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Evaluation of Triticale Genotypes in Terms of Yield Stability for the Southern Marmara Region

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Abstract

This research was conducted in three different locations of, Turkey, during the 2005-2006 and 2006-2007 growing seasons. In this study, eight triticale genotypes were used as trial material. The triticale genotypes 'C9', 'C11', 'Nx2015(17)' and 'Nx2003(12)', based on high grain yield and high stability, were identified as promising genotypes for the region. In particular, genotypes 'C9' and 'Nx2003(12)' were considered to be stable genotypes, in terms of grain yield, for the southern Marmara region of Turkey because of their minimal Sd_i^2 and b_i values near 1. In addition, genotype 'Nx2003(12)' had a higher grain yield than the general mean. Accordingly, this genotype is recommended as having especially good adaptability in all environments.

Keywords: triticale genotypes, genetic diversity, genotype x environment interaction, grain yield, stability

Introduction

Hexaploid triticale (*x Triticosecale Wittmack*) is a synthetic species. Previous studies have indicated that the grain production of newer and improved triticale cultivars, both as a monocrop and in small grain mixtures, is acceptable in a wide range of environments (Barnett *et al.*, 2006; Juskiw *et al.*, 2000 a, b; Pfeiffer, 1996). The forage production and silage yield as well as the quality of hexaploid triticales, both as a monocrop and in small grain mixtures, have been reported to be favorable in comparison with other small grains (Erekul and Kohn, 2006; Juskiw *et al.*, 2000 a, b; Sun *et al.*, 1996; Rao *et al.*, 2000). These studies have indicated that triticale has great potential to fit into current small-grain areas and to contribute to the improvement of grain and forage production in diverse geographical environments. Triticale is, in general, more tolerant to environmental stresses than are wheat and barley (Jessop, 1996). Additionally, triticale combines high plant productivity and grain yield (Royo *et al.*, 1999), good flavor after backing (Gupta and Priyadarshan, 1982) and stability to environmental variations (Hoerlein and Valentine, 1995). The increased acceptance and production of triticale will depend on obtaining information on the extent of genetic diversity available and on the response of triticale genotypes to a wide range of environmental conditions. It is widely accepted that information regarding germplasm diversity and genetic relatedness among elite breeding material is a fundamental element in plant breeding (Mukhtar *et al.*, 2002; Siddiqui, 1994). Hence, the breeding of genotypes having a diverse genetic base is essential to achieve a desirable level of self-sufficiency and sustainability. According to Ashraf *et al.* (2001) the adaptability of a variety over diverse environments is usually indicated by the degree of its interaction with the different environments in which it is grown. A variety or genotype is considered to be more adaptive or stable if it has a high mean yield but a low degree of fluctuation in its yield when grown over diverse environments (Ashraf *et al.*, 2001).

Regression coefficient is the nearest stability parameters (Eberhart and Russell, 1966; Finlay and Wilkinson, 1963). Severel methods have been proposed to analyze genotype environment interaction and phenotypic stability (Becker *et al.*, 1988; Lin *et al.*, 1986; Piepho, 1998). The genotype environment interaction from analysis of variance is portioned into heterogeneity of regression coefficients (b_i) and the sum of deviations from regressions. Finlay and Wilkinson (1963) defined a genotype with regression coefficient equal to zero (b_i=0) to be stable. According to joint regression model, a stable genotype is one with a high mean yield b_i=1 and Sd_i^2=0 (Eberhart and Russell, 1966). Some stability studies have been carried out on different cereals in Turkey: Akcura *et al.* (2004), Aktas *et al.* (2009), Akgun *et al.* (2011) in triticale, Kara *et al.* (2000), Bayram *et al.* (2009), Dogan *et al.* (2009) in wheat and Akcura *et al.* (2005) in oat.

The purpose of this research was to determine genotype x environment interaction and phenotypic stability of the triticale lines over three environments.

Materials and methods

In this study, four triticale genotypes developed by the crossing method in the Agriculture Faculty of Uludag University (Coplu *et al.*, 2001) and three lines obtained from CIMMYT were studied in terms of yield in the southern Marmara region of Turkey. Variety 'Nörtingen' was used as the standard cultivar (Tab. 1).

