Evaluation of Drought Resistance Indicates for Yield and Its Components in Three Triticale Cultivars

I. Kutlu G. Kinaci

Department of Field Crops, Faculty of Agriculture, Eskisehir Osmangazi University, Eskisehir

Drought is a wide-spread problem seriously influencing cereal production and quality. The development of triticale cultivars which are tolerant to drought is an objective in many breeding programmes, but so far success has been limited. This study was carried to examine differences in yield and yield components and kernel features among triticale cultivars (Tatlicak 97, Karma 2000 and MIKHAM 2002) under drought stress. Three triticale cultivars with different yield performance were grown in separate experiments under the rain fed and irrigated conditions at Eskisehir, Turkey, in 2006-2007 growing season. In the study, susceptibility index (SSI), stress tolerance index (STI), tolerance (TOL), yield index (YI), yield stability index (YSI), mean productivity (MP) and geometric mean productivity (GMP) were calculated. The best yielding cultivar under the drought stress, hence having a low susceptibility index, was Karma 2000. This cultivar may be utilized for improvement of drought resistance in triticale breeding programmes.

Key Words: Drought tolerance, triticale, dry conditions, irrigated conditions, resistance indices.

Üç Tritikale Çeşidinde Verim ve Verim Komponentleri İçin Kuraklığa Dayanım İndekslerinin Değerlendirilmesi

Kuraklık, tahıl üretimi ve kalitesini ciddi şekilde etkileyen yaygın bir problemdir. Kuraklığa toleranslı tritikale çeşitlerinin geliştirilmesi pek çok ıslah programının amacıdır fakat bugüne kadarki başarı sınırlı kalmıştır. Bu çalışma, kuraklık stresi altında verim, verim ögeleri ve tane özellikleri bakımından tritikale çeşitleri (Tatlicak 97, Karma 2000 and MIKHAM 2002) arasındaki farklılıkları incelemek amacıyla yürütülmüştür. Verim performansları farklı üç tritikale çeşidi 2006–2007 üretim sezonunda, Eskişehir, Türkiye'de sulu ve kuru koşullar altında farklı denemelerde yetiştirilmiştir. Çalışmada, stres duyarlılık indeksi (SSI), stres tolerans indeksi (STI), tolerans (TOL), verim indeksi (YI), verim stabilite indeksi (YSI), ortalama verimlilik (MP) ve geometrik ortalama verimlilik (GMP) indeksleri hesaplanmıştır. Kuraklık stresi altında en iyi verime sahip olan çeşit, en düşük duyarlılık indeksine sahip olmasına karşılık Karma 2000'dir. Bu çeşit, tritikalede kuraklığa dayanımı geliştirmek için ıslah programlarında kullanılabilir.

Anahtar Kelimeler: Kuraklığa tolerans, tritikale, kuru koşullar, sulu koşullar, dayanıklılık indeksleri.

Introduction

Tolerance of triticale to drought, winter and plant nutrition deficiencies is complemented by its good resistance to common cereal diseases. These advantages make triticale a good alternative to other cereals (Bagcı *et al*., 2004).

Triticale (*Triticosecale* Wittmack), has demonstrated high yield potential even under the marginal growing conditions and could be attractive alternative for raising cereal production globally. Despite the high productivity of triticale, its global production is increasing slowly, and the crop has not yet become well established in local or world markets.

The main reason for the lower than expected production is that triticale, a good source of protein and energy (Hill,1991), is used mainly for animal feed but very little for human consumption (Pena,2004).

In Turkey, cereals are commonly grown in the areas where a rain fed agricultural system is practiced and the possibility of growing crops other than cereals is limited. The most important yield-limiting factor in these regions is the lack of water. To increase the productivity, with suitable growing techniques, triticale cultivars are a good option for farmers, especially in areas of

Central and Eastern Anatolia where winter type triticale has shown comparative advantage, and its planting area has increased in the recently years.

Triticale area in Turkey was estimated as 10 000 ha at the end of the 1990s. Nowadays, with dramatic increases, its area has reached approximately 160 000 ha, and it is becoming one of the main cereals after wheat and barley. Since triticale is a new crop for Turkey, its end-use is not as diverse as would be expected.

The first studies on triticale in Turkey started at universities in the 1940s. These studies focused on testing and evaluating of triticale for quality and yield. Winter-facultative triticale studies started at Bahri Dagdas International Winter Cereal Research Center in Konya in the early 1990s. As a result of these studies, the first triticale cultivar Tatlicak-97 was registered in 1997. The newly released triticale, having longer spikes and more kernels per spike when compared with wheat and barley, was introduced to Turkish farmers as an alternative crop in marginal areas. Farmers immediately showed great interest, and since then triticale has expanded rather quickly.

