The Journal of Animal & Plant Sciences, 26(3): 2016, Page:754-765
ISSN: 1018-7081

THE STABILITY OF SOME SPRING TRITICALE GENOTYPES USING BIPLOT ANALYSIS

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ABSTRACT

This research examined the adaptability of triticale genotypes in three sub-regions of Southeastern Anatolia that represent distinct agro ecological zones. The study was conducted using a total of 25 genotypes, including 20 advanced lines, three triticale varieties, one durum wheat variety, and one bread wheat variety. Yield and crop quality traits for these genotypes were assessed at four locations over the 2010–2011 growing season. The stability and superiority of genotypes were assessed in terms of crop traits including grain yield, yield components, and crop quality parameters using GGE biplot analysis. Three study locations showed distinct traits: Diyarbakir was found to be the most suitable overall location with a high stability value, Kızıltepe showed high grain yield, and Mardin showed superior crop quality traits. However, when all crop traits were analyzed with respect to location, crop quality parameters formed the first group, plant height (PH) and grain yield (GY) formed the second group, and heading time (HT) formed a third group. When the parameters were analyzed for genotypes, three different groups were formed, in which grain yield and thousand-grain weight (TGW) formed the first group, protein content (PC) and test weight (TW) formed the second group, HT and PH formed the third group. Consequently, the Sarıçanak 98 (durum wheat) and Nurkent (bread wheat), which are referred to as standard varieties in this study, as well as genotype lines 3, 7, 12, 13, 16, and 21 were considered suitable for cultivation in Southeastern Anatolia, whereas the remaining genotypes were below average with respect to overall performance. Furthermore, we found that the GGE biplot method generated highly useful results with high visual quality.

Key words: *GGE Biplot, Genotype × environment interaction, Spring Triticale, Turkey.*

INTRODUCTION

Triticale *(× Triticosecale Wittmack)* is a relatively new cereal crop obtained via the hybridization of summer and winter wheat with rye genotypes. Triticale is much more tolerant than wheat to both biotic and abiotic stressors and thus more suitable for cultivation in marginal areas (Ugarte *et al.,* 2007; Villegas *et al.,* 2010). Triticale is quite different from other cereals in that it shows wide adaptability and high nutritional quality (Oettler, 2005) as well as high yield potential, and it is generally more competitive against weeds than wheat is (Beres *et al.,* 2010). It also shows greater tolerance toward drought and pests than its progenitors (Darvey *et al.,* 2000; Erekul and Kohn, 2006). In addition, triticale is a important crop with respect to providing high-quality roughage (Bilgili *et al.,* 2009), its shortage one of the biggest problem of animal husbandry of Turkey (Sakarya *et al.,* 2008; Sayar *et al.,* 2014). For this reason, triticale has been cultivated either pure or mixedwith annual legumes for fresh forage and dry forage producing (Karadag and Buyukburc, 2004) and silage making (Demirel *et al.,* 2013). Recent researches have been revealed that triticale is suitable for production raw material of ethanol and recrystallized (Beres e*t al.,* 2010; Pejin *et al.,* 2009).

The presence of genetic variation within a plant population is very important in achieving an effective breeding program (*i.e.,* in terms of yield and other agronomic traits). The development of high-yield varieties requires information about the size and diversity of the currently available germplasm. For this reason, previous studies have examined the genetic diversity of triticale in depth (Mittal and Sethi, 2005; Barnett *et al.,* 2006; Thiemt and Oettler, 2008). The diversity of triticale genotypes in terms of many traits can be found also in Ukalska and Kociuba (2013).

Triticale studies in Turkish universities began in the 1940s and primarily focused on adaptation, yield, and quality; the first commercial varieties were registered in 1997. According to data from 2013, total triticale production for grain production has reached 118.000 tons from 35.402 ha in Turkey, representing a yield of approximately 3340 kg ha^{-1}, while roughage production with triticale has reached 67.801 tons dry forage from 5558 ha representing a yield of approximately 1220 kg ha^{-1} (TUIK, 2013).

Temperature stress, drought, and bird damage are the primary factors limiting cereal production in Southeastern Anatolia. Therefore, as an alternative to more sensitive crops such as wheat and barley, triticale varieties are being developed with the aim of improving grain yields from this region. Crop breeders have been improving to develop genotypes with superior grain yield, quality and other desirable traits over a wide range of different environmental conditions. Genotype by environment interaction (GEI) makes it difficult to select the best performing and most stable genotypes. Plant breeding programs should take GEI into consideration as well as an estimate of it's magnitude, relative to the magnitude of G and E effects, which affects yield and yield components (Gauch *et al.*, 1996; Gauch, 2006; Yan *et al*., 2007). Since its first time reported by Gabriel (1971), GGE biplot analysis has been applied to numerous disciplines, including sociology, economics, business, medicine, genetics, and ecology (Yan and Tinker, 2006). Agricultural scientists have applied this visual data analysis method to many different crops (Yan and Hunt, 2001; Yan and Kang, 2003; Ukalski*et al.*, 2010; Kendal and Sener, 2015; Sayar and Han, 2015).GGE biplot analysis allows comparison amongst test locations in terms of their discriminating ability and representativeness. These values can be assessed using the discriminating power of the testers' biplot screen of the GGE biplot (Yan and Kang 2003; Yan *et al.*, 2007).

In a multi-environment trial (MET) for durum wheat, biplots were constructed by plotting the first two principal components (PC1 and PC2) derived from subjecting environment-centered yield, yield components, and quality criteria data (yield variation due to GGE) to singular value separation (Yan *et al*., 2000).

The present study aimed to (1) to apply a GGE biplot analysis to evaluate the magnitude of the effect of GEI on grain yield and yield components in 25 cereal genotypes (including 23 triticale, one durum wheat, and one bread wheat) tested across four locations, and (2) evaluate the relationships among test environment parameters to identify appropriate triticale genotypes for cultivation in Southeastern Anatolia.

MATERIALS AND METHODS

Plant material and experimental arrangement: The study was conducted using a total of 25 genotypes, including 20 advanced lines (from CIMMYT), three triticale varieties(Presto, Tacettinbey and Karma), one durum wheat variety (Saricanak 98), and one bread wheat variety (Nurkent). The orjins and pedigrees of the used genotypes indicated in the Table 1.

Table 1. The names, orjins and pedigrees of the genotypes used as material in the study

