UDC 575.633.11
https://doi.org/10.2298/GENSR2001081A
Original scientific paper

EVALUATION OF YIELD AND AGRONOMIC TRAITS OF NEW WINTER BREAD WHEAT CULTIVARS

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Aktas B. (2020). Evaluation of yield and agronomic traits of new winter bread wheat cultivars.- Genetika, Vol 52, No.1, 81-96.
Yield and quality attributes of 13 bread wheat cultivars registered for Thrace region in 2018 and 5 standard bread wheat cultivars were determined and compared in this study. Tested cultivars are originated from Turkey, Bulgaria, Romania, Croatia, Austria and Ukraine. Experiments were conducted in 2015-2016 and 2016-2017 growing seasons. Since the locations were not equally distributed to growing seasons, statistical analyses for yield and other parameters were performed through assuming each location as an environment. Therefore, assessments were made over 7 environments. Environment (E) explained 54.9% of the total variation (E+G+GEI), genotype (G) and genotype × environment interaction (GEI) generated 25.6% and 19.5%, respectively. GGE (Genotype + Genotype by environment interaction) biplot analysis was able to explain 78.51% of variation in grain yield. Trial environments gathered under 3 mega-environments. Of the cultivars registered in 2018, Adali, Bc Anica, Topkapi, FDL Miranda, Otilia, ZT Ziyade, Viktoria and Dragana had values larger than the average and thus they had the largest PC1 (Principal component 1) scores. Tested cultivars were also assessed based on vector lengths to average environment coordinate (AEC). Adali cultivar with a high PC1 score and the closest position to AEC apsis was found to be quite prominent for grain yield. In environment-focused assessments, E3, E4 and E5 had the closest position to ideal environment circle. With regard to physical quality attributes, Pehlivan, Bojana and Adali cultivars had high performance values. The cultivar Bojana, Topkapi and Iveta had protein contents above 15%. For Zeleny sedimentation values, Krasunia odes'ka had the best performance.
Keywords: wheat, genotype, environment, variability, stability, grain yield, quality traits.

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INTRODUCTION

Wheat is the primary cereal crop cultivated over the agricultural fields of Turkey. Wheat cultivation is practiced over 7.7 million hectares (ASR, 2017). Together with such a large size production, number of registered varieties is also increasing year by year. Since 1963, 349 bread wheat cultivars have been registered and 268 of them are in current national lists (TNCCAPS, 2018) With the enaction of plant breeders' rights law in 2004, a significant increase was observed in registration applications. The aim of this law is to encourage the development of plant varieties and to protect the rights of new varieties and breeders. Wheat breeding programs of State Research Institutes have long been continued, but private seed companies mostly preferred to register foreign registered cultivars in Turkey instead of conducting their own breeding programs.

Assessment of multi-environment yield trials is not only a significant issue for breeders, but also plays a significant role in value for cultivation and use (VCU) trials. Multi-environment trials are mostly used to test newly developed genotypes or to test foreign varieties to be registered among the registered cultivars list of Turkey (TPVCU, 2009). Test durations, number of locations and the other criteria are all specified in legal legislation of the countries. In Turkey, candidate genotypes should be tested for at least two growing seasons and three different locations. Before the official trials, applicant should test candidate genotype for yield, quality and diseases for at least one growing season in two locations or for at least two growing seasons in one location.

According to variety registration legislation of Turkey, bread wheat varieties can be tested in 7 different ecological regions. Initially the applicant determines the region with the best performance of the candidate variety and then applies registration for that region. Thrace region is located in continent Europe and it has the ecological regions of Turkey with the closest characteristics to Europe. The region has a transitional climate between Asia and Europe. In Thrace region, a state research institute, universities and private sector companies are running wheat breeding programs. Turkish seed companies generally obtain production rights of varieties registered in Balkan or European countries and apply for registration in Turkey.