Water stress limits cereal productivity in many environments and the timing and intensity of drought stress is highly variable. Triticale is generally more tolerant than other cereal crops to stress conditions. However, it is not clear whether the current stress regime used to differentiate triticale germplasm is the most efficient and effective way to select materials of relevance to triticale production environments in the developing world (Trethowen *et. al*., 2006). Breeding for drought resistance is very complex because stress environments are intrinsically erratic in the nature (Blum *et al*., 1983a and Blum *et al*., 1983b), and the success of cultivars is not predictable (Ceccarelli and Grando, 1996). However the development of resistant cultivars, however, is hampered by low heritability for drought tolerance and a lack of effective selection strategies (Kirigwi *et al*., 2004). Stress resistance of a given plant genotype is the product of many physiological and morphological characters for which effective selection criteria have not yet been developed (Fischer and Maurer, 1978). Therefore grain yield and its components remain as the major selection criteria for improved adaptation to a stress environment in many breeding programmes.

The effect of drought stress on grain yield of cereal crops may be analyzed in terms of yield components, some of which can assume more importance than others, depending upon the intensity of stress and the growth stage of plants (Johnson and Kanemasu, 1982; Giunta *et al*., 1993). Yield reduction at high temperatures can be directly or indirectly caused by acceleration physic development (Midmore *et al*., 1984; Shpiler and Blum, 1986), accelerated senescence (Kuroyanapi and Paulsen, 1985), reduction in photosynthesis (Blum, 1986), increase in respiration (Berry and Biorkman, 1980; Wardlaw *et al*.,1980) and the inhibition of starch synthesis in growing kernel (Bhullar and Jenner, 1986; Rijven, 1986). While an intense drought mainly affects the number of kernels per spike through a general decrease in fertility, a mild drought may cause only a decrease in the grain weight (Giunta *et al.*, 1993).

The relative yield performance of genotypes in drought-stressed and more favorable environments seems to be a common starting point in the identification of traits related to drought tolerance and the selection of genotypes in breeding for dry environments (Clarke *et al*., 1992).

Several selection indices have been suggested on the basis of a mathematical relationship between favorable and stress conditions for differentiate drought resistance genotypes (Clarke *et al*., 1984 and Huang, 2000). Tolerance (TOL) (McCaig and Clarke, 1982 and Clarke *et al*., 1992), mean productivity (MP) (McCaig and Clarke, 1982), stress susceptibility index (SSI) (Fischer and Maurer, 1978), geometric mean productivity (GMP) and stress tolerance index (STI) (Fernandez, 1992) have all been employed under various conditions.

The aim of this study was to evaluate the influence of drought stress on the agronomic characters of different triticale cultivars and to determine range of variability for these characters under drought stress conditions.

Materials and Methods

Three triticale cultivars including Tatlıcak 97, Karma 2000 and MIKHAM 2002 were chosen for study based on their reputed differences in yield performance under irrigated and non-irrigated conditions. The experiment was conducted during the 2006-2007 growing seasons at Eskisehir province of the semi-arid Central

Anatolian Region of Turkey. Eskisehir is located at 39° 48′ N, 30° 31′ E at an elevation of 789 m above the sea level and it has 347,8 mm annual rainfall in a long term average. The year of the field experiment had contrasting precipitation regime with 300,7 mm. The rainfall in this growing season was above the long term average. Temperatures were warmer in 2007 than the long term average (Figure 1).

The soil texture was loam with 1.7 % organic matter and a pH of 8,1. Total P and K were 38,5 and 2164 kg/ha, respectively. In the experiment, the three cultivars were planted in a randomized complete block design with four replications and grown under rain-fed and irrigated conditions. Irrigated plots were irrigated at stem elongation and heading stage, non-irrigated plots received no water other than rainfall. The irrigated plots were irrigated manually when water in the top 40 cm of soil had declined. Sowing was done in October and seed density was 220 kg/ha under rain-fed conditions and 200 kg/ha under irrigated conditions. The plots had six rows with 6 m length spaced 20 cm. Fertilizer was applied during sowing and at tillering stage (total, 70 kg/ha N and 60 kg/ha P_2O_5 under rain-fed conditions, 100 kg/ha N and 80 kg/ha P_2O_5 under irrigated conditions).