Number	The name of variety or pedigree of genotypes	Orjin
1	BEAGLE_1/X1530-1-MXI06-07\C40ITYN\190,001	CIMMYT
2	ERONGA 83/ X21295-159-MXI06-07\C40ITYN\190,002	CIMMYT
3	DAHBI_6/3/ARDI_1/TOPO1419//ERIZO_9/4/….CTSS99Y00115S-1Y-0M-0Y-8B-2Y-0B-	CIMMYT
4	ARDI_1/TOPO 1419//ERIZO_9/3/LIRON_1…CTSS99B00483S-0M-10Y-11M-2Y-1M-0Y-	CIMMYT
5	**KARMA-2000**	AARI
6	DAGRO/IBEX//CIVET#2/3/F3 IND. PCZ/ CTSS00Y00230S-0Y-0M-10Y-6M-3Y-4M-0Y	CIMMYT
7	T1505_WG//ERIZO_10/BULL_1-1/...CTSS00Y00759T-0TOPB-8Y-7M-2Y-1M-4Y-2M-0Y	CIMMYT
8	DAHBI_6/3/ARDI_1/TOPO 1419//ERIZO….CTSS00B00197S-0M-4Y-010M-3Y-4M-0Y	CIMMYT
9	POLLMER_2.2.1//FARAS/CMH84….CTSS00B00627T-0TOPY-0M-5Y-010M-6Y-5M-0Y	CIMMYT
10	**PRESTO**	AARI
11	POLLMER_2.2.1//FARAS/CMH84….CTSS00B00627T-0TOPY-0M-4Y-010M-6Y-1M-0Y	CIMMYT
12	LIRON_2/5/DIS B5/3/SPHD/PVN//YOGUI_6/….CTSS01Y00040S-1M-3Y-3Y-4M-0Y	CIMMYT
13	LIRON_2/5/DIS B5/3/SPHD/PVN//YOGUI_6/4/….CTSS01Y00040S-1M-5Y-3Y-3M-0Y	CIMMYT
14	LIRON_2/5/DIS B5/3/SPHD/PVN//YOGUI_6/4/….CTSS01Y00040S-1M-5Y-3Y-4M-0Y	CIMMYT
15	**TACETTİNBEY**	CU
16	PRESTO//2*TESMO_1/MUSX 603/4/ARDI_1/….CTSS01Y00150S-4Y-010M-1Y-10M-Y	CIMMYT
17	PRESTO//2*TESMO_1/MUSX 603/4/ARDI_1/….CTSS01Y00150S-4Y-010M-1Y-5M-0Y	CIMMYT
18	PRESTO//2*TESMO_1/MUSX 603/4/ARDI_1/….CTSS01Y00150S-4Y-010M-6Y-6M-0Y	CIMMYT
19	PRESTO//2*TESMO_1/MUSX 603/4/ARDI_1/….CTSS01Y00150S-4Y-010M-1Y-2M-0Y	CIMMYT
20	**NURKENT(Bread wheat varieties)**	GAPIARTC
21	DAHBI_6/3/ARDI_1/TOPO 1419//….CTSS01Y00519T-0TOPB-20Y-010M-7Y-6M-0Y	CIMMYT
22	DAHBI_6/3/ARDI_1/TOPO 1419//….CTSS01Y00519T-0TOPB-20Y-010M-10Y-5M-0Y	CIMMYT
23	ARDI/GNU//2*FAHAD_1/4/BULL_10/MANATI….CTSS01B00018S-10M-6Y-4Y-1M-0Y	CIMMYT
24	DAHBI/3/FAHAD_8-2*2//PTR/PND-T/7/LIRON_2….CTSS02Y00771S-040Y-5Y-3M-0Y	CIMMYT
25	**SARİCANAK-98(Durum wheat varieties)**	GAPIARTC

CIMMYT: International Maize and Wheat Improvement Center ,**CU**: Cukurova University, **GAPIARTC**: GAP International Agricultural Research and Training Center, **AARI:** The Anatolia Agricultural Research Institute

Yield and crop quality traits for these genotypes were assessed at four locations, representing three sub-regions of Southeastern Anatolia that represent distinct agroecological zones over the 2010–2011 growing season. Climatic data recorded in the locations during the growing season are shown in Figure 1 and Figure 2. When the Figures analyzed, for all of the months of the growing season, the highest average temperatures, and the lowest precipitation amount were recorded in Kızıltepe and Mardin locations. The two locations represent first agro ecological zone of Southeastern Anatolia. On the other hand, the lowest average temperatures and the highest precipitation amounts were recorded in Hani location. With these climatic records, Hani represent the third agro ecological zone of Southeastern Anatolia. The temperatures and precipitation amount recorded in Diyarbakır location were found generally in the middle of the locations, and the location represent the second agro ecological zone of Southeastern Anatolia.

Made soil analysis indicated that the soil of experimental areas of locations had clay loam soil texture with high lime content (16.6.0-18.5%), low salt (0.044-0.235%), alkaline (pH 7.86-7.95), poor in phosphorus (P_2O_5 2.72-14.64 kg ha^{-1}) and organic matter (1.220-1.937%), but it is rich in terms of potassium (K_2O 420-540 kg ha^{-1}) content (Table 2). Additionally, in contrast to highland soil conditions of Hani location, there were more favorable soil conditions for plant growth in Kızıltepe, Mardin and Diyarbakır locations. Soil of the locations had more depth fertile soil layer, plain and without stone.

The experiments were conducted in a randomized block design with four replications. The seeding rates were 450 seeds m^{-2} in second sub-region (Diyarbakır), and 500 seeds m^{-2} first (Kızıltepe and Mardin) and third sub-regions (Hani). Plot size was 7.2 m^{-2} (1.2 × 6 m) consisting of 6 rows spaced 20 cm apart. Sowings were made by using an experimental drill. The fertilization rates for all plots were 60 kg N ha^{-1} and 60 kg P ha^{-1} with sowing time and 60 kg N ha^{-1} was applied to plots at the early stem elongation. Harvests were made using Hege 140 harvester in 6 m^2.

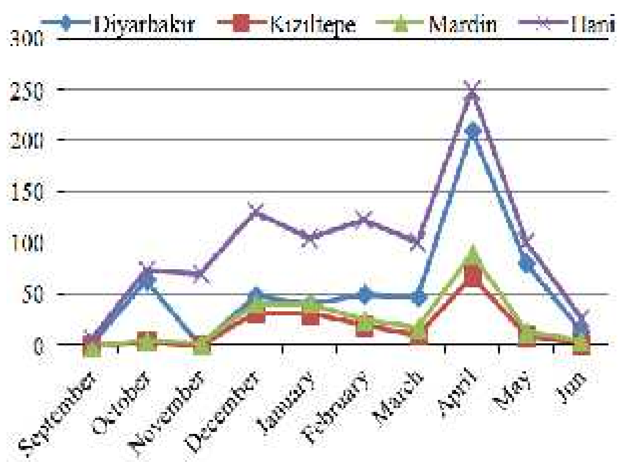

Figure 1. The precipitation (mm) of the environments in 2010-2011 growing season

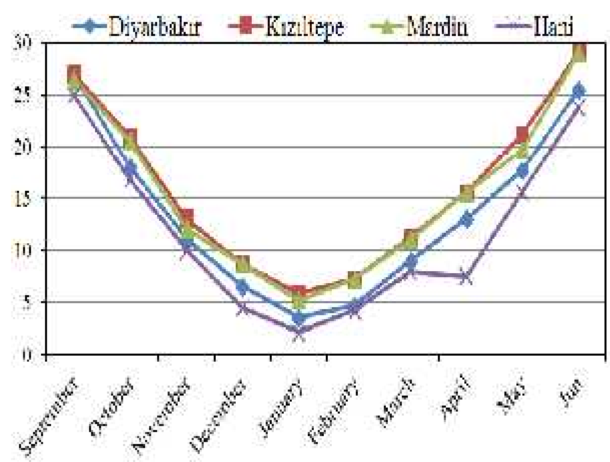

Figure 2. The temperature (˚C) of the environments in 2010-2011 growing season

Table 2. Location status and soil properties of the environments.

