ASSESSMENT OF THE IMPACT OF ECOLOGICAL FACTORS ON YIELD AND QUALITY PARAMETERS IN TRITICALE USING GGE BIPLOT AND AMMI ANALYSIS

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Abstract

We examined the effects of late spring frost on grain yield (GY) and quality of spring triticale ($\times$ *Triticosecale)* genotypes, based on genotype plus genotype $\times$ environment interaction (GGE) biplot analysis. The study included a total of 25 genotypes, including 20 advanced lines, 3 triticale varieties, and 2 candidate lines. The genotypes were evaluated for GY and quality traits during the 2012/2013 (normal season) and 2013/2014 (late spring frost) seasons. We observed significant differences between seasons for GY and quality traits, as affected by changing environmental conditions over the two seasons. Late spring frost caused a statistically significant 50% reduction in GY, 7.1% reduction in test weight (TW), and 26.1% reduction in thousand grain weight (TGW); however, it positively affected protein content (PC), and it increased by 42.6%. We observed that early heading genotypes were differently affected by late spring frost, compared to late maturing genotypes, in terms of GY, TW, and TGW. The GGE biplot analysis highlighted three and four distinct groups of traits in the 2012/2013 and 2013/2014 growing seasons, respectively. Results from the GGE biplot analysis revealed that G12 and G16 were stable and ideal genotypes for all of the traits in the 2012/2013 season, and G10 and G23 were stable and ideal for the 2013/2014 season. In addition, G10 was the best genotype averaged over the two growing seasons. The genotypes G9, G13, and G17 were more stable and higher yielding, based on Additive Main Effect and Multiplicative Interaction (AMMI) analysis, compared to the remaining genotypes.

Key words: Genotype $\times$ environnent interactions, Test weight, Protein content, AMMI analysis.

Introduction

The impact of ecological factors is increasing at an alarming rate and important percentage of the cereal areas needs to overcome for this negative impact. Triticale ($\times$ *Triticosecale* Wittmack) is a relatively new cereal crop obtained via the hybridization of summer and winter wheat with rye genotypes (Villegas *et al*., 2010; Geren *et al*., 2012). Grain and forage of the crop are of great importance in feeding of livestock in Turkey. Exclusively, because of great quality roughage deficiency, its forage has great importance in the country (Sakarya *et al*., 2008; Sayar *et al*., 2014). For this reason, triticale is a important crop with respect to providing high-quality roughage (Bilgili *et al.,* 2009), and it has been cultivated either pure or mixed with annual legumes for fresh forage and dry forage producing (Karadag & Buyukburc, 2004) and silage making (Demirel *et al*., 2013).

A considerable problem in several areas of world is post head-emergence spring radioactive frost damage of winter cereals. The problem happens in regions that main growing season restrict to the late winter and spring by drought and heat of summer that daytime temperatures are ideal for growth, but night temperatures can down to destructive levels. Farmers usually in order to minimize frost risk, delay tillage to stalling head emergence but this practice confront crops to increasing temperatures and dwindling water supplies late in the season, decreasing yield potentials as heading is delayed (Frederiks *et al*., 2011; Asadi *et al*., 2013) .

Low temperature effects may be harmful to triticale at all stages of crop development. However, the effects increase with increasing growth of the crop. Nonetheless, the hazard of damaging frosts occurring reduces as spring progresses (Whaley *et al*., 2004). Each plant needs special temperature requirements that are optimum for its suitable growth and development which this set of temperature conditions may be stressful for another plant. When plants those are native to warm habitat exposed to low non-freezing temperatures, display symptoms of injury, that are appear from 48 to 72 h after stress induced. This time is different from plant to plant and also depends upon the sensitivity of a plant to cold stress (Mahajan & Tuteja, 2005).

Cold stress may cause various seedling injuries, late heading and reduction in yield due to spikelet sterility (Andaya & Mackill, 2003), and chilling stress also reduced leaf expansion, wilting, chlorosis (yellowing of leaves) and may lead to necrosis (death of tissue) and strongly disturbed the reproductive development of plants (Mahajan & Tuteja, 2005). Low temperature stress induce significant changes in biochemistry and physiology of plants (Berova *et al*., 2002). In generally; many physiological processes and photosynthesis are sensitive to cold stress that is low temperature is a main reason for decreases in plant growth and plant productivity (Liang *et al*., 2007).

Cold damage, temperature stress and drought are the primary factors limiting cereal production in Southeastern Anatolia. Therefore, determining genotypes resisted to cold and drought is important for the region as high grain yield and quality traits. Crop breeders have been endeavored to develop genotypes with superior grain yield, quality and other desirable characteristics over a wide range of

different environmental conditions. Genotype by environment interaction (GE) 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, Sayar *et al*., 2013).

The study aimed (1) to apply a GGE biplot model to evaluate the magnitude of the effect of GE interaction on grain yield and quality in 25 triticale genotypes (including 20 promising line, two candidate and 3 varieties) tested in two seasons (one normal, second affected from cold and drought damage), and (2) evaluate the relationships among genotypes and traits to identify appropriate triticale genotypes for registration 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 & Karma) and two candidate line (G15 and G10). Yield and crop quality characteristics for these genotypes were assessed at two growing seasons (2012/13-2013/14), representing of Southeastern Anatolia. The names, orjins and pedigrees of the genotypes used as material in the study is indicated in the Table 1.

The experiments were conducted in a randomized block design with four replications. The seeding rates were 450 seeds m^{-2}. 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. Although we couldn't observed any ecological stress in 2012/13, the cold damage and drought were observed in 2013/14 growing season. During the second growing season (2013/14), cold damage occurred in plant stem elongation stage (30 March 2014). Then, drought occurred in April and May (Fig. 1). Exclusively, grain yields and quality of winter sowing crops greatly depend on falling rainfall amount in these two months,

especially in April, for rainfed conditions of Southeastern Anatolia region and Turkey.

Statistical analyses (GGE): The data obtained from the study related the investigated traits were analyzed respectively for each location and combined by using the JMP 5.0.1 statistical software package (Anon., 2002), and the differences between means were compared using a least significant difference (LSD) test at the 0.05 probability level (Steel & Torrie, 1980).

GGE biplot analyses were carried out using GGE biplot software to assess crop characteristics in two growing seasons (Yan & Hunt, 2001; Yan & Kang, 2003). GGE biplot analysis also allows comparison amongst seasons 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 & Kang 2003; Yan & Thinker, 2006). In a multi-environment trial (MET) for triticale, biplots were constructed by plotting the first two principal components (PC1 and PC2) derived from subjecting environment-centered yield, and quality criteria data (yield variation due to GGE) to singular value separation (Yan *et al*., 2000).