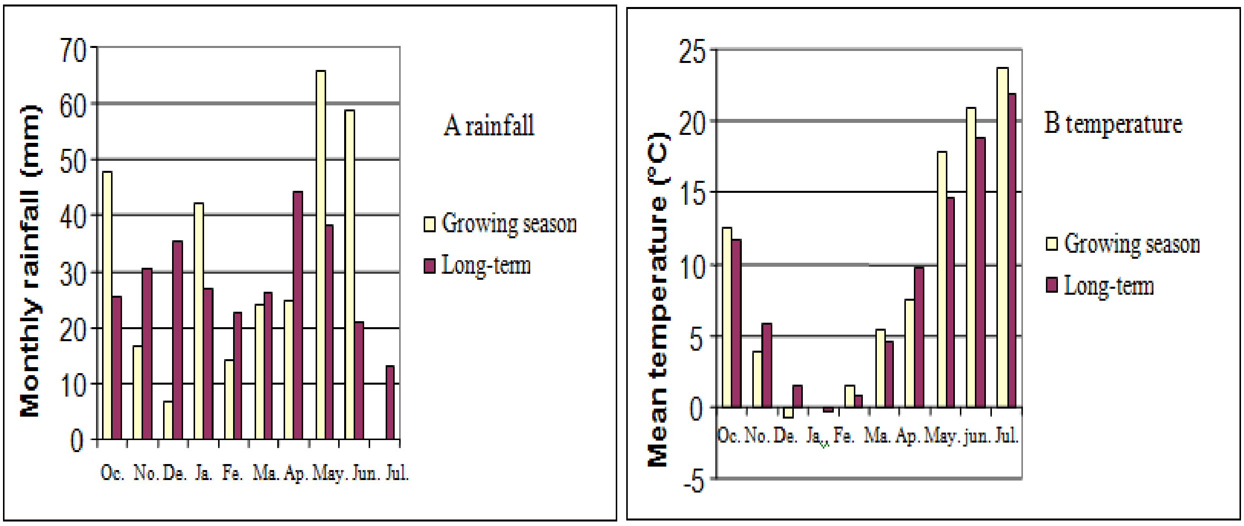

Fig. 1. Monthly rainfall (A) and temperature (B) in the growing season (2006-2007) and long term (1990-2005).

The grain yield was measured by harvesting 1.2 m^2 of central part of each plot at crop maturity (Zadoks 92). Fifteen plants were randomly chosen from each plot to evaluate the number of grains per spike, grain weight and plant height. Harvest index and test weight were also determined for each plot. Kernel width, kernel length and kernel thickness were measured on randomly selected twenty kernels.

Drought resistances were calculated using the following equation:

(1) $$SSI = \frac{1 - Y_S / Y_P}{1 - \bar{Y}_S / \bar{Y}_P}$$ (Fischer and Maurer, 1978)

where Y_s is the yield of cultivar under stress, Y_p the yield of cultivar under irrigated condition, $\bar{Y}_s$ and $\bar{Y}_p$ the mean yields of all cultivars under stress and non-stress conditions, respectively, and $1 - (\bar{Y}_s / \bar{Y}_P)$ is the stress intensity. The irrigated experiment was considered to be a non-stress condition in order to have a better estimation of optimum environment.

(2) $$MP = \frac{Y_P + Y_S}{2}$$ (Hossain *et al*., 1990).

(3) $$TOL = Y_P - Y_S$$ (Hossain *et al*., 1990).

(4) $$STI = \frac{Y_P + Y_S}{\bar{Y}_P^2}$$ (Fernandez, 1992).

(5) $GPM = (Y_P \text{ x } Y_S)^{0,5}$ (Fernandez, 1992).

(6) $YI = \frac{Y_S}{\overline{Y}_S}$ (Gavuzzi *et al.*, 1997)

(7) $YSI = \frac{Y_S}{Y_P}$ (Bouslama and Schapaugh, 1984).

Standard analyses of variance were used for analyze of the data obtained from study. Least Significant Differences (LSD) test was used to compare the mean values at 5% level of probability.

Results and Discussion

The results of mean values and analyses of variance for yield and yield components under rain-fed and irrigated conditions were shown at Table 1. The values of the yield and yield components under rain fed conditions were lower than irrigated conditions as expected. The highest value of the spike length, spike weight, number of kernel per spike, kernel weight per spike and grain yield under rain fed conditions was found at Karma 2000. The highest yield under irrigated conditions was also obtained from Karma 2000. The cultivars showed significant differences in traits except for harvest index, kernel weight per spike and plant height. The "cultivar x treatment" interaction was not significant, because irrigation has effected all cultivars same way.