Environ.	Altitude (m)	Latitude	Longitude	The status of irrigation	Satur. with water (%)	Total salt (%)	Organic matter (%)	Phosphor (P_2O_5) (kg ha-1)	Potassium (K_2O) (kg ha-1)	Lime $CaCo_3$ (%)	pH
Diyarbakır	611	37° 55'N	40°14' E	rain fed	64	0.060	1.330	2.72	440	16.6	7.86
Kiziltepe	484	37° 19'N	40°58' E	sup. Irr.	54	0.044	1.937	14.64	420	18.5	7.95
Mardin	488	37° 10'N	40°57' E	rain fed	59	0.053	1.854	10.20	425	17.9	7.90
Hani	995	38° 24N	40° 24'E	rain fed	62	0.235	1.220	5.63	540	18.3	7.91

Statistical analysis: To determine statistically significance status of interactions of environments, genotypes and GEI, the data obtained in the study were analyzed by mixed model (Piepho,1997). The analysis results are presented in the Table 3. Also, in order to present understandably performance of the genotypes in terms of the investigated traits in the each location, the data of each location were subjected to analysis of variance (ANOVA) for each traitseparately. Where the "F" statistics indicated significance, the means were separated using Tukey's HSD(honest significant difference) test at the 0.05 probability level (Tukey, 1953; Kramar, 1956) by using the JMP 5.0.1 statistical software package (SAS Institute, 2002). On the other hand; GGE biplot analyses were carried out by using GENSTAT statistical software package (VSN International, 2011) to assess crop traits across all four environments as described by Yan *et al.*, (2001), and Yan and Kang (2003).

With the GGE biplot analysis graphs in the study: It was aimed at revealing the mega-environments on grain yield of genotypes (**Figure3A)**, showing the relationships genotypes and environments for grain yield (**Figure3B),** illustrating stability of genotypes on grain yield in four environments (**Figure 3C),**showing the stability of genotypes based on grain yield in four environments **(Figure 3D),**discriminating ability and representativeness of environments for grain yield(**Figure 4A),** showing the phenotypic correlations among traits by environments (**Figure 4B)**, definite discriminating ability and representativeness of environments by traits with different shapes**(Figure 4C)**showing the stability of environments based on traits (**Figure 4D),**discriminating ability and representativeness of environments for traits (**Figure 5A),** showing the stability of genotypes based on traits **(Figure 5B),** showing relationships among genotypes and traits (**Figure 5C)** showing groups of traits by genotypes **(Figure 5D**) demonstrate discriminating ability and representativeness of genotypes for traits.

RESULTS AND DISCUSSION

The study results indicated that the environments, where the researches were carried out in there, had significantly different environmental conditions from each other for the investigating traits. In addition, highly significant differences (P < 0.01) were determined among the genotypes for all of the investigated traits, except protein content (P >0.05) (Table 3). Moreover; were found to be highly significant (P < 0.01) for grain yield, plant height, test weight and thousand grain weight traits, while for heading time was found significant at 0.05 level(Table 3). Similarly; GEI were found to be highly significant (P < 0.01) by Sayar *et al.* (2013) for investigated traits, and they reported that this stemmed from changing of ranking of genotypes as a result of changing environmental conditions. Also, Sayar *et al.* (2013) and Ezzat *et al.* (2010), indicated that in the assessment of genotypes many locations and years could increase the reliability of plant breeding programs. Furthermore, they drew attention the point that many location trials were more important than many years trials in the same location in determining performance of tested genotypes in terms of investigated traits in plant breeding programs. This enhances importance of our study, conducted in many locations, which are different from each other in terms of environmental conditions.

Table 3. Analysis of variance for investigated traits.

Source of variation	d.f.	Mean squares					
		Grain yield	Heading time	Plant height	Test weight	T.G.W	Protein content
Environments	3	4066740.3**	7014.0**	15705.3**	603.1**	2671.0**	203.1**
Rep(E)	3	34066.9	20.6	83.4	7.9	6.4	2.2
Genotype	24	41465.9**	68.3**	746.1**	112.5**	178.5**	4.6**
GEI	72	12873.3**	13.6*	190.9**	7.7**	43.9**	2.9**
Error	288	6427.7	10.1	49.5	2.8	2.8	0.7
Total	399	41058.3	67.2	235.6	15.0	41.0	

**Value significant at 0.01 probability level,*Value significant at 0.05 probability level.

The results of the data reviewed: When examined grain yields of the locations, conducted the field trials, the highest grain yields were obtained from Kızıltepe location (8886kg ha^{-1}), an area that is supported by irrigation, whereas the lowest yields were observed in Hani(4146kg ha^{-1}). The grain yields of the other locations were determined as 6771 kg ha^{-1} and 5490 for Diyarbakır and Mardin locations respectively (Table 4).

When grain yields among the varieties examined in Table 4, the highest mean yield was obtained from line16(6942 kg ha^{-1}), whereas the lowest yield was obtained from the Karma variety (5883 kg ha^{-1}). The grain yield values of the study varied from 2396 kg ha^{-1} to 9623 kg ha^{-1} among the locations and the used genotypes (Table 4). Similarly many researchers reported that grain yields of triticale genotypes varied between 3680kg ha^{-1} and 9250 kg ha^{-1}.

Table 4. The means and rankings of the genotypes in four environments for grain yield and protein content*.

Genotype	Yield(kg/ha^{-1})				Average	Protein content(%)				Average
	Diyarbakir	Kiziltepe	Mardin	Hani		Diyarbakir	Kiziltepe	Mardin	Hani	
1	6314^{ab}	8421^{ab}	4894^{a}	4776^{b}	6101^{AB}	13.2^{hk}	13.0^{ns}	15.5^{i}	12.6^{h}	13.6^{HI}
2	6538^{ab}	9623^{ab}	5877^{a}	3655^{bd}	6423^{AB}	13.3^{gj}	11.6	15.2^{k}	12.6^{h}	13.2^{KL}
3	7439^{a}	9442^{ab}	5623^{a}	4426^{ad}	6732^{AB}	12.4^{df}	11.4	14.5^{n}	12.3^{k}	12.7^{LM}
4	6888^{ab}	8406^{b}	5638^{a}	5276^{a}	6552^{AB}	14.1^{de}	10.7	14.0^{o}	11.8^{m}	12.7^{N}
Karma 2000	4605^{ab}	7046^{ab}	2396^{b}	3563^{bd}	4403^{C}	14.9^{ab}	12.3	18.0^{a}	13.4^{b}	14.7^{A}
6	5685^{ab}	9069a	5014^{a}	4160^{ad}	5982^{AB}	13.8^{df}	12.3	16.2^{d}	13.2^{c}	13.9^{FG}
7	6383^{ab}	10315^{a}	5950^{a}	4491^{ac}	6785^{AB}	14.4^{cd}	12.5	15.2^{k}	13.7^{a}	14.0^{EF}
8	6455^{ab}	8533^{ab}	5682^{a}	4314^{ad}	6246^{AB}	13.6^{fg}	13.6	14.9^{m}	13.2^{c}	13.8^{FG}
9	6788^{ab}	8308^{ab}	5844^{a}	4402^{ad}	6335^{AB}	12.9^{jl}	14.5	14.9^{m}	12.8^{i}	13.8^{GH}
Presto	6142^{ab}	8477^{ab}	5665^{a}	3451^{cd}	5934^{AB}	13.6^{fh}	14.6	16.2^{d}	12.7^{g}	14.3^{CD}
11	7660^{a}	7992^{ab}	5175^{a}	4235^{ad}	6265^{AB}	12.8^{kl}	13.6	16.0^{e}	12.4^{j}	13.7^{GH}
12	7597^{a}	8848^{ab}	5694^{a}	3977^{ad}	6529^{AB}	12.7^{l}	13.5	16.0^{e}	12.8^{f}	13.8^{EH}
13	7750^{a}	9200^{ab}	5999^{a}	4397^{ad}	6837^{AB}	12.3^{ac}	13.9	15.9^{f}	12.4^{j}	13.6^{CD}
14	7974^{a}	9175^{ab}	5813^{a}	3906^{bd}	6717^{AB}	13.4^{fi}	12.6	15.8^{l}	11.8^{m}	13.4^{IJ}
Tacettinbey	6806^{ab}	8098^{ab}	5458^{a}	3169c	5883^{B}	12.8^{kl}	11.7	16.0^{l}	12.6^{h}	13.3^{JK}
16	7491^{a}	9648^{ab}	6138^{a}	4490^{ac}	6942^{A}	14.7^{ac}	11.5	15.1^{j}	12.4^{j}	13.4^{IJ}
17	7508^{a}	9035^{ab}	6373^{a}	3798^{bd}	6678^{AB}	14.6^{bc}	11.5	15.1^{j}	11.9^{l}	13.3^{JK}
18	6006^{ab}	9327^{ab}	5742^{a}	3350^{cd}	6106^{AB}	13.5^{fh}	12.3	15.3^{h}	10.8^{q}	13.0^{LM}
19	7088^{a}	9696^{ab}	6023^{a}	3945^{bd}	6688^{AB}	13.3^{gj}	13.1	15.3^{j}	11.4^{p}	13.3^{JK}
Nurkent	6325^{ab}	7867^{ab}	5854^{a}	4348^{ad}	6098^{AB}	13.8^{df}	14.1	15.6^{h}	12.9^{e}	14.1^{DE}
21	6955^{ab}	9683^{ab}	5038^{a}	3931^{bd}	6402^{AB}	12.8^{kl}	15.0	16.8^{c}	13.0^{d}	14.4^{BC}
22	7142^{a}	9827^{a}	5094^{a}	3757^{bd}	6455^{AB}	12.8^{kl}	14.4	16.2^{d}	11.6^{n}	13.8^{EH}
23	5719^{ab}	8517^{ab}	5363^{a}	4648^{ac}	6061^{AB}	13.0^{il}	14.8	15.8^{g}	11.9^{l}	13.9^{FG}
24	7519^{a}	9317^{ab}	5602^{a}	4792^{ab}	6808^{AB}	12.7l	12.3	14.9^{m}	11.5^{o}	12.9^{MN}
Saricanak 98	6500^{ab}	8271^{ab}	5313^{a}	4394^{ad}	6119^{AB}	15.1^{a}	13.8	17.2^{b}	12.3^{k}	14.6^{AB}
Average	6771^{B}	8886^{A}	5490^{C}	4146^{D}		13.5^{B}	13.0C	15.7^{A}	12.4^{D}	
CV(%)	10.9	11.3	13.0	11.8	**12.6**	1.1	1.2	10.5	2.7	**1.12**

