Turkish Journal of Field Crops, 2011, 16(1): 59-63

DETERMINATION OF TOLERANCE LEVEL OF SOME WHEAT GENOTYPES TO POST-ANTHESIS DROUGHT

Emre İLKER* Özgür TATAR Fatma AYKUT TONK Muzaffer TOSUN

Ege University Faculty of Agriculture Department of Field Crops, Turkey
**Corresponding author: emre.ilker@ege.edu.tr*

Received: 18.02.2011

ABSTRACT

Drought, especially after anthesis, is one of the major abiotic stress factors limiting wheat production in Mediterranean basin. Tolerance level of seven wheat genotypes to drought conditions in post anthesis stage were evaluated based on some tolerance indices in four years field experiments differing in rainfall distribution and quantity. Six selection indices including Relative Decrease in Yield (RDY), Stress Tolerance Index (TOL), Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress Susceptibility Index (SSI) and Stress Tolerance Index (STI) were calculated based on grain yield under dry and wet conditions. Higher grain yield was recorded in Basribey-95 during both dry and wet seasons whereas Menemen-88 had considerably lower yield than other genotypes. It was concluded that MP, GMP and STI values were convenient parameters to select high yielding wheat genotypes in both stress and non-stress conditions whereas RDY, TOL and SSI values were better indices to determine tolerance levels.

Keywords: Stress indices, post anthesis, TOL, SSI, STI, *Triticum aestivum* L.

INTRODUCTION

Global warming and concomitant increase in drought effected areas limit plant production in the world. Wheat production is also restricted by drought exposed areas and this loss led to considerable economic and social problems because of its great importance on human nutrition. Reduction in wheat production (about 50-60%) as a result of severe drought in 2005 was experienced in Portugal and Spain (Isendahl and Schmidt, 2006). Wheat is mostly grown under rainfed condition in Mediterranean Basin characterized by variation in its rainfall distribution. The rainfall in winter periods is generally adequate for the plant growth and exceeds crop demands whereas drought often occurs with hot weather and limited rainfall after generative stage (Acevedo et al., 1999). In addition to influence of erratic rain distributions, severity of drought effect on plants is variable depending on development phase of wheat (Gupta et al., 2001). Since dry matter production after heading is the main source of grain yield in wheat (Schnyder, 1993; Saidi et al., 2008), this stage of plant growth has a critical importance in terms of drought. Thus, considering these generative stages for determining wheat tolerance is one of the most plausible strategies for better crop improvement under water limited conditions especially in Mediterranean region.

Selecting wheat lines based on their yield performance under drought conditions is a common approach. Another approach to identify tolerant genotypes to dry environment, some drought stress indices or selection criteria has been suggested by different researches (Talebi et al., 2009; Pireivatlou et al., 2010). Stress Tolerance Index (TOL) and Mean Productivity (MP) were defined as the difference in yield and the average yield between stress and non-stress environments, respectively (Rosielle and Hamblin, 1981). Other yield based indice is Geometric Mean Productivity (GMP) that 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). Another selection criterion for a high yielding cultivar under drought conditions is Stress Susceptibility Index (SSI) proposed by Fischer and Maurer (1978). Stress Tolerance Index (STI) was defined as a useful tool for determining high yield and stress tolerance potential of genotypes (Fernandez, 1992).

In present study, tolerance level to post-anthesis drought conditions of seven wheat genotypes were investigated based on some tolerance indices in four year field experiment differ in rain distributions.

MATERIALS AND METHODS

Five advanced bread wheat lines selected from the International Maize and Wheat Improvement Center (CIMMYT) genotypes in our department and two registered bread wheat varieties for Aegean Region were evaluated in present study (Table 1). The wheat lines and varieties were grown in the research area of Field Crops Department, Faculty of Agriculture, Ege University, Izmir-Turkey during 2002-03, 2003-04, 2005-2006 and 2008-09 growing seasons. The trials were conducted in a randomized complete block design with 3 replications. Each plot consisted of 6 rows 3 m long spaced 20 cm apart where the seeds were drill-planted at 5 cm spacing within the row. At each trials, fertilization were applied as 60 kg/ha nitrogen and 50 kg/ha phosphorus at sowing time and 30 kg/ha nitrogen at jointing stage (Öztürk, 1999; Güler and Akbay, 2000).