Table 1. Mean values and mean squares for yield and yield components

		Plant height	Spike length	Spike weight	Number of kernel per spike	Kernel weight per spike	Harvest index	Grain yield
TATLICAK 97	Rain Fed	97,45	8,34	1,65	32,67	1,39	35,54	475,97
	Irrigated	116,53	9,35	2,33	42,20	1,71	38,54	940,79
	Increase%	**19,58**	**12,11**	**41,21**	**29,17**	**23,02**	**8,44**	**97,66**
KARMA 2000	Rain Fed	96,95	10,88	2,26	39,39	1,51	34,83	539,54
	Irrigated	110,53	10,73	2,63	43,20	1,81	35,70	958,96
	Increase%	**14,01**	**-1,42**	**16,37**	**9,67**	**19,87**	**2,50**	**77,74**
MIKHAM 2002	Rain Fed	98,73	8,98	1,82	35,49	1,29	28,20	383,79
	Irrigated	113,84	9,88	2,54	44,90	1,84	34,93	699,53
	Increase%	**15,30**	**9,97**	**39,56**	**26,51**	**42,64**	**23,85**	**82,27**
Means of Three Cultivars	Rain Fed	97,71	9,40	1,91	35,85	1,40	32,86	466,43
	Irrigated	113,63	9,99	2,50	43,43	1,79	36,39	866,43
	Increase%	**16,30**	**6,89**	**32,38**	**21,78**	**28,51**	**11,60**	**85,89**
LSD $_{cultivar}$		6,90	0,61	0,24	3,12	0,27	5,06	87,06
LSD $_{treatment}$		2,69	1,23	0,36	4,99	0,23	7,71	108,82
LSD $_{cultxtreat}$		9,75	0,86	0,34	4,41	0,38	7,15	123,12
	DF	**ANOVA**						
REP	3	2,25	0,60	0,03	5,66	0,03	20,16	827,65
TREAT	1	1520,84**	2,05	2,09**	343,98**	0,88**	74,85	959954,67**
ERROR1	3	2,86	0,60	0,05	9,82	0,02	23,48	4678,30
CULTIVAR	2	23,38	8,06**	0,41**	31,91*	0,03	62,37	96745,76**
CXT	2	16,11	0,82	0,07	20,90	0,04	17,56	11678,64
ERROR2	12	40,07	0,31	0,05	8,18	0,06	21,56	6384,75

* significant at the 5 % , **significant at the 1 %

The results of mean values and analyses of variance for kernel features under the rain-fed and irrigated conditions were shown at Table 2. The values of the thousand kernel weight, test weight, kernel width, kernel length and kernel thickness values under the rain fed conditions were lower than irrigated conditions. But thousand kernel weight at MIKHAM 2002 and kernel width at Tatlicak 97 performed visa versa. The cultivars showed significant differences in grain yield and other traits except for thousand kernel weight and kernel thickness. The "cultivar x treatment" interaction was significant for test weight and kernel length, because of significant differences presented by both treatment and cultivars. Treatment was found significant for other traits.

Table 2. Mean values and mean squares for kernel features.

		Thousand kernel weight	Test weight	Kernel width	Kernel length	Kernel thickness
TATLICAK 97	Rain Fed	37,40	76,00	3,27	7,37	2,82
	Irrigated	41,40	76,50	3,22	8,18	2,93
	Increase%	**10,70**	**0,66**	**-1,53**	**10,99**	**3,90**
KARMA 2000	Rain Fed	39,40	71,13	2,85	8,62	2,72
	Irrigated	41,00	74,00	3,09	8,28	2,86
	Increase%	**4,06**	**4,04**	**8,42**	**-3,94**	**5,15**
MIKHAM 2002	Rain Fed	37,60	74,75	3,09	7,93	2,74
	Irrigated	41,80	74,50	3,22	8,04	2,93
	Increase%	**11,17**	**-0,33**	**4,21**	**1,39**	**6,93**
Means of Three Cultivars	Rain Fed	38,13	73,96	3,07	7,97	2,76
	Irrigated	41,40	75,00	3,18	8,17	2,91
	Increase%	**8,64**	**1,46**	**3,70**	**2,81**	**5,33**
LSD $_{cultivar}$		1,96	0,58	0,11	0,31	0,07
LSD $_{treatment}$		2,49	0,32	0,10	0,23	0,16
LSD $_{cultxtreat}$		2,78	0,82	0,15	0,44	0,10
	DF	**ANOVA**				
REP	3	3,02	0,32	0,01	0,01	0,02
TREAT.	1	64,35*	6,51**	0,06*	0,22*	0,13*
ERROR1	3	2,44	0,04	0,004	0,02	0,01
CULTIVAR	2	1,43	27,32**	0,16**	0,96**	0,01
CXT	2	4,10	5,32**	0,04	0,68**	0,003
ERROR2	12	3,25	0,28	0,01	0,08	0,004