Eight diverse winter triticale genotypes were examined in a randomized-blocks design with three replications in the years 2005-2006 and 2006-2007. Grain yield of genotypes was measured in all three environments (Bursa, 40°

Tab. 1. The new genotypes and standard cultivar used in the study

Genotypes and standard cultivars	Pedigree	Source
'C6'	GIRAF/YOGUI-1FARAS-1/3LAMB-4(CTM88. 1948 -3RES-1M-0Y-2M-3Y-0M)	CIMMYT
'C9'	LAMB-2(X65985-5M-3Y-2M-1Y-4M-1Y-1M-0Y)	CIMMYT
'C11'	CAGUAN-3 (CTM86M.2281-5Y-2B-1Y-1B-2RES-0B-1Y-OPAP)	CIMMYT
'Nörtingen x 2015(17)'	2015 (FAHAD9-1)	New Line
'Nörtingen x 2003(12)'	2003 (Juannillo 98x21295-OAP)	New Line
'Nörtingen x Eronga(3)'		New Line
'Nörtingen x Eronga(14)'		New Line
'Nörtingen (Standard)'		Germany

Tab. 2. Precipitation in 2005-2006, 2006-2007 and long-term (1975-2007) in Bursa, Eskisehir and Sakarya

The months of the year	Precipitation (mm)								
	Bursa			Eskisehir			Sakarya		
	2005-2006	2006-2007	Long-term	2005-2006	2006-2007	Long-term	2005-2006	2006-2007	Long-term
October	33.0	25.8	38.6	11.5	47.5	29.2	91.8	50.3	88.2
November	109.3	101.1	68.4	48.0	16.8	34.9	165.7	64.6	87.7
December	87.7	27.9	96.5	17.0	6.8	43.3	76.6	74.4	103.2
January	59.9	86.8	81.1	45.3	42.2	40.0	77.5	100.8	93.7
February	132.5	21.1	66.9	34.5	14.2	27.5	98.6	17.9	72.3
March	57.0	57.9	61.0	23.9	24.0	31.4	67.2	55.8	67.8
April	13.0	32.8	66.0	2.9	25.0	43.9	3.3	50.5	61.6
May	9.3	12.1	44.1	20.7	65.6	46.8	13.8	53.9	48.2
June	62.8	47.2	33.8	13.6	58.6	25.7	101.0	29.6	69.5
Total	564.5	413.1	556.4	217.4	300.7	322.7	695.5	497.8	692.2

W and 28°30′N, Eskisehir 29°32′E and 39°40′N, Sakarya 30°E and 40°N).

Precipitation patterns and amount differed markedly between the 2005-06 and 2006-07 growing seasons for all provinces (Anonymous, 2008). The distribution of precipitation is uneven and nearly 90% occurs during the period when wheat exists in the field for almost all province (Tab. 2).

The plots were 8 rows, 10 m in length with 15 cm between rows, with the harvested area = 12 m².

Statistical analyses

Analyses of variance were computed for the seed yield data within and across the six years of the study. The variance of "Homogenity of Regressions" and "Regression-Biased Variance" were partitioned from the cultivar x year interaction sum of squares in the analyses of variance (Eberhart and Russell, 1966; Yildirim *et al.*, 1979). The "Simple Regression Method" was used in estimating the adaptation and stability parameters (Finlay and Wilkinson, 1963). The regression coefficient (b_i), regression-biased square means (S^2, xi).

1. Regression coefficient (b_i) for 1 th genotype proposed by Finlay and Wilkinson (1963) was defined by the following formula:

$$bi = \frac{\sum_{j=1}^{m} YijXij - \frac{(Yi)(X)}{m}}{\sum_{j=1}^{m} xj^2 - \frac{X^2}{m}}$$

where i and j explain genotype (1-8) and environment (1-6), respectively. In addition, m was number of environments.

2. Mean squares of deviations from regression (Sd_i^2) proposed by Eberhart and Russell (1966) was calculated by the following equation:

$$Sdi^2 = \frac{1}{m-2}[(\sum_{j=1}^{m} Yij^2 - \frac{Yi^2}{m})bi^2(\sum_{j=1}^{m} Xj^2 - \frac{X^2}{m})]$$

were bi^2 was square of regression coefficient for genotype,

and the term $\sum_{j=1}^{m} Yij^2 - \frac{Yi^2}{m}$ was sum of squares of dependent variable (genotype).

All data were subjected to analysis of variance for each character using MSTAT-C (version 2.1 Michigan State University of Texas at Austin). The significant of genotype, year and cultivar x year (Environment) interactions were determined at 0.05 and 0.01 probability levels, by the F-test. The F protected least significant difference (LSD) was calculated at 0.05 probability level according to Steel and Torrie (1980).

Results and discussion

Each experimental year in the three locations was considered to represent an environment, and the mean of each environment was taken as an environmental index.

Tab. 3. The mean squares of analysis of variance of triticale genotypes

Source of variation	DF	Bursa		Eskisehir		Sakarya	
		2005-2006	2006-2007	2005-2006	2006-2007	2005-2006	2006-2007
Blocks	2	9508.3	704.0	698.2*	11.7	95.0	310.2
Genotypes	7	9752.5**	5009.0	6526.3**	2.87*	13003.0**	5632.6**
Experimental Error	14	950.5	1883.0	666.0	251.0	621.0	455.1
Total	23						

*,**: Significant at 0.05 and 0.01 probability levels, respectively

The results of analysis of variance for the grain yields of the triticale genotypes in six environments, including each experimental year in three locations, are shown in Tab. 3. Significant differences among grain yields of genotypes were found. Non significant differences were found only for Bursa during the 2005-2006 growing season.