*Means shown with the same letter in the same column are not significantly different at 0.05 probability level using Tukey's HSD (Honest Significant Difference) test, ns: not significiant

(Karadag and Buyukburc 2008;Aydogan*et al.*, 2010; Kara *et al.*,2010)These results confirm our findings related to grain yields in triticale genotypes. However; grain yields determined in triticale genotypes reported by Kaydan and Yagmur (2008) (543-3283 kg ha^{-1}) and Geren *et al.* (2012), (1570-5390 kg ha^{-1}) were partly confirmed and partly lower than our findings. As a cause of the lower grain yield data, the follow points were specified by the researchers. These were the later sowing dates, the lower seeding ratings per unit area and adverse environmental conditions, especially the high temperature stress.

The multi-locations mean values for protein content ranged from 12.7-14.7% among the genotypes (Table 4). This indicated that the genotypes are different genotypically each other in terms of protein content. Many researchers indicated that grain protein content is a genotypic trait for the grains, also the property is influenced with environmental conditions (Alaru *et al.*,2003; Oettler, 2005; Burhan and Uysal, 2009; Ukalska and Kociuba, 2013). In previous studies; grain protein content in triticale genotypes were reported by many researchers between 6.3% and 15.7% (Kara *et al.*, 2010; Janušauskaitė, 2013; Ukalska and Kociuba, 2013). The results comprise with our data determined for grain protein content in triticale genotypes.

The locations mean and multi- locations mean values of the genotypes for heading time and plant height indicated in Table 5. The multi-locations mean values for heading time ranged from 107 to 114 days among the genotypes. Line 3, Line 7, Line 17 and Line 23 were found as earliest heading genotypes, while the latest heading time occurred in the Nurkent, bread wheat used as control cultivar. At the same time, Karma-2000, control triticale cultivar, Line 8, Line 4, Sarıçanak-98, durum wheat cultivar used as control cultivar, took place in the same homogeneous group with Nurkent in terms of heading time (Table 5).

Table 5. The means and rankings of the genotypes in four environments for heading time and plant height*.

Genotype	Heading time (date)				Average	Plant height (cm)				Average
	Diyarbakir	Kiziltepe	Mardin	Hani		Diyarbakir	Kiziltepe	Mardin	Hani	
1	114^{hj}	104^{ac}	100de	117^{ab}	110^{DI}	130^{a}	140^{ad}	105de	101^{ac}	119^{AE}
2	117^{ej}	104^{ac}	98de	116^{ab}	109^{DI}	125^{ab}	145^{ab}	115de	108^{ac}	123^{AD}
3	115^{fj}	100^{c}	100de	114^{ab}	107^{I}	110^{ac}	120^{f}	90de	98^{bc}	104^{GH}
4	123^{bd}	105^{ac}	106^{ac}	117^{ab}	112^{AC}	135^{a}	145^{ac}	116^{ac}	115^{ab}	128^{A}
Karma 2000	125^{ac}	105^{ac}	110^{a}	120^{a}	113^{AB}	120^{ab}	150^{a}	130^{a}	109^{ac}	127^{AB}
6	114^{gj}	103^{ac}	97^{e}	113^{ab}	108^{GI}	110^{ac}	130^{df}	110^{e}	109^{ac}	115^{DF}
7	117^{e}j	101^{ac}	98de	113^{ab}	107^{I}	125^{ab}	130^{df}	100de	110^{ac}	116^{CF}
8	119^{dg}	110^{a}	101^{ce}	119^{a}	113^{AB}	111^{ac}	150^{a}	100^{ce}	116^{ab}	119^{AE}
9	118^{dı}	103^{ac}	102^{ce}	116^{ab}	110^{CH}	125^{ab}	121^{f}	120^{ce}	118^{a}	121^{AD}
Presto	117^{ej}	102^{bc}	101^{ce}	115^{ab}	109^{DI}	124^{ab}	130^{df}	110^{ce}	103^{ac}	117^{CF}
11	115^{fj}	103^{bc}	99de	118^{ab}	109^{DI}	120^{ab}	140^{ad}	100de	105^{ac}	116^{CF}
12	121^{cf}	102^{bc}	102^{bd}	118^{ab}	110^{CG}	125^{ab}	125^{ef}	101^{bd}	106^{ac}	114^{DF}
13	119^{dh}	101^{bc}	102^{ce}	118^{a}	109^{CG}	111^{ac}	130^{df}	95^{ce}	103^{ac}	110^{FG}
14	119^{dh}	106^{ac}	102^{ce}	117^{ab}	111^{CG}	125^{ab}	145^{ab}	115^{ce}	115^{ab}	125^{AC}
Tacettinbey	116^{fj}	104^{ac}	98de	114^{ab}	109^{DI}	132^{a}	130^{df}	110de	103^{ac}	119^{AF}
16	115^{gj}	103^{ac}	101^{ce}	113^{ab}	108^{FI}	109^{ac}	130^{df}	110^{ce}	98^{bc}	112^{EG}
17	114^{hj}	102^{bc}	99de	110^{b}	107^{I}	110^{ac}	135^{be}	105de	106^{ac}	114^{DF}
18	116^{fj}	104^{ac}	99de	112^{ab}	108^{FI}	110^{ac}	125^{ef}	110de	111^{ac}	114^{DF}
19	116^{fj}	102^{bc}	100de	113^{ab}	108^{EI}	110^{ac}	140^{ad}	105de	104^{ac}	115^{DF}
Nurkent	129^{a}	107^{ab}	107^{ab}	119^{a}	114^{A}	100^{bc}	135^{be}	110^{ab}	101^{ac}	112^{EG}
21	112^{j}	102^{bc}	99de	114^{ab}	108^{HI}	120^{ab}	135^{ce}	110de	108^{ac}	118^{BF}
22	113^{ıj}	105^{ac}	100de	112^{ab}	108^{GI}	115^{bc}	135^{ce}	110de	109^{ac}	117^{CF}
23	115^{gj}	101^{bc}	100de	114^{ab}	107^{GI}	125^{ab}	140^{ad}	115de	103^{ac}	121^{AE}
24	121^{be}	103^{bc}	103^{bd}	117^{ab}	110^{CD}	120^{ab}	135^{be}	115^{bd}	109^{ac}	120^{AF}
Saricanak 98	126^{ab}	105^{ac}	108^{a}	119^{a}	113^{AB}	90^{c}	102^{g}	95^{ce}	96^{c}	96^{H}
Average	118^{A}	103^{C}	101^{D}	115^{B}		117^{B}	134^{A}	108^{C}	106^{C}	
CV(%)	1.7	2.47	1.85	2.42	**2.9**	13.0	3.0	4.0	7.0	**6.04**