With the AMMI biplot analysis graph in the study: It was aimed at illustrating grain yield performance and stability status of triticale genotypes and growing seasons (Fig. 2). Also, with the GGE biplot analysis graphs in the study: It was aimed at revealing relation among examined traits for two growing seasons means (Fig. 3A), for 2012/13 growing season (Fig. 3B), and 2013/14 growing season (Fig. 3C), separately. Additionally, the GGE biplot analysis graphs were used for showing relation between genotypes and examined traits over two growing seasons means (Fig. 4A), for 2012/13 growing season (Fig. 4B) and 2013/14 growing season separately (Fig. 4C). Moreover, GGE biplot analysis graphs in Fig. 5A-C were used respectively to demonstrate ranking of genotypes on means of traits in two years, for 2012/13 and 2013/14 growing seasons. Similarly, GGE biplot analysis graphs in Fig. 6A-C were used respectively to demonstrate comparison of genotypes on means of traits in two years, for 2012/13 and 2013/14 growing seasons.
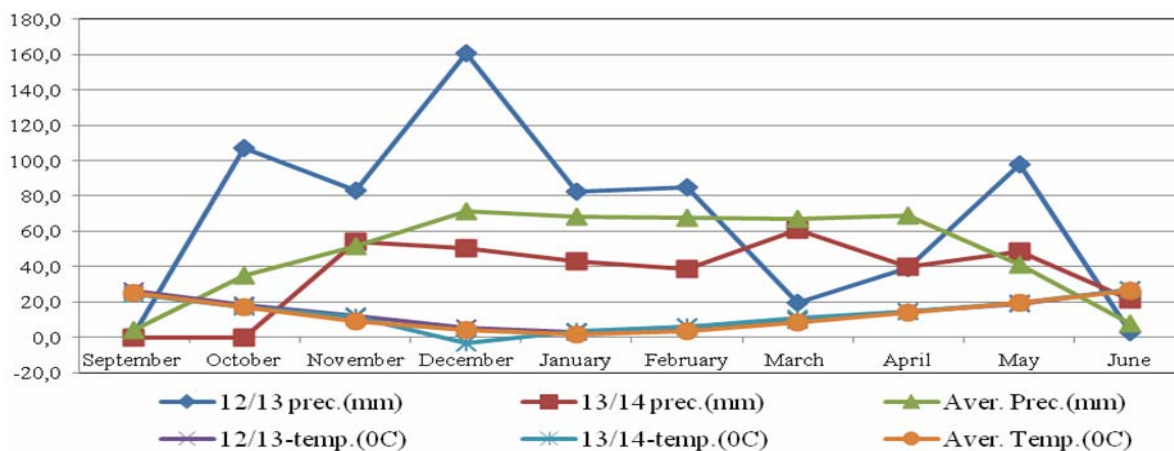

Fig. 1. The values of meteorological data.

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

No.	The name of variety or pedigree of genotypes	Orjin
1.	HUI-UB//CENT.TURKEY/3/…CTSS02B00107T-21Y-2M-3Y-1M-2Y-0M-0SD-0SD	CIMMYT
2.	CMH82.1082/ZEBRA31/7/LI…CTSS02B00268T-53Y-5M-1Y-2M-2Y-0M-0SD-0SD	CIMMYT
3.	LIRON_2/5/DIS B5/3/SPHD/….CTSS02B00413S-22Y-2M-3Y-1M-1Y-0M-0SD-0SD	CIMMYT
4.	HX87-244/HX87-255/5/PRE…CTSS03SH00028S-25Y-2M-3Y-4M-2Y-0M-0SD-0SD	CIMMYT
5.	(CONTROL) DAHBI_6/3/ARDI_1/_..CTSS99Y00115S-1Y-0M-0Y-8B-2Y-0B- 0SD	CANDİDATE
6.	HX87-244/HX87-255/7/LIR…CTSS03SH00030S-13Y-1M-3Y-3M-1Y-0M-0SD-0SD	CIMMYT
7.	BULL_10/MANATI_1//FARAS…CTSS04Y00002S-104Y-06M-06Y-2M-4Y-0M-0SD	CIMMYT
8.	LIRON_2/5/DIS B5/3/SPH…CTSS04Y00163S-102Y-06M-06Y-2M-3Y-0M-0SD-0SD	CIMMYT
9.	PRESTO//2*TESMO_X…CTSS03Y00091T-050TOPY-5M-2Y-06Y-5M-1Y-0M-0SD--SD	CIMMYT
10.	(CONTROL)LIRON_2/5/DIS B5/3/SPHD/P…..CTSS01Y00040S-1M-5Y-3Y-3M-0Y	CANDİDATE
11.	LIRON_2/5/DIS B5/3/SPHD/P...CTSS03Y00033T-A-62M-1Y-06Y-2M-4Y-0M-0SD-0SD	CIMMYT
12.	LIRON_2/5/DISB5/3/SPHD/PVN..CTSS03Y00036T-A-1M-2Y-06Y-5M-3Y-0M-0SD-0SD	CIMMYT
13.	TURACO/CENT.SARDEV/7/LIR…CTSS02B00186T-8Y-3M-3Y-4M-1Y-0M-0SD-0SD	CIMMYT
14.	DRIRA/2*CMH77A.1165/8/NIMIR…CTSS02B0028T-6Y-3M-3Y-4M-2Y-0M-0SD-0SD	CIMMYT
15.	TACETTİNBEY (CONTROL)	CU
16.	LIRON_2/5/DISB5/3/SPHD/PVN/..CTSS02B00413S-22Y-2M-3Y-1M-2Y-0M-0SD-0SD	CIMMYT
17.	HX87-244/HX87-255/5/PRES…CTSS03SH00028S-25Y-2M-4Y-3M-1Y-0M-0SD-0SD	CIMMYT
18.	HX87-244/HX87-255/7/LIRON_… CTSS03SH00030S-17Y-3M-4Y-3M-1Y-0M-0SD-0SD	CIMMYT
19.	LIRON_2/5/DISB5/3/SPHD/…CTSS04Y00163S-102Y-06M-06Y-5M-1Y-0M-0SD-0SD	CIMMYT
20.	KARMA (CONTROL)	AARI
21.	LIRON_2/5/DISB5/3/SPHD/…CTSS04Y00163S-102Y-06M-06Y-5M-2Y-0M-0SD-0SD	CIMMYT
22.	LIRON_2/5/DISB5/3/SPHD…CTSS03Y00090T-050TOPY-4M-1Y-06Y-1Y-0M-0SD-0SD	CIMMYT
23.	LIRON_2/5/DISB5/3/SPHD//…CTSS03Y00036T-A-1M-2Y-06Y-2M-4Y-0M-0SD-0SD	CIMMYT
24.	LIRON_2/5/DISB5/3/SPHD/P…CTSS03Y00036T-A-1M-4Y-06Y-4M-1Y-0M-0SD-0SD	CIMMYT
25.	PRESTO (CONTROL)	AARI