*significant at the 5 % , **significant at the 1 %

Resistance indices were calculated on the basis of grain yield and yield-related traits of cultivars (Table 3). A larger value of TOL show more sensitivity to stress, thus a smaller value of TOL is favored (Zangi, 2005). MIKHAM 2002 had the smallest TOL value, so it was the best cultivar based on this index. As shown in Table 1 and Table 3, Karma 2000 had greater the TOL value than MIKHAM 2002, but it had shorter the yield reduction than latter under stress condition. So, a selection based on minimum yield decrease under stress with respect to favorable conditions (TOL) failed to identify the best genotypes (Clarke *et al*., 1992; Rosielle and Hamblin, 1981). MP is mean production under both stress and non-stress conditions (Rosielle and Hamblin, 1981). It is based on arithmetic means and therefore it has an upward bias due to a relatively larger difference between Y_p and $Y_{s,}$ whereas the geometric mean is less sensitive to large extreme values (Fernandez, 1992). The MP can be related to yield under stress only when stress is not too severe and difference between yield under stress and non-stress conditions is not too much (Mardeh *et al*, 2006). Cultivars with a high MP would belong to uniform performance in both stress and non stress conditions. Mardeh *et al*. (2006) reported that relatively low yields under stress condition, exhibited high MP values. But, this is not found in our investigation, because cultivars were also showed similar values in irrigated conditions. SSI has been widely used by researchers to identify sensitive and resistant genotypes (Fischer and Maurer, 1978; Clarke *et al*., 1984; Winter *et al*., 1988 and Clarke *et al*., 1992). In this study, the mean SSI appeared to be a suitable selection index to distinguish resistant cultivars. Karma 2000 with a lower SSI were identified as resistant cultivar whereas MIKHAM 2002 and Tatlicak 97, with the highest SSI were sensitive (Table1 and Table 3). YI defined as the rate in stress and mean stress. YI, proposed by

Gavuzzi et al. (1997), was significantly correlated with stress yield. This index ranks cultivars only on the basis of their yield under stress. Karma 2000 and Tatlicak 97 have higher yield in stress environments (Table 1 and Table 3). YSI, as Bouslama and Schapaugh (1984) stated, evaluates the yield

under stress of a cultivar relative to its non-stress yield, and should be an indicator of drought resistant genetic materials. So the cultivars with a high YSI are expected to have high yield under both stress and non-stress conditions. In the present study, cultivars with the highest YSI exhibited the highest yield under non-stress conditions and the highest yield under stress conditions (Table 3). The mean SSI values calculated for each genotype ranged from 0,947 to 1,070 for grain yield and from -0,242 to 2,797 for test weight (Table 3 and 4).

Table 3. Resistance indices of the yield and yield components.

		MP	TOL	STI	GMP	YI	YSI	SSI
Plant height	TATLICAK 97	106,990	19,080	0,017	106,564	0,997	0,836	1,168
	KARMA 2000	103,740	13,580	0,016	103,518	0,992	0,877	0,877
	MIKHAM 2002	106,285	15,110	0,016	106,016	1,010	0,867	0,947
Spike length	TATLICAK 97	8,845	1,010	0,177	8,831	0,887	0,892	1,849
	KARMA 2000	10,803	-0,155	0,217	10,802	1,157	1,014	-0,247
	MIKHAM 2002	9,428	0,895	0,189	9,417	0,955	0,909	1,551
Spike weight	TATLICAK 97	1,990	0,680	0,637	1,961	0,864	0,708	1,237
	KARMA 2000	2,445	0,370	0,782	2,438	1,183	0,859	0,596
	MIKHAM 2002	2,180	0,720	0,698	2,150	0,953	0,717	1,201
Number of kernel per spike	TATLICAK 97	37,435	9,530	0,040	37,130	0,911	0,774	1,293
	KARMA 2000	41,295	3,810	0,044	41,251	1,099	0,912	0,505
	MIKHAM 2002	40,195	9,410	0,043	39,919	0,990	0,790	1,200
Kernel weight per spike	TATLICAK 97	1,550	0,320	0,971	1,542	0,995	0,813	0,857
	KARMA 2000	1,660	0,300	1,040	1,653	1,081	0,834	0,759
	MIKHAM 2002	1,565	0,550	0,981	1,541	0,924	0,701	1,369
Harvest index	TATLICAK 97	37,037	3,001	0,056	37,007	1,082	0,922	0,802
	KARMA 2000	35,265	0,870	0,053	35,262	1,060	0,976	0,251
	MIKHAM 2002	31,565	6,725	0,048	31,385	0,858	0,807	1,984
Grain yield	TATLICAK 97	708,383	464,819	0,002	669,173	1,020	0,506	1,070
	KARMA 2000	749,250	419,415	0,002	719,304	1,157	0,563	0,947
	MIKHAM 2002	541,661	315,738	0,001	518,145	0,823	0,549	0,978