*Means shown with the same letter in the same column are not significantly different at 0.05 probability level using Tukey's HSD (Honest Significant Difference) test

The genotypes having higher plant height are desired in high yield intended triticale productions. The multi-locations mean values for plant height ranged from 96 to 128 cm among the genotypes. The highest plant height was recorded in Line 1, Line 2, Line 4, Line 8, Line 9, Line 23, Line 24 Line 14 and Tacettinbey and Karma 2000 cultivars, whereas the lowest plant height was recorded in Sarıçanak 98 durum wheat cultivar (Table 5). Ukalska and Kociuba (2013) reported that plant height among the triticale genotypes changed from 114 cm to 141 cm in their studies, which prolonged almost three decades (1982-2008) and covering hundreds triticale germplasm. Their plant height findings are fully in compliance with our findings. On the other hand; Geren *et al'* (2012) plant height findings (87.7-119.2 cm) are partly confirmed with our findings, while the findings (76.3-93.4 cm) of Kaydan and Yagmur (2008) determined in triticale genotypes were found lower than our findings The differences between the findings of the researches can be attributed to differences between environmental conditions and used genotypes.

The locations mean and multi-location values of the genotypes for test weight and thousand grain weight indicated in Table 6. Among the genotypes test weight values varied from 69.7 to 81.7 kg. The highest test weight value was obtained by far from durum wheat cultivar, Sarıçanak 98, and it was followed by bread wheat cultivar, Nurkent. Furthermore, Line 2 and Line 12 had higher test weight values than the other triticale genotypes. Geren *et al.* (2012), (59.5-76.7 kg) findings, determined in triticale genotypes related to test weight, largely confirm our test weight findings.

The multi-locations mean values for thousand-grain weight ranged from 32.9 to 49.3 g among the genotypes. The highest thousand-grain weight value was determined in Line 21, while the lowest thousand-grain weight was recorded in Karma 2000 cultivar. Also Line 2, Line 13 and Line 14 had higher thousand-grain weight values. Previously, many researchers reported that thousand-grain weight values of triticale genotypes ranged from 23.9 g to 54.9 g (Kaydan and Yagmur, 2008; Geren *et al.*, 2012; Janušauskaitė, 2013; Ukalska and Kociuba, 2013) These results greatly confirm our findings.

Table 6. The means and rankings of the genotypes in four environments test weight yield and thousand grain weight*.

Genotype	Test weight (kg/hl)				Average	TGW(g)				Average
	Diyarbakir	Kiziltepe	Mardin	Hani		Diyarbakir	Kiziltepe	Mardin	Hani	
1	69.1^{fg}	72.0^{df}	74.0^{cd}	68.9^{cd}	71.0^{GH}	38.9^{be}	46.1^{eg}	50.0^{bd}	40.0^{ac}	43.7^{CD}
2	74.1^{bd}	76.1^{bd}	77.0^{bd}	74.1^{ab}	75.3^{BD}	40.0^{bd}	50.0^{ce}	52.9^{b}	38.9^{bd}	45.5^{BC}
3	72.6^{cf}	75.1^{be}	77.9^{bc}	73.0^{ac}	74.6^{CE}	37.0^{ce}	47.9^{df}	46.1^{df}	41.1^{ab}	43.0^{DE}
4	65.9^{g}	71.1^{ef}	72.9^{d}	68.9^{cd}	69.7^{HI}	35.1^{e}	47.9^{df}	45.0^{eg}	41.1^{ab}	42.3^{DF}
Karma 2000	66.1^{g}	69.9^{f}	67.9^{e}	68.9^{cd}	68.2^{I}	28.9^{f}	38.9^{j}	30.0^{ı}	33.9^{eg}	32.9^{J}
6	69.6^{eg}	75.0^{be}	76.0^{bd}	71.0^{ac}	72.9^{EG}	34.8^{e}	45.0^{fh}	47.9^{ce}	36.1^{cf}	40.9^{EG}
7	70.0^{dg}	75.0^{be}	78.0^{bc}	71.0^{ac}	73.5^{DF}	37.9^{ce}	47.9^{df}	47.9^{ce}	41.1^{ab}	43.7^{CD}
8	66.1^{g}	70.9^{ef}	74.0^{cd}	69.3^{bd}	70.1^{HI}	37.9^{ce}	42.9^{gj}	51.1^{bc}	40.0^{ac}	43.0^{DE}
9	71.1^{df}	72.9^{cf}	76.1^{bd}	72.0^{ac}	73.0^{EG}	36.1^{d}	40.6^{ıj}	46.1^{df}	36.1^{cf}	39.7^{GH}
Presto	70.9^{bd}	72.0^{df}	74.0^{cd}	70.1^{ac}	71.8^{FH}	35.0^{e}	41.1^{hj}	40.8^{gh}	32.9^{fh}	37.4^{I}
11	74.1^{bc}	74.9^{be}	76.0^{bd}	72.0^{ac}	74.2^{CE}	38.9^{be}	43.9^{fı}	42.1^{fh}	37.9^{be}	40.7^{FG}
12	75.9^{be}	77.1^{bc}	78.0^{bc}	72.2^{ac}	75.8^{BC}	40.0^{bd}	51.1^{bd}	42.1^{fh}	38.9^{bd}	43.0^{DE}
13	73.8^{bf}	76.1^{bd}	77.9^{bc}	71.0^{ac}	74.7^{CE}	46.1^{a}	57.9^{a}	42.9^{fh}	41.1^{ab}	47.0^{B}
14	73.0^{dg}	74.9^{be}	76.1^{bd}	71.0^{ac}	73.8^{CF}	46.1^{a}	55.0^{ab}	46.1^{df}	41.1^{ab}	47.0^{B}
Tacettinbey	70.1^{bf}	73.0^{cf}	74.1^{cd}	67.0^{d}	71.1^{GH}	41.1^{bc}	47.9^{df}	48.9^{be}	35.0^{dg}	43.2^{D}
16	73.1^{cf}	75.9^{bd}	77.0^{bd}	72.1^{ac}	74.5^{CE}	41.1^{bc}	47.9^{df}	45.8^{df}	38.9^{bd}	43.4^{CD}
17	72.0^{cf}	75.9^{bd}	76.0^{bd}	67.0^{d}	72.7^{EG}	42.9^{ab}	46.1^{eg}	50.0^{bd}	33.9^{eg}	43.2^{D}
18	72.0^{df}	75.0^{be}	76.0^{bd}	69.0^{cd}	73.0^{EG}	38.9^{be}	46.1^{eg}	49.2^{be}	35.0^{dg}	42.3^{DF}
19	71.2^{df}	76.0^{bd}	76.0^{bd}	70.0^{ac}	73.3^{DF}	37.9^{ce}	46.1^{eg}	47.9^{ce}	31.1^{gh}	40.7^{FG}
Nurkent	77.0^{b}	78.8^{b}	79.0^{bd}	74.9^{a}	77.4^{B}	35.0^{e}	42.9^{gj}	40.0^{h}	32.9^{fh}	37.7^{HI}
21	72.8^{bf}	75.0^{be}	76.0^{bd}	72.9^{ac}	74.2^{CE}	40.3^{bd}	52.9^{bd}	60.0^{a}	43.9^{a}	49.3^{A}
22	73.0^{bf}	75.1^{be}	76.1^{bd}	72.0^{ac}	74.0^{CE}	38.9^{be}	43.7^{fı}	48.9^{be}	36.1^{cf}	41.9^{DF}
23	71.0^{df}	74.0^{cf}	76.1^{bd}	69.1^{cd}	72.5^{EG}	40.0^{bd}	46.9^{dg}	48.9^{be}	36.1^{cf}	43.0^{DE}
24	71.9^{cf}	74.0^{cf}	76.9^{bd}	68.7^{cd}	72.9^{EG}	35.0^{e}	43.9^{fı}	45.0^{eg}	32.9^{fh}	39.2^{GI}
Saricanak 98	83.1^{a}	84.0^{a}	84.9^{a}	74.9^{a}	81.7^{A}	42.9^{ab}	51.1^{bd}	47.9^{ce}	28.9^{gh}	42.7^{DF}
Average	72.0^{C}	74.8^{B}	76.1^{A}	70.8^{D}		38.6^{B}	46.8^{A}	46.5^{A}	36.9^{C}	
CV(%)	2.24	2.14	2.18	2.61	**2.29**	4.36	3.43	3.84	4.29	**3.95**