CIMMYT: International Maize and Wheat Improvement Center ,**CU**: Cukurova Univ., **AARI:** The Anatolia Agricultural Res. Institute
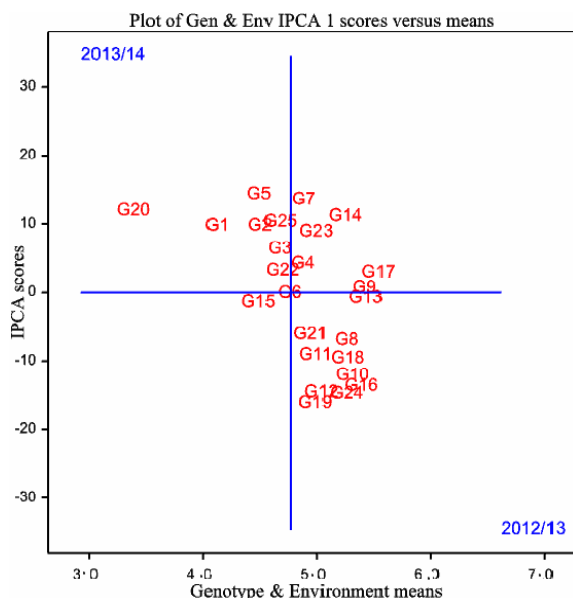

Fig. 2. AMMI analysis of grain yield of 25 genotypes in years (t ha^{-1}).

Results

The combined ANOVA revealed highly significant differences among the growing seasons and genotypes for all traits (p<0.01), as shown in Table 2. Moreover, Genotypes × Season's Interaction (GSI) were found to be highly significant (p<0.01) for GY and TGW, while for PC was found significant (p<0.05), it was not significant for TW. This indicated that the growing seasons, had significantly differences ecological characteristics from each other for the investigating traits. Similarly, found significant interactions among the tested genotypes indicated that the genotypes had difference genotypic structures in terms of examined traits. On the other hand, found statistically significant GSI for GY, TGW and PC traits indicated that effect of different ecological conditions of the two growing seasons led to different rankings of the genotypes for these four traits (Tables 2 and 3). Generally, breeders interested in the genotypes with high genotypic main effect (average over location years) and with low fluctuation in yield or other traits of interest (stable).
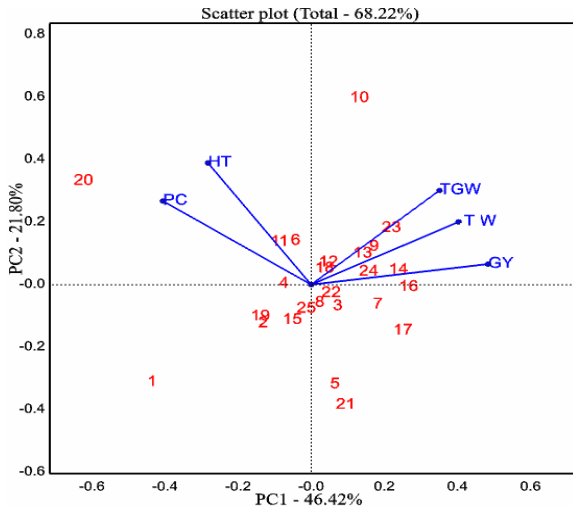
Fig. 3A. Relation among traits over mean of growing seasons.
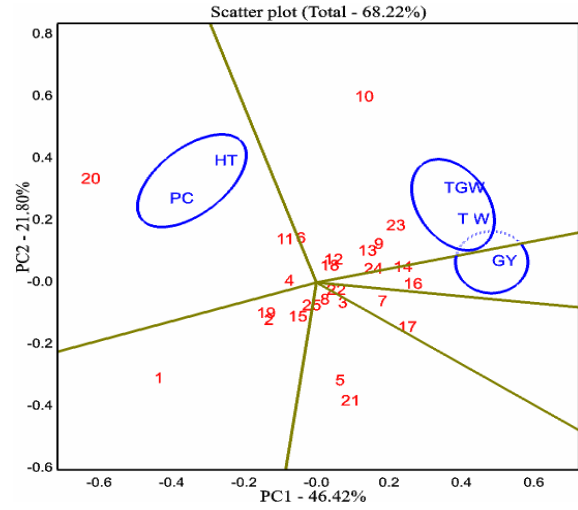

Fig. 4A. Relation between genotype and traits and grouping of traits over two growing seasons.
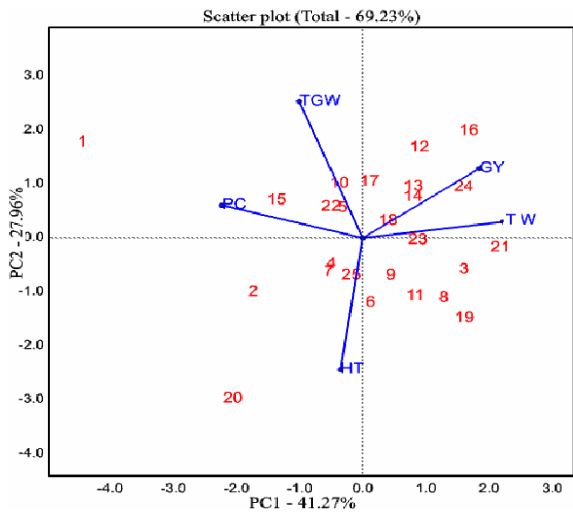

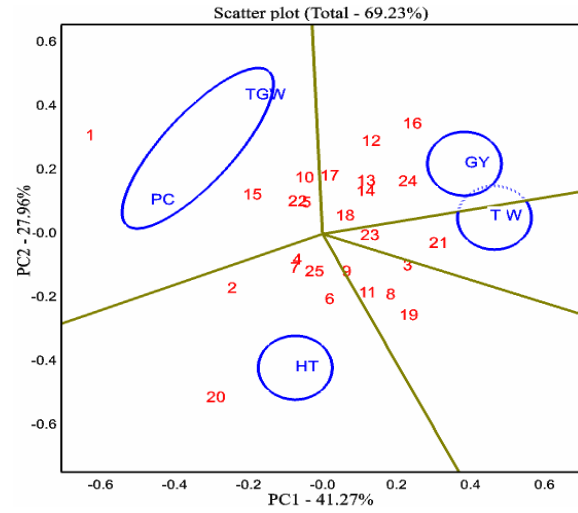Fig. 3B. The relation among traits in 2012/13.