Genotype × environment interaction (GEI) is commonly encountered in multi-environment yield trials. Multi-environment trials are conducted to assess genotype performance based on GEI as well as genotypes (YAN and TINKER, 2006). Analysis of variance reveals source of variation in data set. On the other hand, GGE (G, genotype + GEI, genotype by environment interaction) biplot is an efficient way of visual assessment of G and GEI, phenotypic performance of genotypes in different environments and genotype separation power of the environments (YAN, 2014). Assessment of the environments in which the genotypes were tested is a significant issue for the researchers (YAN and HOLLAND, 2010). In bread wheat, biplot analysis was used for grain yield (MEHARI *et al.*, 2015; KARAMAN, 2020), quality traits (SAHIN *et al.*, 2011) and disease studies (AKCURA *et al*., 2017).

In several countries, it is required that the genotypes passed through breeding programs and ready for registration phase should be subjected to performance trials in multi-environments together with standard or control cultivars by an independent authority. In present study, the cultivars approved by the registration committee in 2018 were tested for yield and quality attributes in comparison with the standard cultivars. The candidate genotypes determined in distinctness, uniformity and stability (DUS) tests, which consisted of more than one genotype or contained too many off-types plants, were not included in the statistical analysis.

In stability studies, phenotypic performances of the experimented genotypes are used to define the environments. The candidate genotypes without genetic purity (bearing the adaptation capabilities of different genotypes) hinder accurate assessment of the environments. GGE-biplot method was used by AKCURA *et al.* (2011) for bread wheat genotypes of Central Anatolia of Turkey and by MOHAMMADI *et al.* (2016) under Iranian conditions to determine stabilities of the cultivars and lines. GGE-biplot method was also used for the other plant species (GOYAL *et al.*, 2011; YARI *et al.*, 2017).

Recent more remarkable impacts of climate change have made multi-environment trails more prominent in assessment of genotype performance. This study was conducted to assess grain yield and some agronomic traits of bread wheat genotypes newly registered for Thrace Region with GGE biplot analysis performed with the use of experimental results from 7 different environments.

MATERIALS AND METHODS

Experiments were conducted with 18 bread wheat genotypes at Edirne, Kesan, Luluburgaz and Tekirdag locations in 2015-2016 and 2016-2017 growing seasons. Information on tested cultivars and trial locations are provided in Table 1. In 2016-2017 growing season, Tekirdag location was omitted. Since the locations were not equally distributed to growing seasons, statistical analyses for yield and other parameters were performed through assuming each location as an environment. Therefore, assessments were made over 7 environments. Experiments were conducted in randomized blocks design with 4 replications. Of 18 bread wheat cultivars investigated in this study, 13 cultivars (Bojana, Dragana, ZT Ziyade, Iveta, Topkapi, Damla, FDL Miranda, Otilia, Adali, Asiya, Viktoria, Maja, Bc Anica) were registered in April 2018 and included in national list (TNCCAPS, 2018). The other 5 cultivars (Gelibolu, Kate A-1, Selimiye, Pehlivan, Krasunia odes'ka) have commonly grown in Thrace region and registered in previous years. All of the new and standard cultivars have red grain colour.

Sowing was performed with 6-row plot sowing machine as to have 500 seeds per m^2 over 9 m long rows spaced 17.0 cm apart. Sowings were done between the last week of October and the second week of November. Together with sowing, 200 kg ha^{-1} composed fertilizer (20-20-0) was applied, then 150 kg ha^{-1} urea (46%) was applied in February and 180 kg ha^{-1} ammonium nitrate (26%) fertilizer was applied in April. Harvest was performed between the last week of June and the first week of July with a plot combine harvester.

Thousand-kernel weight and hectolitre weight (test weight) were used as physical quality parameters; protein content and Zeleny sedimentation values were used as the chemical quality criteria. Thousand-kernel weight results were calculated on dry matter and hectolitre weight results were calculated according to 10% moisture. Protein content was determined in accordance with AACCI (2010) and Zeleny sedimentation value was determined in accordance with ICCI (2011).