*Means shown with the same letter in the same column are not significantly different at 0.05 probability level using Tukey's HSD (Honest Significant Difference) test.

Interpretation of the biplot analysis and its graphic representation: The total variation of grain yield for the GEI was 77.50%, with PC1 and PC2 accounting for 52.81% and 24.69%, respectively (Figs. 3A and 3B). This indicated that there was a great variation among the environments in terms of grain yield. In the GGE biplot analysis, the correlation coefficient between any two or more environments is approximated by the cosine of the angle between their vectors. Narrow angles (<90°) indicate a positive correlation, wide angles (> 90°) indicate a negative correlation, and right angles (90°) indicate no correlation (Yan and Kang, 2003). As shown in Figs. 3A and 3B, the length and angle of the vectors revealed the presence of three distinct groups of test locations within the environment. The first group consisted of the Kızıltepe location, the second group included the Mardin and Diyarbakir locations, and the third group consisted of the Hani environment (Fig. 3A). A positive correlation was observed between the first and second groups, as indicated by narrow angles (< 90°), whereas a negative correlation was observed with respect to the third group, as indicated by relatively wide angles (>90°) (Fig. 3B). Mizrak (1996) described the division of Southeastern Anatolia into its three distinct agroecological sub-regions. The results obtained from this study show that each of the experimental groups represented a different sub-region. The cultivars examined here were positioned relatively near to the various environments on the biplot, indicating that these environments discriminate similarly and that it may be possible to reduce the number of genotype testing environments and thereby economize during the performance of GGE. As mentioned above, the biplot showed that Line 7 is an ideal cultivar and is stable for all four test locations. Furthermore, the biplot indicated that Line 3, Line 7, Line 13, and Line 16 were suitable for Diyarbakır and Mardin, whereas Line 12, Line 14, Line 17 were favorable for Kızıltepe, and Line 4 for the Hani location. The biplot revealed that the best overall genotypes were Line 7, Line 13, and Line 16, which were stable in all environments, unlike the remaining genotypes, which adapted to specific environments (Figs. 3A and 3B).

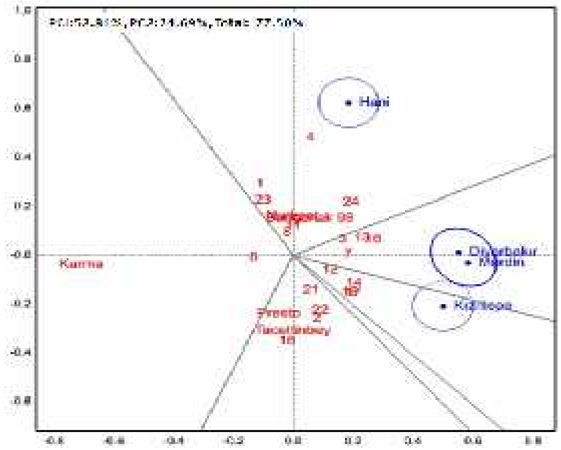

Figure 3A.GGE biplot model showing mega-environments based on grain yield

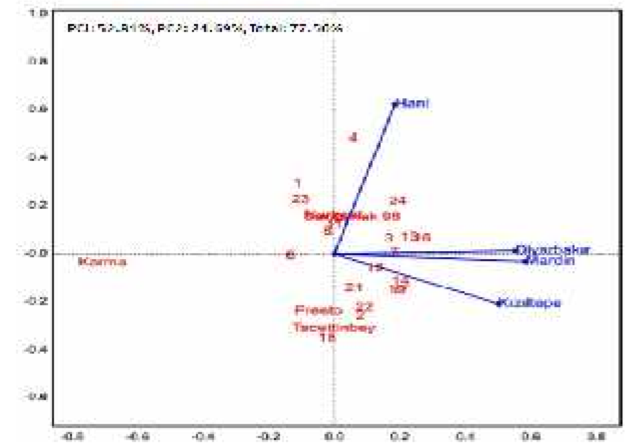

Figure 3B. GGE biplot model showing relationships among test environments and genotypes based on grain yield

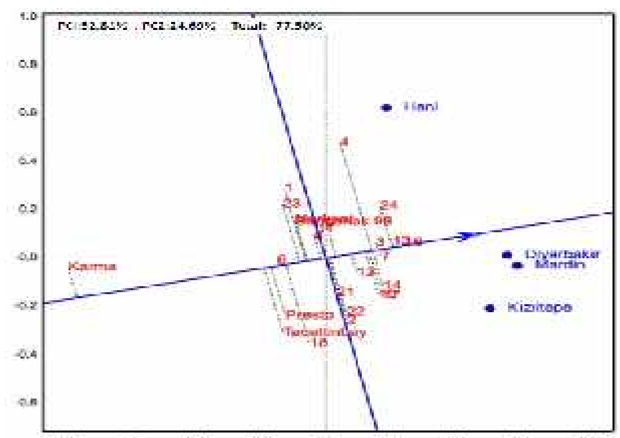

Figure 3C. GGE biplot model showing the stability of genotypes based on grain yield in four environments