Fig. 4B. Relation of genotype-traits and grouping of traits in 2012/13.
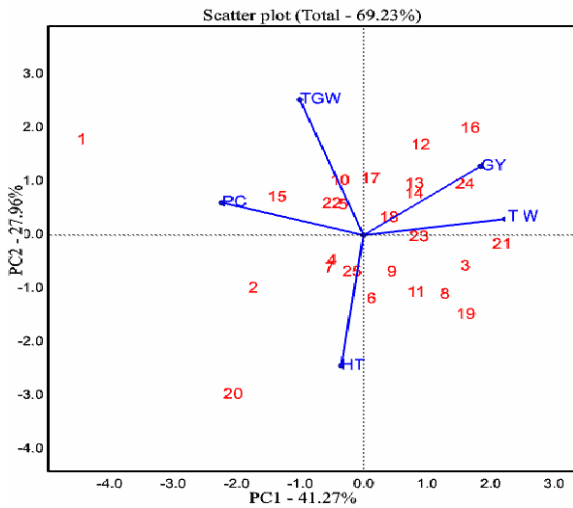

Fig. 3C. The relation among traits in 2013/14.
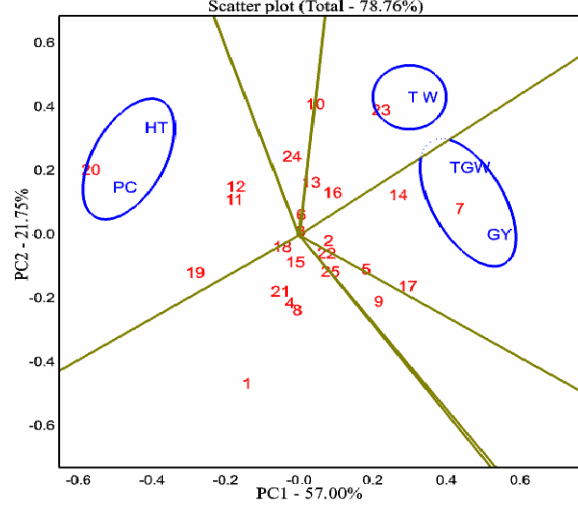

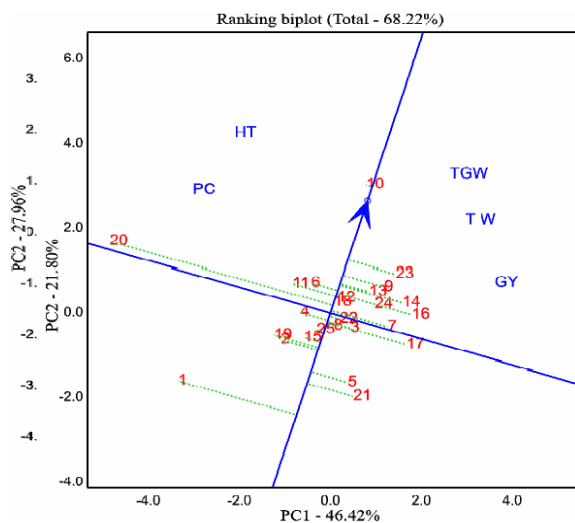Fig. 4C. Relation of genotype-traits and grouping of traits in 2013/14.

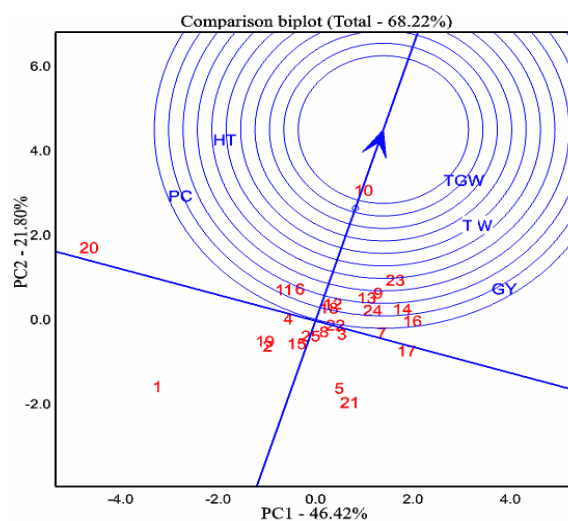Fig. 5A. Ranking of genotypes on means of traits in two years.

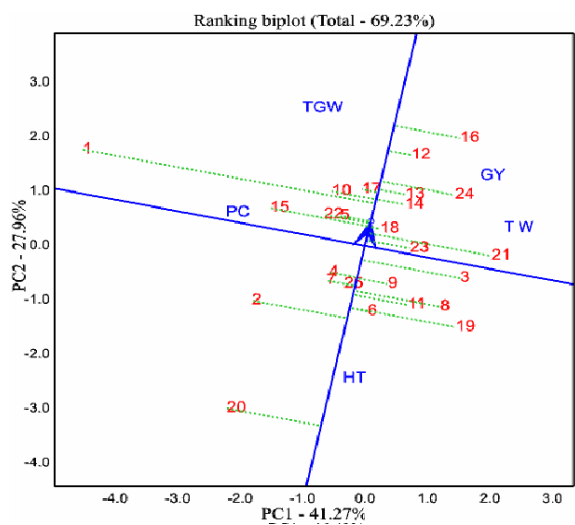Fig. 6A. Comparison of genotypes on means of traits in two years.

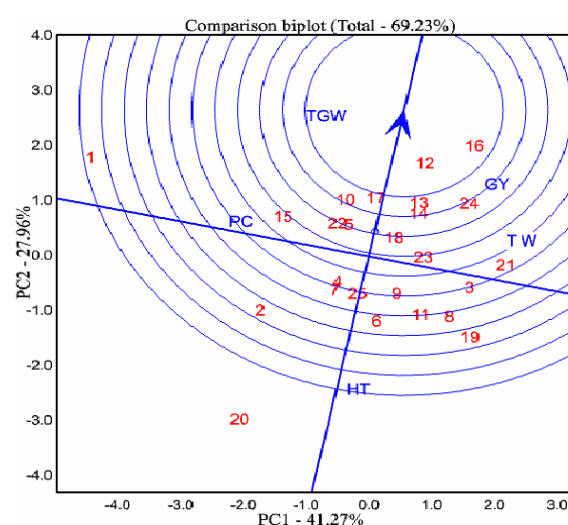Fig. 5B. Ranking of genotypes on means of traits in 2012/13.