Table 1. Genotype numbers and pedigrees of advanced bread wheat lines used in the study.

Genotype No/Name	*Pedigree/Source*
L4	THB//MAYA/NAC/3/RABE/4/MİLAN
L5	RL6043/6* NAC//TNMU/31BAU
L6	VEE"S"//KOEL"S" VEE"S'
L8	TEVE"S"/KARAVAN"S"
L12	NESSER
Basribey 95	Aegean Agricultural Research Institute
Menemen 88	Aegean Agricultural Research Institute

Out of the growing seasons, 2003-04 and 2005-06 were dry years (total rainfall from April to July 45.3 mm and 39.6 mm, respectively) and 2002-03 and 2008-09 were wet years (total rainfall from April to July 114.9 mm and 137.3 mm, respectively) (Table 2).

Analysis of variance was performed for grain yield considering dry and wet years using *Tarist* statistical software (Acikgoz et al., 2004) and LSD (least significant difference) test was applied to compare the differences between the means of dry and wet years.

The average yield data of the dry and wet seasons were used to calculate several drought stress indices or selection criteria for each genotype:

$$RDY = 100-(Ys/100 \times Yp)$$

$$TOL = Yp-Ys$$

$$MP = (Ys+Yp)/2$$

$$GMP = \sqrt{(Ys \times Yp)}$$

$$SSI = [1-Ys/Yp]/SI$$

SI [Stress Intensity] $= [1-(MYs/MYp)]$

$$STI = [Yp \times Ys/MYp^2]$$

Yp : Yield under non-stress conditions

Ys : Yield under the stress conditions

MYp: mean yield over all genotypes evaluated under non-stress conditions

MYs: mean yield over all genotypes evaluated under stress conditions

RESULTS AND DISCUSSION

Drought is one of the major constraints to cereal production in Mediterranean areas (Araus et al., 2003). Wheat is mostly grown under rainfed conditions in these areas and frequently affected by post-anthesis drought because of the limited rainfall in spring. In this study, four growing seasons (Table 2) differ in rain amount during post anthesis stage were selected to evaluate response of seven wheat genotypes (Table 1). Significant reduction in grain yield of genotypes was observed in dry seasons comparing to wet seasons (Table 3, Table 4). The highest mean yield (3895 kg/ha in dry and 4652 kg/ha in wet seasons) was recorded in Basribey-95 during both diverse seasons. The mean grain yield of Menemen-88 (2618 kg/ha) was considerably lower than those of other genotypes in the seasons subjected to post-anthesis drought whereas there were no discernable differences among other genotypes except Basribey-95 in wet seasons.

Table 2. Average monthly rainfall (kg m^{-2}) and temperature (ºC) during growing seasons of wheat in the experimental site

Months	*Rain Distribution (kg/m^2)*				*Average Temperature (°C)*			
	Wet Seasons		*Dry Seasons*		*Wet Seasons*		*Dry Seasons*	
	2002-03	*2008-09*	*2003-04*	*2005-06*	*2002-03*	*2008-09*	*2003-04*	*2005-06*
November	126.4	93.0	15.6	155.9	14.6	15.7	14.2	12.9
December	148.3	101.0	116.3	67.5	8.8	11.3	10.3	11.3
January	102.7	204.1	228.5	77.5	12.0	10.5	8.3	6.9
February	201.0	165.2	27.9	93.4	5.6	10.0	9.4	9.6
March	25.3	175.7	21.3	180.9	9.4	11.7	12.9	12.1
Total	**603.7**	**739.0**	**409.6**	**575.2**	-	-	-	-
April	104.5	83.8	30.3	29.4	13.6	16.0	16.6	17.4
May	10.3	44.3	11.3	0.2	22.4	21.4	20.4	21.1
June	0.1	9.2	3.7	10.0	27.5	26.2	26.1	25.7
Total	**114.9**	**137.3**	**45.3**	**39.6**	-	-	-	-