Table 4. Resistance indices of the kernel traits value.

		MP	TOL	STI	GMP	YI	YSI	SSI
Thousand kernel weight	TATLICAK 97	39,400	4,000	0,046	39,349	0,981	0,903	1,224
	KARMA 2000	40,200	1,600	0,047	40,192	1,033	0,961	0,495
	MIKHAM 2002	39,700	4,200	0,046	39,644	0,986	0,900	1,273
Test weight	TATLICAK 97	76,250	0,500	0,027	76,250	1,028	0,993	0,471
	KARMA 2000	72,563	2,875	0,026	72,548	0,962	0,961	2,797
	MIKHAM 2002	74,625	-0,250	0,027	74,625	1,011	1,003	-0,242
Kernel width	TATLICAK 97	3,245	-0,050	0,643	3,245	1,065	1,016	-0,462
	KARMA 2000	2,970	0,240	0,589	2,968	0,928	0,922	2,313
	MIKHAM 2002	3,155	0,130	0,625	3,154	1,007	0,960	1,202
Kernel length	TATLICAK 97	7,775	0,810	0,233	7,764	0,924	0,901	4,183
	KARMA 2000	8,450	-0,340	0,253	8,448	1,081	1,041	-1,735
	MIKHAM 2002	7,985	0,110	0,239	7,985	0,995	0,986	0,578
Kernel thickness	TATLICAK 97	2,875	0,110	0,681	2,874	1,022	0,962	0,744
	KARMA 2000	2,790	0,140	0,660	2,789	0,986	0,951	0,970
	MIKHAM 2002	2,835	0,190	0,671	2,833	0,993	0,935	1,285

Ozkan *et al* (1999) reported that the stress susceptibility index in triticale under field conditions ranged from 0,759 to 1,224 for grain yield and from 0,701 to 1,240 for test weight. Fisher and Maurer (1976) showed that 1° C rise in temperature above ambient during the period between the end of tillering to beginning of grain filling reduced yield by 4 % under their test conditions. Yield reduction was associated with reduced numbers of spikes per plant and grains per spike. In the our study temperatures were warmer in 2007 than the long term average in June. Drought during grain filling, especially it accompanied by high temperature, hastens leaf senescence, reduces the duration of grain filling and reduces grain weight, presumably by reducing assimilate supply to developing kernels (Day and Intalop, 1970; Davidson and Birch, 1978; Austin, 1989). Yield in hot environments was reduced (Midmore *et al*., 1984) due to the acceleration of all plant developmental phases. While growth at high temperature is affected by the reduced photosynthesis at supra-optimal temperatures and the increase in respiratory loss of photosynthate (Wardlaw *et al*., 1980) the dominant effect of high temperature is undoubtedly on the physic development of the plant. Reduced assimilate supply has been related to reduced photosynthesis (Denmead and Millar, 1976). High temperature reduces spikelet number through its effect on both the duration and rate of spikelet iniation (Halse and Weir, 1974).

Conclusions

Yield and yield-related traits under stress were independent of yield and yield-related traits under non-stress condition, but this was not the case in less severe stress condition. As STI, GMP and MP were able to identify cultivars producing high yield in both conditions, when the stress was severe, SSI was found to be more useful indices discriminating resistant cultivars, although none of the indicators could clearly identify high yield cultivars under both stress and non-stress conditions. Genotypes with low SSI values are considered stress tolerant, because such genotypes show a lower reduction in grain yield under stress environments compared to non-stress conditions. Fischer and Maurer (1978) explained that genotypes with an SSI of less than a unit are drought resistant, since their yield reduction in drought condition is smaller than the mean yield reduction of all genotypes (Bruckner and Frohberg, 1987).