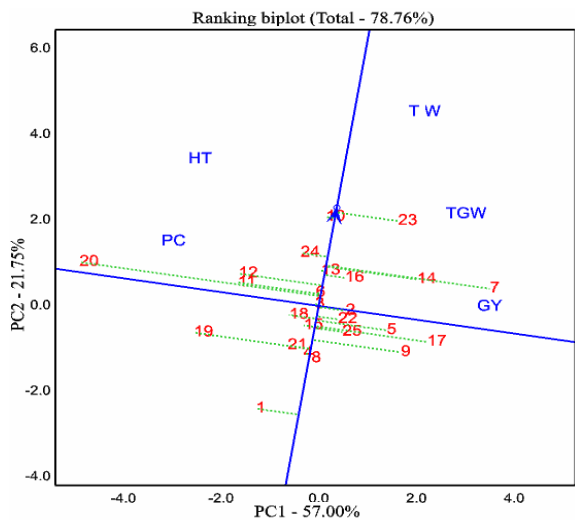Fig. 6B. Comparison of genotypes on means of traits in 2012/13.

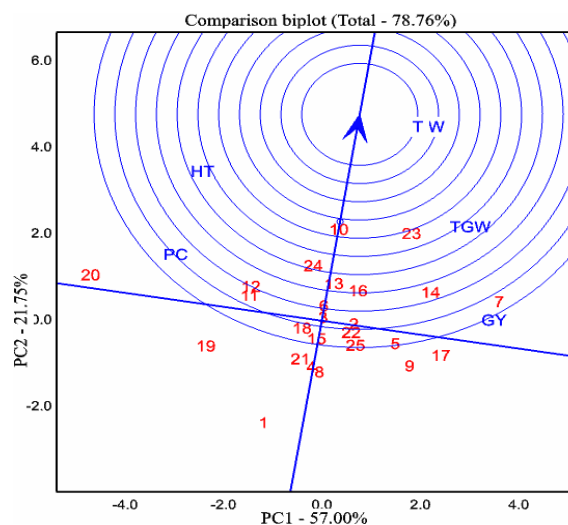Fig. 5C. Ranking of genotypes on means of traits in 2013/14.

Fig. 6C. Comparison of genotypes on means of traits in 2013/14.

Table 2. Analysis of variance for investigated traits.

Source of variation	d.f.	Mean squares			Protein content
		Grain yield	Test weight	T.G.W	
Year	1	238420.3[**]	785.9[**]	2573.3[**]	2573.3[**]
Rep(E)	4	120197.1	0.5	2.3	2.3
Genotype	24	323406.0[**]	11.0[**]	28.2[**]	28.2[**]
G × Y	24	172200.3[**]	2.0[ns]	8.9[**]	8.9[*]
Error	96	141339.5	1.3	3.7	3.7
Total	**149**	**5867594**			

**: Value significant at 0.01 probability level, *: Value significant at 0.05 probability level, ns: Not significant

Table 3. The AMMI-estimates, ranked, mean and IPCA of genotypes in seasons(t h^{-1}).

Number	2012/13(Year 1)		2013/14(Year 2)		G (mean)	IPCA (G)
	AMMI- estimates	Ranked	AMMI-estimates	Ranked		
1.	G16	7.56	G17	3.64	4.02	966.3
2.	G24	7.47	G14	3.64	4.39	967.1
3.	G10	7.43	G9	3.49	4.56	630.9
4.	G18	7.30	G13	3.40	4.77	414.2
5.	G8	7.24	G7	3.40	4.38	1.428.6
6.	G12	7.24	G23	3.30	4.65	-0.2
7.	G19	7.24	G4	3.07	4.78	1.349.2
8.	G13	7.15	G8	3.06	5.15	-703.0
9.	G17	7.14	G25	3.04	5.31	0.6
10.	G9	7.13	G5	3.03	5.16	-1.215.1
11.	G11	7.00	G18	2.94	4.84	-919.7
12.	G21	6.85	G3	2.94	4.89	-1.463.9
13.	G14	6.56	G16	2.92	5.28	-0.9
14.	G6	6.50	G10	2.89	5.10	1.107.6
15.	G4	6.47	G2	2.88	4.33	-150.9
16.	G23	6.38	G22	2.81	5.24	-1.371.6
17.	G22	6.28	G6	2.80	5.39	284.1
18.	G15	6.23	G24	2.75	5.12	-967.9
19.	G3	6.19	G21	2.73	4.83	-1.618.8
20.	G7	6.15	G11	2.68	3.24	1.187.0
21.	G25	6.02	G12	2.53	4.79	-618.8
22.	G2	5.90	G1	2.50	4.55	313.8
23.	G5	5.73	G15	2.43	4.84	881.3
24.	G1	5.53	G19	2.43	5.11	-1.483.1
25.	G20	4.67	G20	1.80	4.53	1.025.7

Table 4. The PCA scores of seasons for grain yield trait and first four genotypes for each growing season.

Seasons	Season mean	Variance	Score	1	2	3	4
2012/13	6.61	786240	34.61	G17	G14	G9	G13
2013/14	2.92	244884	-34.61	G16	G24	G10	G18

The results of the data reviewed: The yield of genotypes in 2012/13 growing season (normal season) ranged from 4.66 t ha^{-1} (Karma cultivar) to 7.67 t ha^{-1} (G16). And the average of grain yield was found as 6.61 t ha^{-1} in this season (Tables 4 and 5). However, as a result of adverse climatic conditions (cold damage and drought) the grain yield of genotypes decreased in significantly amounts. Accordingly, grain yield of genotypes changed from 1.80 t ha^{-1} (Karma cultivar) to 3.64 t ha^{-1} (G17) in 2013/14 growing season, and the average of yield of in this growing season was recorded as 2.92 t ha^{-1}.(Tables 4 and 5). The two years data showed that Karma variety is poorer and G17 is highly yielding among genotypes for both season and average, while G16 is only high yielding in 2013/14 (optimal condition) (Table 5). On the other hand, G9, G13 and G17 were stable and high yielding among genotypes in average for two seasons in terms of grain yield (Table 3, Fig. 2). The means of triticale genotypes for heading time trait were presented in Table 5. Accordingly, the duration ranged from 105 days (G16) to 115 days (G20-Karma variety) among the genotypes according to the two growing seasons average. The heading time of genotypes ranged from 101 (G16) to 115 days (in Karma variety) in 2012/13, although, it was ranged from 107 days to 115 days in 2013/14 growing season (Table 5). The study results revealed that cold damage delayed the heading time in triticale genotypes, and early heading genotypes were more adversely affected from cold damage than those of late heading ones. Karma cultivar, late heading, was severely affected from drought due to its short duration between heading time and seed maturity time.