Table 3. Mean squares for grain yield of bread wheat genotypes

Sources	Degrees of freedom	Mean squares
Replications	2	3072,26
Environment (E)	3	52370,57**
Genotypes (G)	7	12248,35**
G x E	21	4501,02
Error	62	6257,36
CV (%)		2.20

**: Significant at the 0.01 probability level.

Table 4. Grain yield of 7 bread wheat genotypes in 4 growing seasons differ in post-anthesis rainfall.

Genotypes	Grain Yield (kg ha^{-1})					
	Wet seasons			Dry seasons		
	2002-03	2008-09	Mean	2003-04	2005-06	Mean
L4	3750 ab	4467 a	4109 ab	3263 a	2853 bc	3058 abc
L5	3343 b	4230 a	3787 b	3073 a	3187 abc	3130 abc
L6	3383 b	4600 a	3992 ab	3573 a	2740 bc	3157 abc
L8	3747 ab	4147 a	3947 ab	2843 a	2743 bc	2793 bc
L12	3480 ab	3900 a	3690 b	3490 a	3797 ab	3644 ab
Basribey-95	4490 a	4813 a	4652 a	3540 a	4250 a	3895 a
Menemen-88	3530 ab	3917 a	3724 b	2753 a	2483 c	2618 c
Mean	**3675 B**	**4296 A**	3986 X	**3219 C**	**3150 C**	3185 Y
LSD (5%)	***1072***		*856*	***1072***		*856*
LSD (5%) for mean yields over two differ seasons			*405*			

Relative Decrease in Productivity (RDP) has been commonly considered to compare genotypes for their stress tolerance levels in different plants such as wheat (Rahman et al., 2009), rice (Tatar et al., 2010), soybean (Oya et al., 2004) and maize (Olaoye et al., 2009). In the present study, the highest (39.6 %) relative decrease in grain yield was found in L8 whereas the lowest (7.7 %) in L12 (Figure 1). These genotypes can be perceived as more tolerant (L12) and sensitive (L8) to post anthesis drought according to their relative decreases in grain yield. On the other hand, several selection indices have been also performed to identify drought resistant genotypes considering grain yield potential in both favorable and stress conditions (Shahryari et al., 2008; Bahar and Yildirim, 2010). The greater Stress Tolerance Index (TOL) value (153.0) and the higher drought sensitivity were found in L4 whereas lower values recorded in L12 (29.7) (Figure 2). The TOL results showed that genotype L12 was much more tolerant than other genotypes. Based on Mean Productivity (MP) (Figure 3) and Geometric Mean Productivity (GMP) (Figure 4), tolerance level of Bas-95 was more pronounced whereas Men-88 was more sensitive. Geravandi et al. (2011), stated that selection of

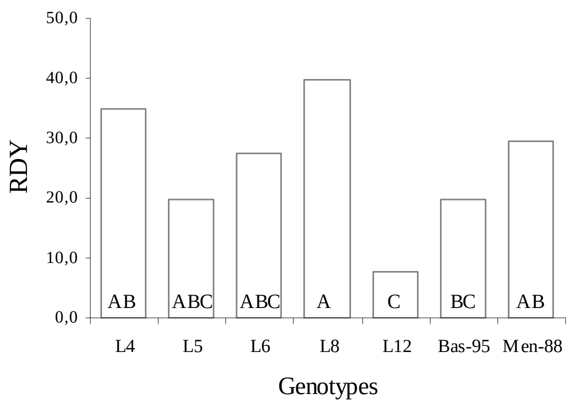

Figure 1. Comparison of Relative Decrease in Yield (RDY) of genotypes as a response to different rainfall during post-anthesis stage in four years experiment.