On the basis of the grain yield stress susceptibility index, Tatlicak 97 was relatively stress susceptible, whereas Karma 2000 was relatively stress tolerant. A large variation was found in stress susceptibility index values of cultivars for grain yield and test weight. Stress susceptibility index calculated on the basis of test weight showed greater variation than grain yield index. Shpiler and Blum (1986) defined heat tolerance by relative reduction in grain yield from normal winter conditions to warm summer growing conditions, under full irrigation. Under warm conditions heat tolerant cultivars sustained relatively more kernels per spike that heat susceptible cultivars. Kernel number per spike is known to be affected by pre anthesis water stress (Shpiler and Blum, 1991). During grain filling period by high temperatures reduces the grain weight, especially when grain number is small (Warrington *et al*, 1977). SSI are suggested as useful indicators for cereal breeding, where the stress is severe, while MP, GMP and STI are suggested if the stress is less severe. None of the indicators could clearly identify cultivars with high yield under both stress and non stress conditions. It is concluded that the effectiveness of selection indicates depends on the stress severity. Genotypes identified by SSI as stress tolerant probably have tolerance mechanisms. According to Fernandez (1992) genotypes can be categorized into four groups based on their yield response to stress conditions (1) genotypes producing high yield under water stress and non-stress conditions (group A), (2) genotypes with high yield under non-stress (group B) or (3) stress conditions (group C) and (4) genotypes with poor performance under both stress and non-stress conditions (group D). Karma 2000 placed in group A, Tatlicak 97 placed in group B, Mikham 2002 in group D. Karma 2000 showed high STI. Therefore, Karma 2000 which was identified as the least stress susceptible could be used as sources of stress resistance and be crossed with triticale genotypes for improved secondary triticale with high yield potential. Farmers may prefer Karma 2000 in semi-arid Eskisehir because of its relatively high yield when water is not so limiting and suffers minimum loss during drought seasons.

Refferences

Austin, R. B. 1989. Maximizing crop production in water- limited environments, In: Drought resistance in cereals. Baker, F. W. G. (Ed), Published for ICSU Press by C. A. B. International, pp.13-20.

Bagci, S. A., M. Keser, S. Taner and T. Tasyurek, 2004. Triticale in Turkey, Triticale improvement and production, FAO Plant Production and Protection Paper, pp.149-154.

Berry, J. and O. Bjorkman, 1980. Photosynthetic response and adaptation to temperature in higher plants. Ann. Rev. plant Physiol, 31: 491-532.

Bhullar, S.S., and C.F. Jenner. 1986. Effects of temperature on the conversion of sucrose to starch in the developing wheat endosperm. Aust. J. Plant Physiol. 13:605–615.

Blum, A., H. Poiarkova, G. Golan and J. Mayer, 1983a. Chemical desiccation of wheat plants as a simulator of post-anthesis stress I. Effects on translocation and kernel growth. Field Crops Res., 6:51–58.

Blum, A., J. Mayer and G. Golan, 1983b. Chemical desiccation of wheat plants as a simulator of post-anthesis stress II. Relations to drought stress. Field Crops Res., 6:149–155.

Blum A., 1986. The effect of heat stress on wheat leaf and ear photosynthesis. J. Exp. Bot. 37: 111-118.

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.

Bruckner, P.L. and R.C. Frohberg, 1987. Stress tolerance and adaptation in spring wheat, Crop Sci.**,** 27: 31–36.

Ceccarelli, S. and S. Grando, 1996. Drought as a challenge for the plant breeder. Plant Growth Regulation**,** 20:149–155.

Clarke, J.M., T.M. Towenley-Smith, T.N. Mccaig and D.G. Green, 1984. Growth analysis of spring wheat cultivars of varying drought resistance, Crop Sci., 24: 537–541.

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.

Davidson, J. L. and J. W. Birch, 1978. Response of standard Australian and Mexican wheat to temperature and water stress, Aust. J. Agric. Res., 29:1091-1106.

Day, A.D. and S. Intalop, 1970. Some effects of soil moisture on the growth of wheat. Apron J., 62: 27–29.

Denmead, O. T. and B. D. Millar, 1976. Field studies of the conductance of wheat leaves and transpiration, Agron J., 68: 307-311.