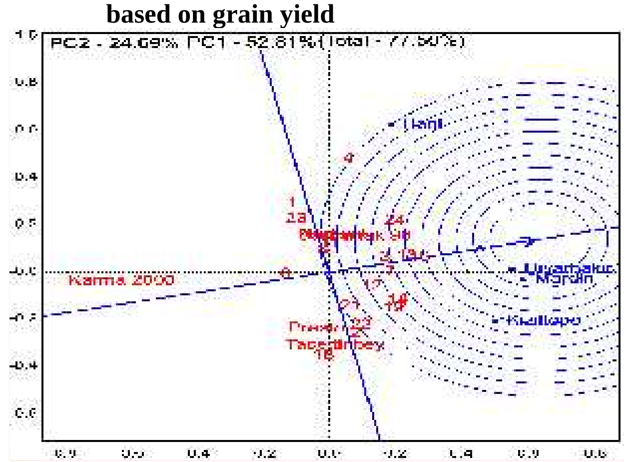

Figure 3D. GGE biplot model discriminating ability and representativeness of environments for grain yield

GGE biplot model discriminating ability and representativeness of environments for grain yield showed in Fig. 3D. As this GGE biplot model, the varieties (standard) used in research and Line 1, Line 6, Line 18 and Line 23 took place below average, while other lines were found over the average (Fig.3D). Similarly; the following researchers reported similar results by using biplot analyses in their studies (Abay and Bjornstad, 2009; Karimizadeh *et al*., 2013; Jalata, 2011).

The results of the evaluation of the test locations (genotype traits, their classification, and change in traits according to location) are shown in Fig. 4A. The scatter, ranking, and comparison biplot explained 95.00% of the total variation (63.26% and 32.13% from PC1 and PC2, respectively) (Figs. 4A, 4B, 4C and 4D). Genotype traits separated into three groups based on location (Fig. 4A). In biplot analysis, the positioning of a given trait or trait in proximity to that of a specific test location indicates that this trait is suitable or favorable with respect to that location. In Fig.4A, PC (protein content), HW (hectoliter weight), and TGW (thousand-grain weight) fell into the same group and were associated with the Mardin location. GY (rain yield) and PH (plant height) were in the same group and were associated with the Kızıltepe location. Heading date formed a third group positioned between the Hani and Diyarbakir locations on the biplot. The vector length between these traits and the distance between traits and locations are shown in Fig. 4B.This revealed a close relationship between protein content, thousand-grain weight, and hectoliters produced, as well as between grain yield and plant height. On the other hand, it was occurred poor relation between heading time and other traits. When these traits were used to generate a ranking biplot (Fig.4C), the Kızıltepe location was shown to be the most appropriate and Mardin was show desirable environment in overall, whereas the Diyarbakır and Hani locations ranked below average. Similarly, GGE biplot model discriminating ability and representativeness of environments for traits showed in

Fig. 4D. In this figure; the environment which located near of the center circle(ideal environment), is ideal and the environment which located near of the ideal environment, it is mean desirable. The environments which located below of mean line, this mean undesirable environment. As this figure, the results obtained using the comparison method (Fig.4D) showed that Kızıltepe was positioned very near to the ideal environment coordinate. The genotype's grain yield traits, thousand-grain weight, and hectoliter weight were all positioned very close to the ideal environment coordinate, and the level of significance was high. However, the Diyarbakir and Hani locations associated with heading time were positioned well below the average environment coordinate, and so the level of significance was found to be very low. These results confirm with those of a number of previous studies using biplot analyses (Farshadfar, 1999; Dehghani, 2006; Abay and Bjornstad, 2009; Jalata, 2011; Karimizadeh *et al.*, 2013).

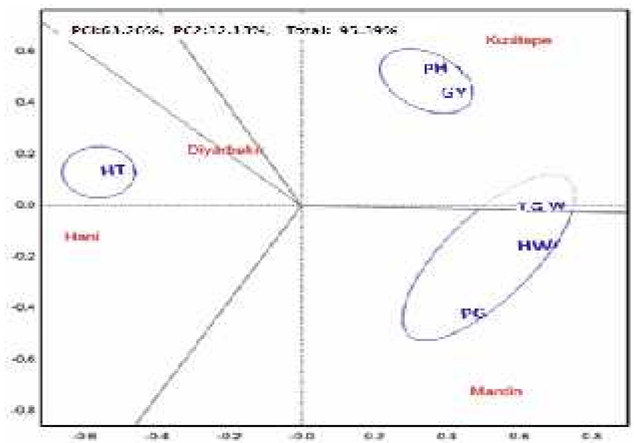

Figure 4A.GGE biplot model showing group of traits in four environments

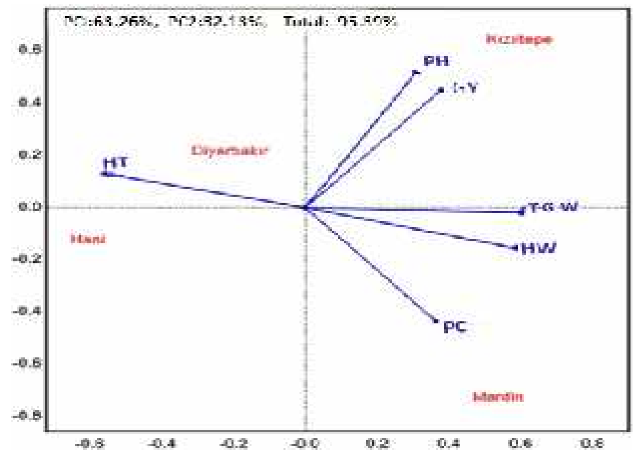

Figure 4B.GGE model showing relationships among test environments and traits

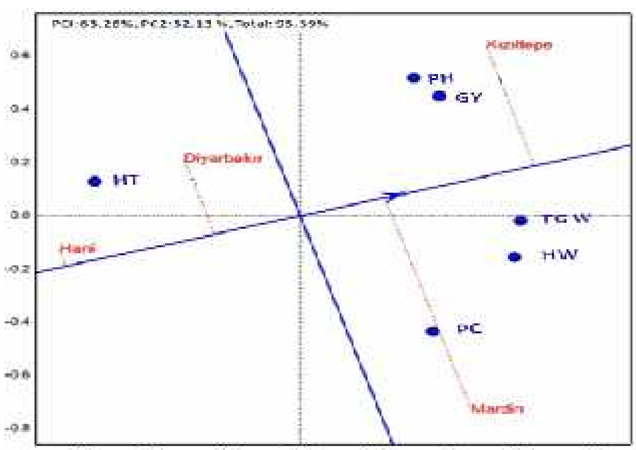

Figure 4C. GGE model showing the stability of environments by traits

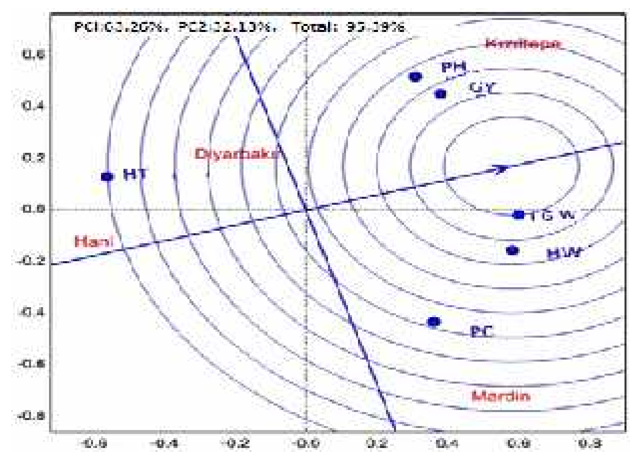

Figure 4D.GGE biplot model discriminating ability and representativeness of traits by environment

Traits observed according to genotype and the change in genotypes according to traits are shown inFig.5A . The scatter, ranking, and comparison biplot explained 71.25% of the total variation (40.63% and 30.61% from PC1 and PC2, respectively) (Figs. 5A, 5B, 5C and 5D). The traits separated into three groups based on the genotype (Fig. 5C); additionally, the distribution of genotypes revealed differences. According to the results for each genotype, grain yield and thousand-grain weight fell into the first group, test weight and protein content into the second group, and plant height and heading time into the third group. These groupings were distinct. The Preston and Karma 2000 triticale varieties were positioned between plant height and heading time, whereas the wheat cultivars were positioned near to protein content and hectoliter weight. Genotypes 3, 13, and 16 were positioned near to heading time and thousand-grain weight; genotype 4 and the Tacettinbey variety were positioned near to plant height, and genotype 22 settled in the center of the biplot graph, indicating that this genotype is equally successful for all parameters. The relationship between genotype and crop traits shown using vectors in the scatter biplot methods pictured in Fig. 5B.This analysis revealed a close relationship between protein content and heading time and between thousand-grain weight and grain yield, whereas there was a much more distant relationship between test weight and plant height.