Test weight of genotypes averaged over the two growing seasons ranged from 71.7 g in G1, to 79.0 g in G14; the overall mean was 75.8 g in Table 5. Test weight of genotypes in normal season, 2012/13, ranged from 73.7 g (G1) to 81.3 g (G16), and the growing year average of TW was found as 78.6 g. In contrast, TW values of genotypes changed from 68.6 g (G1) to 77.1 g (G23) in 2013/14 growing season, seen cold and drought damage. The average TW value of the triticale genotypes in 2013/14 growing season was recorded as 73.0 g. The results of TW demonstrated that G1 is poorer, having the lowest TW value, among genotypes for both seasons and average, while G16 is only high in 2013/14 (optimal condition), On the other hand, TW values of G14 and G23 lines were found higher than the other genotypes not only for 2012/13 and 2013/14 growing seasons but also for the average of two seasons (Table 5, Fig. 3A). Hence, G14 and G23 promising lines were found as stable genotypes for TW trait.

Thousand grain weight (TGW) of genotypes averaged over two seasons ranged from 28.0 g for G19 to 40.2 g for G10 (candidate line). The overall average TGW was 33.8 g (Table 5). During the 2012/2013 season, which was considered a normal season, TGW ranged from 32.5 g (G1) to 47.5 g (G10), with an overall average of 39.0 g. During the 2013/2014 season, which experienced damage due to cold temperatures and drought, the TGW ranged from 22.2 g.

GGE biplot analysis: Analysis of variance indicated that genotype (G), environment (E), and the genotype × environment interaction (GEI) showed significant (p<0.01) differences among triticale genotypes and total sum of squares explained 5.8% of the year effect, 91.2% of the G effect, and 3.1% of the GEI effects (Table 2). GGE biplot analysis of the means over years for genotypic relationships among traits (Fig. 3A), the relationship between genotype-traits and trait groups (Fig. 4A), ranking of genotypes on traits means (Fig. 5A), and comparison of trait means of genotypes (Fig. 6A) accounted for 68.22% (46.42% and 21.80%, for principal components [PCs] 1 and 2, respectively) of the total variation. The biplot analysis of 2012/2013 data for genotypic relationships among traits (Fig. 3B), the relationship between genotype-traits and trait groupings (Fig. 4B), ranking of genotypes on trait means (Fig. 5B), and comparison of trait means of genotypes (Fig. 6B) accounted for 69.23% (41.27% and 27.96% for PC1 and PC2, respectively) of the total variation. The biplot analysis of 2013/2014 data for genotypic relationships among traits (Fig. 3C), the relationship between genotype-traits and trait groups (Fig. 4C), ranking of genotypes on trait means (Fig. 5C), and comparison of trait means of genotypes (Fig. 6C) accounted for 78.76% (52.00% and 21.75% PC1 and PC2, respectively) of the total variation.

Table 5. The means of the genotypes in four environments for traits.

Genotypes	Heading time(date)			Yield(t ha^{-1})			Test Weight(g)			TGW(g)			Protein content(%)		
	12/13	13/14	Mean	12/13	13/14	Mean	12/13	13/14	Mean	12/13	13/14	Mean	12/13	13/14	Mean
1	105	107	106	5.53	2.50	4.01	73.7	68.6	71.2	32.5	26.9	29.7	14.9	18.8	16.8
2	104	108	106	5.90	2.88	4.39	75.6	72.7	74.1	35.8	31.3	33.5	14.1	18.3	16.2
3	105	109	107	6.19	2.94	4.56	81.2	73.1	77.1	38.4	28.7	33.5	12.0	18.6	15.3
4	108	108	108	6.47	3.07	4.77	77.1	70.3	73.7	40.5	29.4	34.9	12.8	19.1	16.0
5(Candidate)	103	107	105	5.73	3.03	4.38	78.8	73.8	76.3	35.9	28.7	32.3	12.6	17.2	14.9
6	110	109	110	6.50	2.80	4.65	79.1	73.3	76.2	38.1	30.0	34.1	13.1	18.7	15.9
7	108	107	108	6.15	3.40	4.78	77.7	74.7	76.2	36.6	35.6	36.1	12.9	16.3	14.6
8	111	107	109	7.24	3.06	5.15	78.9	72.2	75.6	37.6	25.4	31.5	12.1	18.7	15.4
9	111	108	110	7.13	3.49	5.31	79.5	71.7	75.6	43.4	29.6	36.5	13.2	16.9	15.1
10(Candidate)	110	111	111	7.43	2.89	5.16	79.8	75.2	77.5	47.5	32.9	40.2	14.2	19.2	16.7
11	111	112	112	7.00	2.68	4.84	78.6	72.5	75.5	37.1	27.0	32.1	12.4	19.1	15.7
12	102	111	107	7.24	2.53	4.89	79.7	72.7	76.2	41.1	28.9	35.0	12.8	19.8	16.3
13	105	112	109	7.15	3.40	5.28	79.2	72.8	76.0	40.9	29.6	35.2	12.6	18.5	15.5
14	105	107	106	6.56	3.64	5.10	81.3	76.4	79.0	38.0	28.4	34.3	13.0	18.1	15.6
15Tacettinbey	104	109	107	6.23	2.43	4.33	76.6	72.2	74.4	40.4	29.2	34.8	13.6	17.8	15.7
16	101	109	105	7.56	2.92	5.24	81.3	74.3	77.8	40.6	30.5	35.5	12.9	18.3	15.6
17	105	107	106	7.14	3.64	5.39	77.5	73.0	75.3	41.6	29.4	35.5	12.7	17.0	14.8
18	108	110	109	7.30	2.94	5.12	77.4	71.6	74.5	40.8	28.8	34.8	12.4	18.8	15.6
19	110	111	111	7.24	2.43	4.83	78.9	71.7	75.3	33.9	22.2	28.0	12.1	19.1	15.6
20Karma	115	115	115	4.67	1.80	3.24	77.4	71.4	74.4	35.9	24.2	30.0	13.6	20.8	17.2
21	103	109	106	6.85	2.73	4.79	79.6	72.4	76.0	35.4	24.5	29.9	11.4	17.8	14.6
22	106	108	107	6.28	2.81	4.55	77.4	72.4	74.9	42.4	30.8	36.6	12.6	18.2	15.4
23	108	110	109	6.38	3.30	4.84	80.6	77.1	78.8	40.5	31.2	35.9	12.4	17.9	15.1
24	104	110	107	7.47	2.75	5.11	80.5	75.6	78.0	38.9	27.7	33.3	12.6	18.9	15.7
25Presto	108	107	108	6.02	3.04	4.53	78.5	73.3	75.9	38.1	27.6	32.9	12.8	18.4	15.6
Average				6.61	2.92		78.6	73.0		39.0	28.7		12.9	18.4	
LSD (0.5)			4.8 ^{ns}	073**	0.51**	0.44**	2.2**	2.5**	1.6**	4.1**	3.8**	2.8**	0.9**	2.3^{ns}	1.1*
CV(%)			2.2	6.7	10.6	8.0	1.4	1.7	1.5	5.1	6.5	5.7	3.3	6.0	5.4