The combined analyses of variance for the experiment on grain yields in six environments are given in Tab. 4.

The differences in grain yield among environments (E), blocks (B), and genotypes (G) were statistically significant at the 1% level . In addition, Genotype x Environment interaction was significant at the 1% level of probability. Pham and Kang (1988) indicated that genotype x environment interactions minimize the usefulness of genotypes by confounding their yield performance. Becker and Leon (1988) also indicated that assessment of stability across many locations and years could increase both repeatability and heritability of important traits. There is significant effects of years in terms of genotype's yields. Not only means of genotypes but also stability parameters must be considered on the evaluation of genotypes (Akgun *et al.*, 2011; Ilker *et al.*, 2009).

Genotype x Environment interaction was significant owing to the high significance of the residuals (mean square deviation from the regression). The significant G x E interaction indicated that genotypes were not stable in terms of grain yield (Tab. 4).

The grain yield values of triticale genotypes for individual environments and the overall means for the six-environments are shown in Tab. 5. The stability parameters for all cultivars are given in Tab. 6. Eberhart and Russell (1996) emphasized the need of considering both linear (b_i) and non-linear (Sd_i^2) components of genotype-environment interactions in judging the stability of a genotype. A wide adaptability genotype was defined as one with b_i=1 and high stability as one with Sd_i^2=0. In this study values for the regression coefficient (b_i) ranged from 0.824 ['NxE (14)'] to 1.180 ['Nx2015(17)'] for grain yield (Tab. 6).

Based on the average yield for the six environments, four of the eight triticale genotypes had higher yields than the average found in the trials . These higher yielding genotypes were 'C9', 'C11', 'Nx2015(17)' and 'Nx2003(12)' . The genotypes 'C9', 'C11', 'Nx2015(17)', Nx 23003(12), 'NxE(3)' and 'Nörtingen' (Std.) were in the same statistical group, whereas genotype 'NxE(14)' formed a different group. This genotype ('NxE(14)') had a lower yield value (5549 kg ha^{-1}) than the average yield value for the trial (6027 kg ha^{-1}).

Based on the average values over all environments, four genotypes ('C9', 'C11', 'Nx2015(17)' and 'Nx2003(12)'), with values of b_i=1 and Sd_i^2=0, were considered to be stable (Tab. 6).

Tab. 4. The combined analyses of variance for the six-environment study of grain yields of genotypes

Source of variation	D.F.	Sum of Squares	Means of Squares
Blocks (B)	12	19707.8	1642.3**
Genotype (G)	7	139505.0	19929.3**
Environment (E)	5	2717860.6	543572.1**
Genotype x Environment (GxE)	35	147290.0	4208.3**
Homogeneity of Regressions	7	9334.8	1333.5
Residual	28	137955.3	4926.9
Experimental Error	84	70011.4	833.5
Total	143	3094374.8	

Tab. 5. The seed yields of triticale genotypes in individual environments

Genotypes	(2005-2006)			(2006-2007)			Means
	Bursa	Eskisehir	Sakarya	Bursa	Eskisehir	Sakarya	
'C6'	7356 c	6479 c	7069 cd	5501	3384 ab	5132 bc	5820 bcd
'C9'	7990 abc	7524 a	7248 bc	6168	3737 a	5368 ab	6339 abc
'C11'	8151 ab	6672 bc	8005 a	6201	3679 ab	5737 a	6402 ab
'Nx2015(17)'	8314 a	7498 a	6855 cde	5359	3483 ab	4744 cd	6042 abcd
'Nx2003(12)'	7844 abc	7273 ab	7700 ab	6456	3674 ab	5581 ab	6421 a
'NxE(3)'	7502 bc	6707 bc	6439 ef	5520	3624 ab	4780 cd	5762 cd
'NxE(14)'	6518 d	6650 bc	6035 f	6222	3329 b	4543 d	5549 d
'Nörtingen' (Std.)	7888 abc	6344 c	6550 def	5952	3689 ab	4844 cd	5878 abcd
Means	7695	6889	6988	5922	3575	5092	6027

Tab. 6. Statistical indicators of the adaptation and stability of the triticale genotypes studied

Genotypes	Grain yield $\overline{X}$	b_i (regression coefficients)	S^2y.xi (regression biased square means)
'C6'	5820 bcd	0.969	580.8
'C9'	6339 abc	1.054	278.8
'C11'	6402 ab	1.060	2168.1 **
'Nx2015(17)'	6042 abcd	1.180	2158.3 **
'Nx2003(12)'	6421 a	1.046	634.6
'NxE(3)'	5762 cd	0,920	330.9
'NxE(14)'	5549 d	0,824	2729.3 **
'Nörtingen' (Std.)	5878 abcd	0,947	1059.7 **
Means	6027		

$\overline{X}$: Mean grain yield (kg ha^{-1}); b_i: regression coefficient, Sd_i^2: deviation from regression (Eberhart and Russell,1966). *,**: Significant at 0.05 and 0.01 probability levels, respectively.

