.87	0.88	0.9	1413.5	296.2167
26	2773.63	2835.08	1174.06	1.29	0.63	1336.81	391.9933
27	2789.3	2820.36	834.86	0.97	0.63	1218.73	278.82
28	2960.72	3078.99	1690.39	1.62	0.71	1590.333	564.24
29	2664.18	2702.54	907.38	1.08	0.58	1203.667	303.0133
30	3017.07	3033.72	634.7	0.71	0.74	1223.043	212.05
31	2691.56	2914.51	2235.98	2.08	0.59	1717.523	746.2167
32	3480.82	3551.47	1409.73	1.24	0.99	1654.147	470.6533
33	3184.79	3202.75	677.42	0.72	0.83	1293.63	226.3233
34	2587.82	2604.76	-593.14	-0.96	0.54	670.22	-197.853
35	3591.68	3642.11	1207.97	1.07	1.05	1617.05	403.3633
36	3312.67	3369.88	1236.62	1.16	0.89	1535.887	412.89
37	2723.89	2746.83	708.62	0.86	0.6	1152.103	236.6933
38	2414.21	2458.68	931.02	1.19	0.47	1130.297	310.8933
39	3532.25	3550.74	723.78	0.69	1.02	1425.07	241.83
40	3526.22	3615	1592.46	1.35	1.01	1736.27	531.6067

Based on MP, STI, GMP indexes, high rates of these indexes indicate endurance or tolerance of genotypes to tension. Based on this matter genotypes 10 and 35 were resistant.

Among all genotypes, NO. 21 (3.18 t ha^{-1}) and NO. 39 (3.19 t ha^{-1}) had the highest and NO. 9 (1.79 ton/ha) and NO. 31 (1.66 t ha^{-1}) produced the lowest yields in stress condition.

And genotypes NO. 40 (4.41 t ha^{-1}) and NO. 32 (4.25 t ha^{-1}) had the highest and NO. 34 (23.08 ton/ha) and NO. 9 (2.15 t ha^{-1}) produced the lowest yields in optimal condition.

According to the results STI, MO and GMP indices are more successful than SSI and TOL about selection resistant genotypes in both conditions.

Fernandez [9] 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:

- The genotypes that have high yield in stress and non stress environments (group A).
- The genotypes that have high yield only in non stress environments (group B).
- The genotypes that have high yield in stress environments (group C).
- 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, 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.

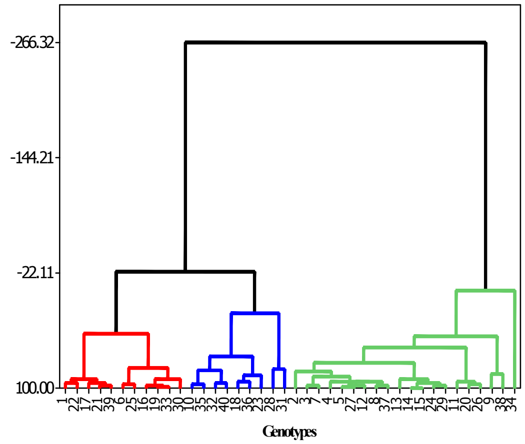

Fig. 1: Cluster based on all drought stress tolerance indexes

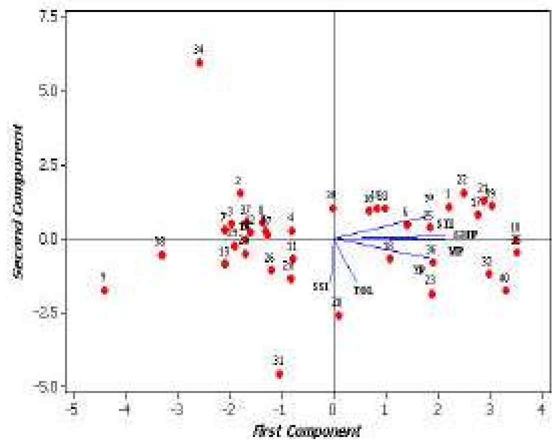

Fig 2: Principal component analysis of drought resistance indices

Cluster analysis showed that the genotypes, based on TOL, MP, GMP, SSI and STI tended to group into three groups with 11, 9 and 20 genotypes, respectively (Fig. 1). In this analysis, the first group had the highest MP, GMP and STI and was thus considered to be the most desirable cluster for both growth conditions. The third group had lower Yield in stress condition values. Therefore, the genotype of this group was considered to be stable in rainfed conditions. In the first group, all genotypes had high SSI and TOL, thus they were susceptible to drought and only suitable for irrigated conditions.

The first two PCAs accounted for about 99.6% of total variation. Based on these two components Biplot Figure (Fig 2) was plotted and genotypes Divided in 4 groups. Those genotypes in second cluster groups were Exposure in Group A and according to Fernandez [9] they were resistant genotypes to drought strers.