tolerance level based on uniform superiority of genotypes under both stress and favorable conditions is the optimum method. And they suggested using Stress Susceptibility Index (SSI) which considers both conditions for identify

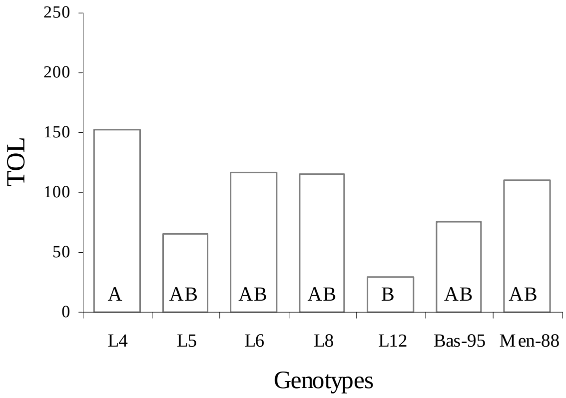

Figure 2. Comparison of Stress Tolerance Index (TOL) of genotypes as a response to different rainfall during post-anthesis stage in four years experiment.

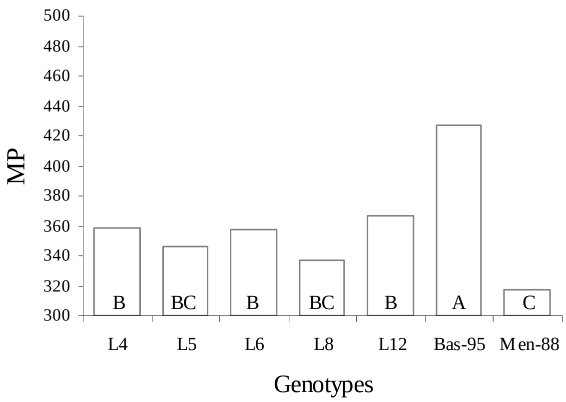

Figure 3. Comparison of Mean Productivity (MP) of genotypes as a response to different rainfall during post-anthesis stage in four years experiment.

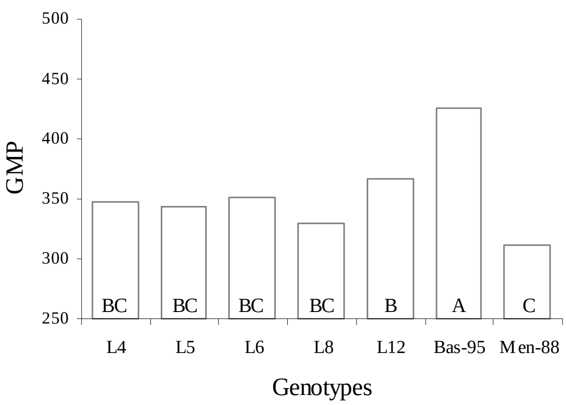

Figure 4. Comparison of Geometric Mean Productivity (GMP) of genotypes as a response to different rainfall during post-anthesis stage in four years experiment.

tolerance level. The SSI value of L12 was significantly lower (0.3) than that of other genotype in the present study (Figure 5). The higher SSI value was recorded in L4 (1.3). L12 was found more tolerant while L4 was sensitive according to Stress Susceptibility Index. On the other hand, Basribey-95 had better performance (1.1) than other genotypes whereas lowest (0.6) value was determined for Menemen-88 based on Stress Tolerance Index (STI) (Figure 6).

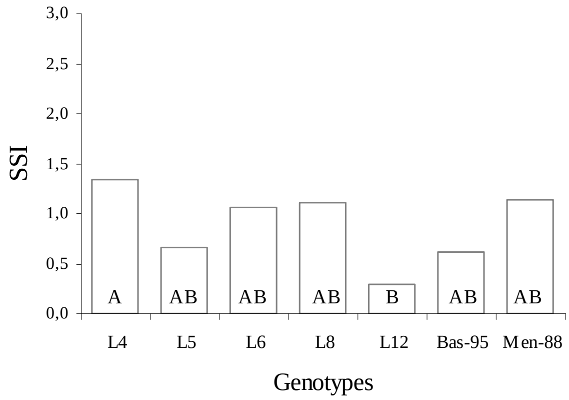

Figure 5. Comparison of Stress Susceptibility Index (SSI) of genotypes as a response to different rainfall during post-anthesis stage in four years experiment.