Table 1. Code, origin, date of registration in Turkey of cultivars; code, growing season, location, geographic coordinate, altitude of test environments

Code	Cultivar	Origin of cultivar	Date of registration in Turkey	Code	Growing season	Location	Coordinate Longitude (E)	Coordinate Latitude (N)	Altitude (m)
G1	Gelibolu	Turkey	2005	E1	2015-2016	Kesan	26°37'	40°54'	94
G2	Kate A-1	Bulgaria	1988	E2	2016-2017	Kesan			
G3	Selimiye	Turkey	2009	E3	2015-2016	Edirne	26°35'	41°38'	41
G4	Pehlivan	Turkey	1998	E4	2016-2017	Edirne			
G5	Krasunia odes'ka	Ukraine	2008	E5	2015-2016	Tekirdag	27°28'	40°58'	22
G6	Bojana	Bulgaria	2018	E6	2015-2016	Luleburgaz	27°18'	41°22'	70
G7	Dragana	Bulgaria	2018	E7	2016-2017	Luleburgaz			
G8	ZT Ziyade	Turkey	2018						
G9	Iveta	Bulgaria	2018						
G10	Topkapi	Austria	2018						
G11	Damla	Turkey	2018						
G12	FDL Miranda	Romania	2018						
G13	Otilia	Romania	2018						
G14	Adali	Turkey	2018						
G15	Asiya	Turkey	2018						
G16	Viktoria	Croatia	2018						
G17	Maja	Croatia	2018						
G18	Bc Anica	Croatia	2018						

Monthly average precipitation and temperatures of trial environments are provided in Table 2. The second growing season had less precipitation than the first growing season. Such a difference was mostly resulted from the winter months (January and February) of the first growing season. The first growing season had also larger average temperatures especially in autumn and winter months. The second growing season had lower temperatures than the long-term averages especially in initial development and dormant seasons of the plants. Especially in recent years, climate data of different years deviate much from the long-term averages even in the same location. Such a case supports the use of years and locations as different environments.

Table 2. Monthly average precipitation of the trial environments and long-term averages

	Precipitation (mm)										
	Edirne			Tekirdag		Kesan			Luleburgaz		
Month	A	B	C	A	C	A	B	C	A	B	C
September	29.5	9.2	37.2	34.9	33.6	63.0	11.4	34.0	35.0	13.2	34.2
October	52.6	44.4	57.7	83.7	62.4	97.2	8.3	58.0	80.4	53.3	54.4
November	26.2	44.6	68.1	48.5	75.4	26.2	90.2	84.0	31.9	45.6	66.1
December	0.3	3.2	70.0	0.6	81.5	3.0	6.9	102.0	0	7.0	70.6
January	114.8	67.8	66.7	70.7	68.8	85.0	116.4	81.0	97.2	48.0	61.9
February	89.2	43.4	52.0	68.4	54.1	77.0	62.0	72.0	91.4	60.3	51.0
March	54.8	51.0	51.6	30.6	54.4	23.6	35.8	69.0	20.9	43.6	46.6
April	116.1	65.6	47.2	22.9	40.9	28.8	54.2	51.0	46.0	75.5	45.6
May	81.4	85.0	53.3	28.4	36.7	45.4	57.0	40.0	50.6	43.8	49.4
June	10.2	44.4	46.5	35.0	37.9	40.4	35.4	36.0	26.2	27.8	47.4
Total	575.1	458.6	550.3	423.7	545.7	489.6	477.6	627.0	479.6	418.1	527.2

Table 2cont. Monthly average temperatures of the trial environments and long-term averages