CONCLUSION

In this experiment, drought stress had significant effects on wheat genotypes yield. In summary, it seems MP, STI and GMP indices have a similar ability to separate drought sensitive and tolerant genotypes [16]. Thus, they can be used to detect the studied genotypes which have low water requirements and/or suffer less yield reduction by water deficits during their growth period and can be cultivated in regions with limited water resources in order to increase cultivated area and production efficiency. 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 [5, 17]. 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 [18-21]. 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 [22]. 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 [23-25].

REFRANCES

1. Arzani, A., 2000. Modified crops. Isfahan University Publishing Center.
2. Talebi, R., 2009. Effectiveselection criteria for assessing drought stress tolerancein durum wheat (*Triticum durum* Desf.). General and Appl. Plant Physiol., 35(1-2): 64-74.
3. Richards, R.A., G.J. Rebetzke, A.G. Condon and A.F. Herwaarden, 2002. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop Sci., 42: 111-121.
4. Hall, A.E., 1993. Is dehydration tolerance relevant to genotypic differences in leaf senescence and crop adaptation to dry environments? In: T.J. Close and Bray, E.A., (Eds.), Plant Responses to cellular Dehydration during environmental stress, pp: 1-10.
5. Blum, A., 1988. Plant Breeding for Stress environments. CRC Press, Florida, pp: 212.
6. Ramirez, P. and J.D. Kelly, 1998. Traits related to drought resistance in common bean. Euphytica, 99: 127-136.
7. Rosielle, A.A. and J. Hamblin, 1981. Theoretical aspects of selection for yield in stress and non-stress environment. Crop Sci., 21: 943-946.
8. Fischer, R.A. and R. Maurer, 1978. Drought resistance in spring wheat cultivars. I., Grain yield response. Aust. J. Agric. Res., 29: 897-907.
9. Fernandez, G.C.J., 1992. Effective selection criteria for assessing stress tolerance. In: Kuo C.G. (Ed.), Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress, Publication, Tainan, Taiwan.
10. Clarke, J.M., R.M. De Pauw and T.M. Townley-Smith, 1992. Evaluation of methods for quantification of drought tolerance in wheat. Crop Sci., 32: 728-732.
11. Guttieri, M.J., J.C. Stark, K. Brien and E. Souza, 2001. Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. Crop Sci., 41: 327-335.
12. Golabadi, M., A. Arzani and S.A.M. Maibody, 2006. Assessment of drought tolerance in segregating populations in durum wheat. Afr. J. Agric. Res., 5: 162-171.
13. 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.
14. Hossain, A.B.S., A.G. Sears, T.S. Cox and G.M. Paulsen, 1990. Desiccation tolerance and its relationship to assimilate partitioning in winter wheat. Crop Sci., 30: 622-627.
15. Khayatnezhad, M., M. Zaefizaeh and R. Gholamin, 2010. Investigation and Selection Index for Drought Stress. Australian J. Basic and App. Sci., 4(10): 4815-4822.

16. Jafari A., F. Paknejad, M. Jami and A.L. Ahmadi, 2009. Evaluation of selection indices for drought tolerance of corn (*Zea mays* L.) hybrids. Int. J. Plant Prod., pp: 3-4.
17. Panthuwan, G., S. Fokai, M. Cooper, S. Rajatasereekul and J.C. O'Toole, 2002. Yield response of rice genotypes to different types of drought under rainfed lowlands. Part 1: grain yield and yield components. Field Crop Res., 41: 45-54.
18. Richards, R.A., G.J. Rebetzke, A.G. Condon and A.F. Herwaarden, 2002. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop. Sci., 42: 111-121.
19. Van Ginkel, M., D.S. Calhoun, G. Gebeyehu, A. Miranda, C. Tian-you, R. Pargas Lara, R.M. Trethowan, K. Sayre, L. Crossa and S. Rajaram, 1998. Plant traits related to yield of wheat in early, late, or continuous drought conditions. Euphytica, 100: 109-121.
20. Rajaram S, Van and M. Ginkle, 2001. Mexico, 50 years of international wheat breeding, In: Bonjean, A.P., W.J. Angus, (Eds.), The World Wheat Book: A History of Wheat Breeding, Lavoisier Publishing, Paris, France, pp: 579-604.
21. Betran, F.J., D. Beck, M. Banziger and G.O. Edmeades, 2003. Genetic analysis of inbred and hybrid grain yield under stress and nonstress environments in tropical maize. Crop Sci., 43: 807-817.
22. Nasir Ud-Din B.F. Carver and A.C. Clutte, 1992. Genetic analysis and selection for wheat yield in drought-stressed and irrigated environments. Euphytica, 62: 89-96.
23. Ceccarelli, S., 1987. Yield potential and drought tolerance of segregating populations of barley in contrasting environments. Euphytica, 40: 197-205.
24. Ceccarelli, S. and S. Grando, 1991. Selection environment and environmental sensitivity in barley. Euphytica, 57: 157-167.
25. Rathjen, A.J., 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.