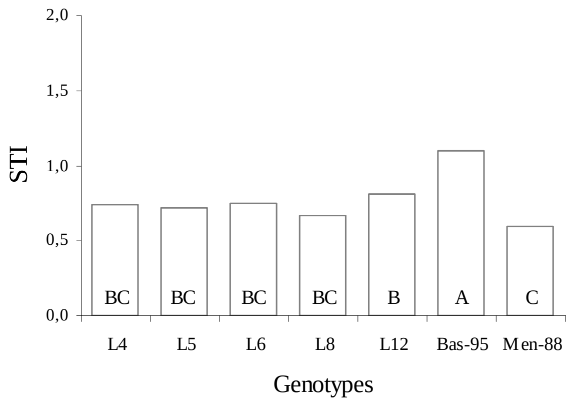

Figure 6. Comparison of Stress Tolerance Index (STI) of genotypes as a response to different rainfall during post-anthesis stage in four years experiment.

The same genotypes were determined as tolerant (Basribey-95) and sensitive (Menemen-88) according to MP, GMP and STI. This correlation implies their grain yield performance in both dry and wet seasons (Table 4). The significantly higher yield was obtained from Basribey-95 and lower from Menemen-88 in both conditions. The consistence between these two data can be attributed that MP, GMP and STI values are useful to select higher yielding genotypes in both conditions. However, drought tolerance can be defined as an ability of plant to be stable in stressed environment compared to non-stress conditions. Therefore, a genotype with higher yielding capacity can not be always perceived as a tolerant. Relative decrease in yield of L12 was lower than other genotypes (Figure 1) although higher yield performance was found in Basribey-95 (Table 4). Genotype L12 can be also defined as tolerant based on TOL and SSI values whereas L4 is sensitive. Talebi et al. (2009) also reported that cultivars producing high yield in both drought and well watered conditions can be identified by STI, GMP and MP values. Pireivatlou et al. (2010) was also noted that STI can be a reliable index for selecting high yielding genotypes. Our findings indicated that RDY, TOL and SSI values can be used for determining tolerance levels of wheat genotypes whereas STI, GMP and MP values are better parameters to identify high yielding genotypes under both drought and favorable conditions.

CONCLUSION

Responses of some advanced bread wheat lines and varieties to post-anthesis drought were investigated in four years field trials. Some common indices were used in order to determine tolerance level of selected wheat genotypes. Basribey-95 was identified as a high yielding genotype during dry and wet seasons whereas L12 showed higher tolerance against post anthesis drought. We eventually concluded that MP, GMP and STI values are convenient parameters to select high yielding wheat genotypes in both stress and non-stress conditions whereas relative decrease in yield, TOL and SSI values are better indices to determine tolerance levels.

LITRATURE CITED

Acevedo, E.H., P.C. Silva, H.R. Silva, B.R. Solar, 1999. Wheat production in mediterranean environments. In Wheat: Ecology and Physiology of Yield Determination, pp.295-323. Eds Satorre E.H. and Slafer, G.A., New York.

Acikgoz, N., E. Ilker, E. Gokcol, 2004. Analysis Methods of Biological Researches, ISBN: 973-483-607-8 E.U. Seed Technology Center, Publication No: 2, Izmir-Turkey.

Araus, J.L., D. Villegas, N. Aparicio, L.F. Garcia del Moral, S. El Hani, Y. Rharrabti, J.P. Ferrio, C. Royo, 2003. Environmental factors determining carbon isotope discrimination and yield in drum wheat under Mediterranean conditions, Crop Science, 43: 170-180.