The relationship between genotype and crop traits analyzed according to the ranking method is shown in Fig. 5A. The wheat varieties used as the control and genotypes 3, 7, 12, 13, 16, and 21 showed high performance on average, whereas the remaining genotypes and triticale varieties showed low performance. Additionally, GGE biplot model discriminating ability and representativeness of genotypes for traits showed in Fig. 5D.In this figure; the genotypes which located near of the center circle (ideal places), is ideal and the genotypes which located near of the ideal genotype, this mean that this genotype is desirable. The environments which located below of mean tick line, this mean that this genotype is undesirable. Therefore, the result showed that Sarıçanak 98 (durum wheat) was located the ideal environment, So this genotype is ideal for all traits and genotype 13 and 12 are nearest the ideal genotype. So these two genotypes can selected as desirable genotype, while Karma variety and genotype 4 were located below the average and far from to ideal genotype and so they are undesirable. . On the other hand; the HW trait was located in center ideal circle, So this is good to select the genotypes (Fig. 5D).

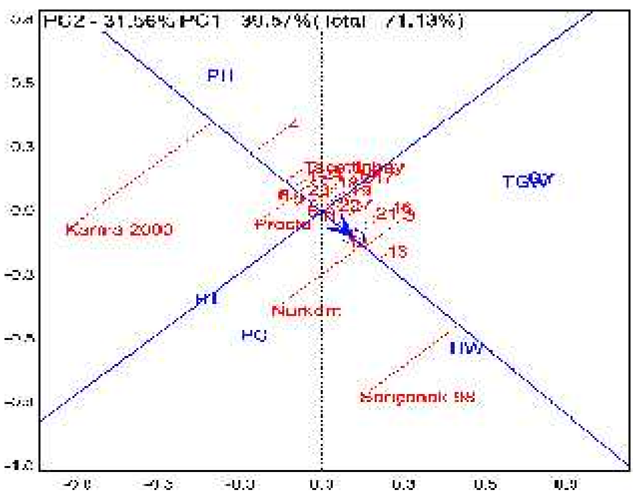

Figure 5A. GGE model showing the stability of genotypes by traits

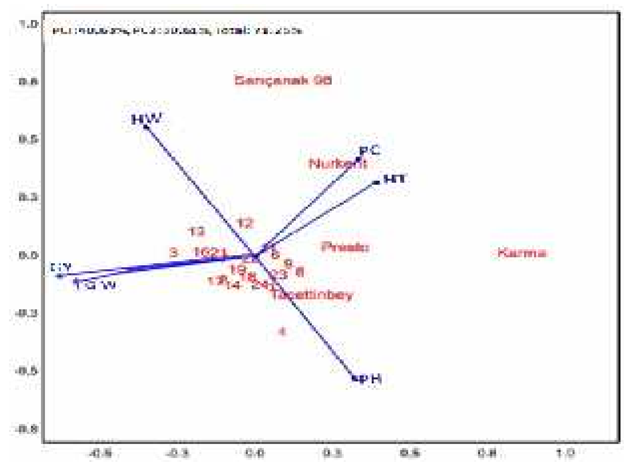

Figure 5B. GGE model showing relationships among genotypes and traits

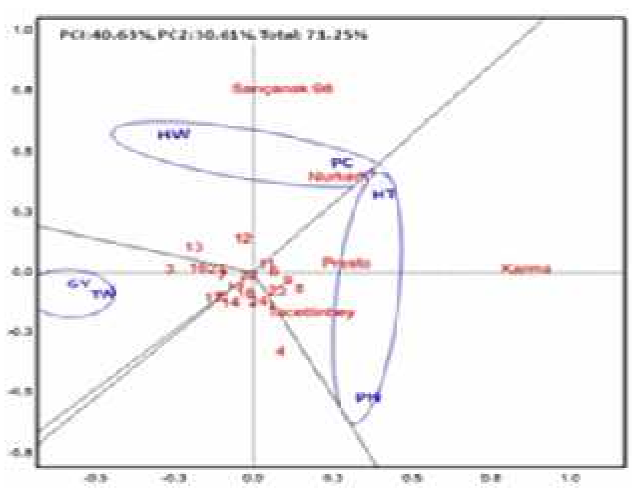

Figure 5C. GGE biplot model showing group of traits by genotypes

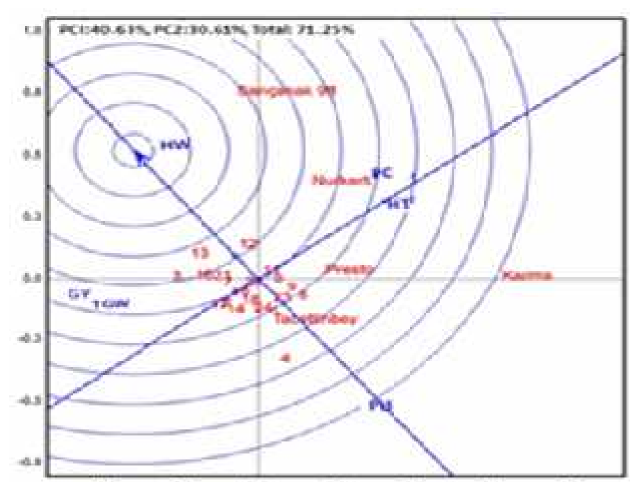

Figure 5D.GGE biplot model discriminating ability and representativeness of traits by genotypes.

Conclusion: GGE biplot analysis showed that Southeastern Anatolia, where this research was conducted, is broadly divided into three agro ecological zones in terms of Triticale breeding. Diyarbakır is the most appropriate location in terms of high yield stability, Kızıltepe for high grain yield, and Mardin for optimal crop traits. Different crop traits predominated in each location, but these locations generally formed three different groups in which crop quality parameters *vs.* plant height and grain yield *vs.* heading time were predominant, respectively. When genotypes were analyzed with respect to crop traits, three different groups were identified; these included grain yield and thousand-grain weight (first group), protein content and hectoliter weight (second group), and heading time and plant height (third group).Triticale lines 3, 7, 12, 13, 16, and 21 as well as the commonly grown wheat varieties showed better adaptation, whereas the remaining genotypes were below average. Finally, it was concluded that triticale genotypes can compete with common wheat varieties in Southeastern Anatolia and that GGE biplot analysis provided useful results and high image quality.

Acknowledgements: General Directorate of Agricultural Research and Policy (TAGEM), Turkish Ministry of Food, Agriculture and Livestock supported this study financially.

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