**= Value significant at 001 probability level,*= Value significant at 005 probability level, ns: Not significant

The AMMI model showing GEI means of GY and stability: The Additive Main Effect and Multiplicative Interaction (AMMI) polygon view of the stability of 25 genotypes was based on GY data averaged over years (Tables 3, 4; Fig. 2). The polygon consisted of average and stability axes. In the AMMI model, the x-axis represents the G and year (Y) main effects, and the y-axis represents the GEI effects. The Y and G sources of variation were more variable for both main and interaction effects. According to the AMMI polygon, the majority of the genotypes (particularly G9, G13, and G17) in the 2012/2013 season were high performing, as they are located above the x-axis. The GY was high for these genotypes during the 2012/2013 season. Some genotypes (particularly G1 and G20) in the 2013/2014 season demonstrated low performance, and are under the x-axis. These genotypes in the 2013/2014 season had a relatively low GY. It can be concluded that the 2012/2013 season had high GY potential, whereas the 2013/14 season had low GY potential. The genotypes G9, G13, and G17 had high GY potential and were stable across years, whereas G1, G20, and the 2013/2014 season had low GY potential and were unstable (Table 5).

The relationship between genotypes-traits and grouping of traits: The genotypes-traits vectors and groups illustrate the specific interactions of each genotype with each trait (Figs. 3A, 3B, 3C, 4A, 4B, 4C). The biplot showed three groups that were highly correlated in terms of trait means (Figs. 3A, 4A). Positive correlations were found between GY (Grain yield), TW (Test weight), and TGW (Thousand grain weight) (Group 1), and PC and HT (Heading time) (Group 2), as indicated by the acute angles (vector angles < 90°) of their respective vectors. The biplot of the relationship between genotypes and traits for 2013/2014 (Figs. 3C, 4C) showed three groups as mean of the two years (Figs. 3A, 4A). The biplot of the relationship between genotypes and traits for 2012/2013 (Figs. 3B, 4B) also showed three groups: the GY and TW (Group 1), TGW and PC (Group 2), and HT only (Group 3).

The relationships among genotypes, with regard to traits, were observed. The biplot of trait means (Figs. 3A, 4A) identified three groups of genotypes, consisting of three genotypes (G4, G11, and G20) for two traits (PC and HT), five genotypes (G9, G10, G12, G18, and G23) for two traits (TW and TGW), and one genotype (G16) for one trait (GY). In contrast, the biplot model showed no significant relationship between G1, G2, G5, G19, and G21 and any of the traits, as these five genotypes were not grouped for any of the traits. The biplot of trait means for the 2012/2013 season (Figs. 3B, 4B) showed no significant relationship between genotypes and traits, whereas the biplot of trait means for the 2013/2014 season (Figs. 3C, 4C) showed relationships between G20 and two traits (PC and HT), between G23 and one trait (TW), and between G7 and two traits (TGW and GY). Thus, the biplot showed excellent discriminating ability in selecting specific genotypes with particular traits and in recommending genotypes for their traits.

Ranking and comparison of genotypes–traits: The genotype with both high mean and stability for traits is called an ideal genotype, and should have both high mean performance and high stability for all traits (Figs. 5A, 5B, 5C, 6A, 6B, 6C). The genotypes that are closer to the average environment axis (AEA) and are considered ideal genotypes are more desirable than other genotypes (Yan and Tinker, 2006). The ranking and comparison of genotypes, based on trait means over 2 years (Figs. 5A, 6A), showed that G10 was an ideal genotype. Some genotypes (G1, G9, G13, G16, and G23) performed favorably, as they were above the x-axis. On the other hand, some genotypes (G1, G5, and G21) were not desirable, as they were below the x-axis. The ranking and comparison of genotypes based on trait means in the 2012/2013 season (Figs. 5B, 6B) showed that G12 and G16 were ideal genotypes. Some genotypes (G10, G17, G23, and G24) were favorable, as they were above the x-axis. Other genotypes (G2, G6, G19, and G20) were not desirable, as they were below the x-axis. The ranking and comparison of genotypes based on trait means in the 2013/2014 season (Figs. 5C, 6C) showed that G10 was both stable and more desirable, as it was located at the AEA and was considered an ideal genotype. Some genotypes (G13, G23, and G24) were favorable, as they were above the x-axis. Other genotypes (G1, G8, G17 and G19) were not desirable, as they were below the x-axis.

Discussion

The GGE biplot method has been widely used to analyze the stability and performance of the genotypes for yield and other traits (Goyal *et al.*, 2011). The GGE biplot mainly allows the visualization of any crossover GE interaction, which is very important for the breeding program (Kendal & Sener, 2015; Sayar & Han, 2015). The GGE biplot method provides considerable flexibility, allowing plant breeders to simultaneously select for yield and stability (Sabaghnia *et al.*, 2013). Moreover, GEI and yield stability analyses are important for their consideration of both varietal stability and suitability for cultivation across seasons and ecological circumstances (Adjabi *et al.*, 2014). The GT (genotype-trait) biplot provides an excellent tool for visualizing genotype × trait data (Adjabi *et al.*, 2014). On the other hand, the AMMI method is very effective for studying GEI interaction (Tarakanovas & Ruzgas, 2006), provide the correlative size and significant affects of GEI and its interaction (Asfaw *et al.*, 2009), display large distinction in the addition principal effects for environments and genotypes (Kadi *et al.*, 2010), display more informative in different genotype response over environments, describing specific and non- specific resistance of genotypes, identifying most discriminating environments (Mukherjee *et al.*, 2013).