Bahar, B., M. Yildirim, 2010. Heat and drought resistances criteria in spring bread wheat: drought resistance parameters, 5: 1742-1745.

Fernandez, G.C.J., 1992. Effective selection criteria for assessing plant stress tolerance. In: Proceedings of on the Symposium Taiwan, August 13-18, 1992, 25: 257-270.

Fischer, R.A., R., Maurer, 1978. Drought resistance in spring wheat cultivars. I. Grain responses. Aust. J. Agric. Res., 29: 897-912.

Geravandi, M., E. Farshadfar, D. Kahrizi, 2011. Evaluation of some physiological traits as indicators of drought tolerance in bread wheat genotypes, Russian Journal of Plant Physiology, 58: 69-75.

Guler, M., G. Akbay, 2000. Effect of irrigation and nitrogen fertilization on protein yield of common wheat (Triticum aestivum L), Turkish Journal of Agriculture and Forestry, 24: 317-325.

Gupta, N.K., S., Gupta, A., Kumar, 2001. Effect of water stress on physiological attributes and their relationship with growth and yield of wheat cultivars at different stages…

Isendahl, N. G. Schmidt, 2006. Drought in mediterranean: WWF policy proposals, A WWF Report, July, Germany.

Olaoye, G., O.B. Bello, A.Y. Abubakar, L.S. Olayiwola, O.A. Adesina, 2009. Analyses of moisture deficit grain yield loss in drought tolerant maize (*Zea mays*, L.) germplasm accessions and its relationship with yield performance, African Journal of Biotechnology, 8: 3229-3238.

Oya, T., A.L. Nepomuceno, N. Neumaier, J.R.B. Farias, S. Tobita, O. Ito, 2004. Drought tolerance characteristics of Brazilian Soybean cultivars – Evaluation and characterization of drought tolerance of various Brazilian soybean cultivars in the field, Plant Production Science, 7: 129-137.

Ozturk, A., 1999. Drought resistance in bread wheat genotypes, Turkish Journal of Agriculture and Forestry, 23: 1237-1247.

Pireivatlou, A.S., B.D. Masjedlou, R.T. Aliyev, 2010. Evaluation of yield potential and stress adaptive trait in wheat genotypes under post anthesis drought stress conditions, African Journal of Agricultural Research, 5: 2829-2836.

Rahman, M.A., J. Chikushi, S. Yoshida, A.J.M.S. Karim, 2009, Growth and yield components of wheat genotypes exposed to high temperature stress under control environment, 34: 361-372.

Ramirez, P., J.D., Kelly, 1998. Traits related to drought resistance in common bean. Euphytica, 99: 127-136.

Rosielle, A.A., J. Hamblin, 1981. Theoretical aspects of selection for yield in stress and non-stress environments. Crop Science, *21 (6). 943-946.*

Saidi, A., T., Ookawa, T. Motobayashi, T, Hirasawa, 2008. Effects of soil moisture conditions before heading on growth of wheat plants under drought conditions in the ripening stage: insufficient soil moisture conditions before heading render wheat plants more resistant to drought to ripening, Plant Production Science, 11: 403-411.

Schnyder, H., 1993. The role of carbohydrate storage and redistribution in the source-sink relations of wheat and barley during grain filling-a review, New Phytol., 123: 233-245.

Shahryari, R., E. Gurbanov, A. Gadimov, D. Hassanpanah, 2008. Tolerance of 42 bread wheat genotypes to drought stress after anthesis, Pakistan Journal of Biological Sciences, 11: 1330-1335.

Talebi, R., F. Fayaz and A.M. Naji, 2009. Effective selection criteria for assessing drought stress tolerance in drum wheat (*Triticum durum* Desf.), General and Applied Plant Physiology, 35: 64-74.

Tatar, O., H. Brueck, M.N. Gevrek, F. Asch, 2010. Physiological responses of two Turkish rice (*Oryza sativa* L.) varieties to salinity, Turkish Journal of Agriculture and Forestry, 34: 451-459.