Marmara region of Turkey because of their minimal Sd_i^2 values and b_i values near 1. However, genotypes 'C6' and 'NxE(3)' had lower grain yields than the general mean and b_i values near 1. These genotypes were considered to have poor adaptability to all environments.

Temperature and precipitation that varied across environments were major environmental factors affecting triticale yield (Akgun *et al.,* 2011; Dogan *et al.*, 2009; Frere *et al.*,1987; Korkut *et al.*, 2001). As seen from Tab. 5, there were significant variations in grain yields. It is known that variation in yield were due to annual precipitation and also, variations of precipitation in critical months (especially; March, April and May). Stability analysis identified stable genotypes for grain yield. Some genotypes were considered to have high adaptability to good environments, and several other genotypes were considered to have high adaptability to unfavorable conditions. The genotypes 'C9', 'C11', 'Nx2003(12)' and 'Nx2015(17)' were determined to be the most suitable cultivars for the conditions of the region, based on the results of the trials (Fig. 1). These genotypes may be recommended for triticale production areas in the southern Marmara region, owing to their stability and good adaptability to all environments. However, genotypes 'C6', 'NxE(3)', 'NxE(14)' and cv. 'Nörtingen' (Std.) exhibited poor adaptability to unfavorable environmental conditions or to all environments.

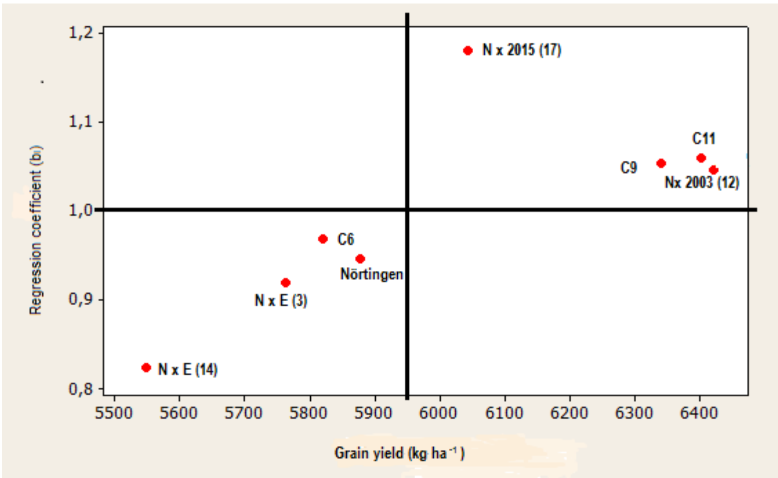

Fig. 1. Plot of deviation from regression coefficient against grain yield in a stability study of eight triticale genotypes

Several genotypes were found to have b_i values near 1. However, the mean square deviations from the regression (Sd_i^2) were highly significant for the genotypes 'C11', 'Nx2015(17)', 'NxE(14)' and 'Nörtingen' (Std.). Therefore, results based on stability parameters and grain yield of genotypes indicated that genotypes 'NxE(14)' and 'Nörtingen' had poor adaptability to unfavorable environmental conditions. These genotypes had lower grain yields than the general mean, and they had highly significant Sd_i^2 values (Tab. 6). The genotypes 'C11' and 'Nx2015(17)' were considered to have good adaptability to favorable environmental conditions because they exhibited highly significant Sd_i^2 values and higher grain yields than the general mean. The genotypes 'C11' and 'Nx2015(17)' had higher grain yields than the general mean and b_i values near 1. However, these genotypes were not considered to be stable, owing to their high Sd_i^2 values. Triticale genotypes 'C9' and 'Nx2003(12)' had higher grain yields than the general mean and b_i values near 1. These genotypes were considered to have good adaptability to all environments. Genotypes 'C9' and 'Nx2003(12)' were considered to be stable genotypes in terms of grain yield for the southern

Conclusions

This study evaluated the response to environmental conditions and the yield performance of several triticale genotypes. According to the results of the analysis of variance, significant differences between environments and genotypes and significant Genotype x Environment interaction effects were found for grain yield.

The results of the present study indicate that considerable genetic diversity and environmental stability for yield are present in triticale and that genetic improvement programs should be successful in developing cultivars with high yield adapted to a broad range of environments.

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