	Average temperature (°C)										
	Edirne			Tekirdag		Kesan			Luleburgaz		
Month	A	B	C	A	C	A	B	C	A	B	C
September	24.0	20.8	19.9	22.7	20.0	24.8	21.6	19.6	22.1	20.3	19.3
October	15.6	14.3	14.2	16.5	15.4	14.1	15.8	14.4	14.7	14.1	13.9
November	13.5	9.3	9.1	13.8	11.0	22.8	10.5	9.9	12.7	9.5	9.1
December	5.5	0.7	4.6	7.3	7.1	4.8	2.8	6.0	5.5	1.2	5.0
January	2.8	-1.9	2.7	5.6	4.7	3.7	-0.3	3.7	3.5	-0.4	2.9
February	9.8	5.3	4.5	9.6	5.4	8.5	7.7	5.1	9.2	5.5	4.2
March	10.2	10.2	7.6	10.4	7.3	9.7	10.9	7.5	9.4	9.5	7.0
April	15.5	12.5	12.9	11.4	11.8	16.5	13.2	12.3	15.1	12.1	12.1
May	17.4	17.9	18.1	17.9	16.8	18.1	18.8	16.9	17.0	17.6	17.3
June	23.9	21.2	22.4	23.6	21.3	22.9	22.5	21.1	23.3	23.1	21.6
Means	13.8	11.0	11.6	13.9	12.1	14.6	12.4	11.7	13.3	11.3	11.2

A: 2015-2016 growing season. B: 2016-2017 growing season. C: Long-term average

Variance analysis (ANOVA) was applied to the obtained data according to the randomized block trial design. Experimental data for the investigated parameters were subjected to variance analysis. Genotype × environment interactions were analyzed with the aid of GGE-biplot method of software GenStat (GENSTAT, 2009). The data on grain yield, plant height, number of days to heading, thousand-kernel weight, test weight, protein content and Zeleny sedimentation values were also subjected to variance analysis and cultivars were grouped with the aid of Least Significant Difference test.

RESULTS AND DISCUSSION

Grain yield

According to combined variance analysis over the environments, E, G and GEI were found to be significant ($p \leq 0.01$) (Table 3). For E, G and GEI-induced sum of squares, 54.9% was resulted from E, 25.6% from G and 19.5% from GEI. The most important source of variation is the environment in normal multi-environment trials (KENDAL, 2016). KAYA *et al.* (2006) have determined the environmental variation as 81% in the multi-environment trials conducted under the rainfed conditions of the Central Anatolia region. Thrace region has a more homogenous structure in terms of climate and soil characteristics compared to other regions. Therefore, the environmental variation may be lower. In addition, the Thrace region has a high value in terms of precipitation and therefore the main effect of G and GEI is more prominent. Mean grain yield performance of the genotypes in different environments are provided in Table 4. Each of the test environments for least significant difference (LSD) test were placed into different statistical groups. E4 environment had the largest grain yield (8485 kg ha^{-1}) and E3 environment had the lowest grain yield (5685 kg ha^{-1}).

Table 3. Variance analysis results for grain yield of 18 bread wheat cultivars in 7 environments

Source of variation	Degrees of freedom (DF)	Sum of squares (SS)	Mean square (MS)	F	SS (%)[1]
Replication	3	1262979	420993	1.10	
Environment	6	343970500	57328417**	150.01	54.9
Genotype	17	160701347	9453020**	24.73	25.6
Genotype × Environment	102	122074260	1196807**	3.13	19.5
Error	375	143314988	382173		
Corrected total	503	771324073			
CV (%): 8.71					

[1]Proportional distribution (Total sum of squares of E, G and GEI); **Significant at p ≤ 0.01

Table 4. Mean grain yields of 18 bread wheat cultivars in experimental environments (kg ha^{-1})