Fernandez, G.C. J., 1992. Effective selection criteria for assessing stress tolerance. In: C.G. Kuo, Editor, Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress Publication, Tainan, Taiwan.pp.

Fischer, R. A. and R. Maurer, 1976. Crop temperature modification and yield potential in a dwarf spring wheat. Crop Sci. 16: 855-859.

Fischer, R.A. and R. Maurer, 1978. Drought resistance in spring wheat cultivars. Part 1: Grain Yield Response, Aust. J. Agric. Res., 29: 897–912.

Gavuzzi, P., F. Rizza, M. Palumbo, R.G. Campaline, G.L. Ricciardi and B. Borghi, 1997. Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals, Can. J. Plant Sci., 77: 523–531.

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

Halse, N. J. and R. N. Weir, 1974. Effect of temperature on spikelet number of wheat. Aust. J. Agric. Res. 25: 687-695.

Hill, G. M., 1991. Quality: Triticale in animal nutrition. In Proc 2nd Int. Triticale. Symp., Passo, Fundo, Rio Grande do Sul, Brazil, 1-5 Oct. 1990, Mexico, DF, CIMMYT, pp.422-427.

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.

Huang, B., 2000. Role of root morphological and physiological characteristics in drought resistance of plants. In: R.E. Wilkinson, Editor, Plant–Environment Interactions, Marcel Dekker Inc., New York, pp.39–64.

Johnson, R.C. and E.T. Kanemasu, 1982. The influence of water availability on winter wheat yields. Can. J. Plant Sci., 62:831–838

Kirigwi, F.M., M. Van Ginkel, R. Trethowan, R.G. Sears, S. Rajaram and G.M. Paulsen, 2004. Evaluation of selection strategies for wheat adaptation across water regimes, Euphytica, 135: 361–371.

Kuroyonapi, T. and G. M. Paulsen, 1985. Mode of high temperature injury to wheat. II Comparison of wheat and rice with and without…. .

Mardeh, A. S., A. Ahmadi, K. Poustini and V. Mohammadi, 2006. Evaluation of drought resistance indices under various enviromental conditions. Field Crop Research, 98: 222-229.

Mccaig, T.N. and J.M. Clarke, 1982. Seasonal changes in nonstructural carbohydrate levels of wheat and oats grown in semiarid environment, Crop Sci., 22: 963–970.

Midmore, D. J., P. M. Cartwright and R. A. Fischer, 1984. Wheat in tropical environments. II Crop growth and grain yield. Field Crops Res. 44: 197-212.

Ozkan, H., I. Genç, T. Yagbasanlar and F. Toklu. Stress tolerance in hexaploid spring triticale under Mediterranean environment. Plant Breeding, 118:365-367.

Pena, R. J., 2004. Food uses of triticale, Triticale improvement and production, FAO Plant Production and Protection Paper, pp.149-154.

Rijven, A. H. G., 1986. Heat inactivation of starch syntheses in wheat endosperm. Plant Physiol, 81: 448-453.

Rosielle, A.A. and J. Hamblin, 1981. Theoretical aspects of selection for yield in stress and non-stress environment, Crop Sci., 21:943–946.

Trethowen, R. M., K. Ammar, M. P. Reynolds and J. Crossa, 2006. The association of managed drought stress regimes in Mexico with global triticale yield evaluation environments, 6th International Triticale Symposium, Stellenbosch, South Africa.pp.

Shpiler, L. and A. Blum, 1986. Differential reactions of wheat cultivars to hot environments. Euphytica, 35: 483-492.

Shpiler, L. and A. Blum, 1991. Heat tolerance for yield and its components in different wheat cultivars, Euphtica, 51:257-263.

Wardlow, I. F., I. Sofield and P. M. Cartwright, 1980. Factors limiting the rate of dry matter accumulation in the grain of wheat grown at high temperature, Aust. J. Plant Physiol. 7: 387-400.

Warrington, I. J., R. L. Dunstone and L. M. Green, 1977. Temperature effects at three development stages on the yield of the wheat ear, Aust. J. Agric. Res. 28: 11-27.

Winter, S.R., J.T. Musick and K.B. Porter, 1988. Evaluation of screening techniques for breeding drought-resistance winter wheat, Crop Sci., 28: 512–516.

Zangi, M. R., 2005. Correlations between drought resistance indices and cotton yield in stress and non stress conditions, Asian Journal of Plant Sciences, 4(2): 106-108.