The AMMI model is the most accurate model, as predictions can be made based on the first two PCs. Genotypes with interactive principal component analysis (IPCA) scores close to zero were the most stable across environments. Actually, these biplots are renamed two types, model of AMMI 1 and model of GGE biplot (Carbonell *et al.*, 2004). According to Mirosavljevic *et al*. (2014), the genotypes that have small IPCA1 values are

more stable. Becker and Leon (1988) indicated that according to the basic static concept of stability, genotypes with minimal variance across different environments are considered stable. However, Becker (1981) indicated that the static concept is not necessarily relevant for plant breeders and agronomists, as they usually prefer genotypes with a high mean GY in favorable environments. Genotypes with a consistently high GY are considered dynamically stable, which is preferred by commercial plant breeders (Flores *et al.,* 1998). In this study, for example, G9, G13, and G17 (Table 5) could be recommended for environments with cold damage and drought, as they were highly responsive and stable across both high- and low-yielding environments with good stability, whereas G10, G16, and G24 were only high-yielding in the favorable environment (Fig. 2).

The GGE biplot could be used to interpret the relationships among genotypes, traits, and groups of traits (Figs. 3, 4). An understanding of the relationship between genotypes and traits can aid in better understanding breeding objectives and in identifying traits that are positively or negatively correlated with genotypes. This understanding can also aid in identifying traits that can be indirectly selected by selecting for correlated traits. It also helps to visualize the strengths and weaknesses of genotypes, which is important for both parental and cultivar selection (Yan & Thinker, 2006).

In the biplot, a vector was drawn from the biplot centered to each marker of the traits to facilitate visualization of the relationships between genotypes and traits, and the angle of vectors among traits. If the angle of the vector was less than 90°, there was a positive correlation between genotypes and traits. If the angle was equal to 90°, they were not correlated. There was a negative correlation if the angle was less than 90° (Yan & Kang, 2003). In this study, there was a positive correlation between TW and GY, and negative correlations among PC, TGW, and GY (Fig. 3). If the heading time for a given genotype was early, GY increased and PC decreased under optimal environmental conditions (Fig. 3B). If the heading time was late, GY decreased and PC increased in a less favorable environment, such as the 2013/2014 season (Fig. 3C).

The GGE biplot also ranks the environments for their ability to discriminate among genotypes. Sectors of the biplot formed COI groups based on the winning genotypes in each group of traits (Fig. 4). In the 2012/2013 season, the traits were grouped in four sectors on the biplot (Fig. 4B). TW was grouped in sector 1, GY in sector 2, TGW and PC in sector 3, and HT in sector 4. In the 2013/2014 season, the traits grouped in three sectors on the biplot (Fig. 4C). GY and TGW were grouped in sector 1, TW was in sector 2, and HT and PC was in sector 3. Therefore, the conditions observed in the 2012/2013 season were superior for ability to discriminate among genotypes for high GY potential, compared to the 2013/2014 season (Fig. 4B). The genotypes G7 (for GY and TGW), G20 (for PC), and G23 (for TW) were superior for specific traits (Fig. 4C).

The GGE biplot was accurate in interpreting the ranking and comparing genotypes and traits (Figs. 5, 6). The genotype with both high mean performance and high stability for all of the traits was called an ideal genotype.

The center of the concentric circles (i.e., ideal genotype) was the AEA in the positive direction. Genotypes located closer to the ideal genotype were more desirable than others (Yan &Tinker, 2006; Farshadfar *et al*., 2013).

In this study, G12 and G16 were ideal genotypes in the 2012/2013 season, as they were in the center circle for the ideal genotype and on the AEA (Figs. 6B, 6C). The biplot did not show an ideal genotype in the 2013/2014 season, but G10 and G23 were closer to the ideal genotype relative to the AEA (Fig. 6C). G10 was the ideal genotype for means over the two seasons, as it was closer to the ideal genotype on the AEA (Fig. 6A).

Agronomic traits are among the most important but least understood traits in crops (Campbell *et al*., 2003). Moreover, very little is known about the agronomic traits in triticale in comparison with other cereal crops (Goyal *et al*., 2011). The recommendation of triticale genotypes for Southeast Anatolia regions requires consideration of both agronomic and quality traits. For example, heading time is very important in terms of grain yield and quality traits. The earlier genotypes sometimes (2013/14) tend to be affected from cold damage, but tend to avoided from drought. The cold damage rarely occurs, but the drought commonly occurs in Southeast Anatolia. Therefore, this study is very important to select the specific genotypes for specific trait, season and environment.

Drought stress and cold damage are main limitations to crop production in the Southeast Anatolia Region. Cold damage affects crops in the spring and earlier crops, whereas drought affects the facultative and winter crops. Therefore, it is very important to know the response of genotypes to drought and cold stress during the early stages of the breeding process. This approach provides an opportunity to select the best genotypes for stressful conditions.

Tester & Langridge (2010), identified drought stress as one of the major limitations to crop production. Low temperatures may damage triticale at all of the stages of crop development. The likelihood of damaging frosts occurring is reduced as spring progresses (Whaley *et al*., 2004). Cold stress may cause various seedling injuries, delay heading, and reduce GY due to spikelet sterility (Andaya & Mackill, 2003).

Chilling stress also reduces leaf expansion, causes wilting and chlorosis (yellowing of leaves), and may lead to necrosis or strongly disturb the reproductive development of plants (Mahajan & Tuteja, 2005). Low temperature stress induces significant changes in biochemistry and physiology of plants (Berova *et al.*, 2002). Typically many physiological processes and photosynthesis are sensitive to cold stress, which explains the decline of growth and productivity in response to low temperature.

Conclusions

The effects of late spring frost on grain yield (GY) and quality of spring triticale (× *Triticosecale)* genotypes were investigated in the study. The results showed that late spring frost was affected negatively on grain yield (GY), test weight (TW), thousand grain weight (TGW) traits, but the effects of late spring frost on protein content (CP) of triticale genotypes were found as positive.

Also, the results of the study revealed that early heading genotypes were more adversely affected from late spring frost, compared to late maturing genotypes. On the other hand; GGE biplot and AMMI analysis revealed that the triticale genotypes for stable grain yield and other quality traits, as well as their interaction with environments and general adaptation, constitutes a starting point towards identifying candidate lines for the Southeast Anatolia Region in Turkey. The results indicated that G9, G13, and G17 can be recommended for stress conditions, whereas G10, G16, and G24 are best for normal conditions. On the other hand, G10 can also be recommended as an ideal genotype across all traits. The GGE biplot analysis provided useful results and high image quality to study stress conditions and define both specific and general recommendations for breeders.

Acknowledgement

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