Genotypes	Environments							Mean
	E1	E2	E3	E4	E5	E6	E7	
G1	6960	7323	5579	8296	6281	7735	8404	7225 d-g
G2	5300	8395	4582	8944	5776	6246	8762	6858 hij
G3	4933	6318	4432	7612	5972	6262	7933	6209 k
G4	5452	6927	4177	7651	5840	6617	7276	6277 k
G5	6339	6912	6270	8609	6556	7229	7215	7019 f-i
G6	5718	6388	4255	7758	5994	6383	7257	6251 k
G7	6773	7552	6276	8521	6129	7228	7314	7113 e-h
G8	7414	7467	5579	8408	7512	7743	7258	7340 def
G9	7068	6812	5876	8030	6096	7463	7618	6995 g-j
G10	8294	7603	6513	8021	7595	8928	7472	7775 bc
G11	6812	6633	5597	7940	5552	6799	7494	6690 j
G12	7995	7089	6596	9220	6467	7878	7583	7547 cd
G13	7210	7663	6724	8852	6271	7477	7661	7408 de
G14	8153	7797	7189	9537	7915	8502	8843	8277 a
G15	6838	6658	5573	8410	5726	7139	7407	6821 hij
G16	6947	6779	5547	8651	6528	7629	7823	7129 e-h
G17	6390	6507	4231	9106	6871	6887	7454	6778 ij
G18	8800	7561	7333	9170	7679	8031	7808	8054 ab
Mean	6855 E	7133 D	5685 G	8486 A	6487 F	7343 C	7699 B	7098

LSD for environment: 202.6; LSD for genotypes : 324.9 (for alpha 0.05); Values with the same letter are not significantly different

With the GGE-biplot analysis for grain yields of the bread wheat cultivars in different trial environments, 78.51% of the variations was explained (Figure 1). Of 78.51% variation, 58.48% was explained by PC1 and 20.03% was explained by PC2. Positive PC1 scores of all environments indicated non-cross GEI. While E1, E3, E5 and E6 environments had positive PC2 scores, E2, E4 and E7 environments had negative PC2 scores. Vector lengths of the environments to biplot origin and angles between them were different from each other. The environments E1 and E7 had the largest angle between them. On the other hand, of the environments with positive PC2 scores, E1 and E6, E3 and E5 had the smallest angle between them. Of the environments with negative PC2 scores, E2 and E4 had acute angle between them. GGE-biplot analyses gathered 7 environments under 3 mega-environments (Figure 2). E1 and E6 were placed in the first mega-environment; E3, E5, E4 and E2 were placed in the second mega-environment; E7 alone was placed in the third mega-environment. A hexagonal polygon was generated through connecting the furthest vectors from the biplot origin. The biplot graph was divided into 6 sectors through the orthogonal lines drawn to hexagon. While 7 experimental environments were gathered in 3 sectors generating mega-environments, any environments were not placed in the other 3 sectors. The vertex cultivars at polygon vertices constitute the genotypes with the best performance of the sector (YAN, 2014).

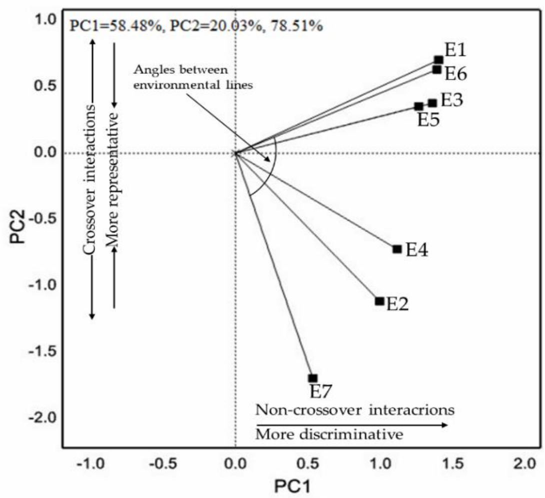


Figure 1. Position of environments on GGE-biplot graph, distance to origin and angles between the vectors

Genotype stability was determined based on average environment coordinate (AEC) generated over the GGE-biplot graph (YAN, 2014). Assessments were made based on the axis connecting average environment point to biplot origin (AEC apsis) and the axis drawn orthogonal to apsis axis passing through the origin (AEC ordinate) (Figure 3). The genotypes were ordered over the AEC apsis along the direction of arrow starting from the AEC ordinate as G7, G16, G2, G1, G8, G13, G12, G10, G18 and G14. Genotype performance increases as moved over the AEC apsis along the direction of arrow. However, lengths of genotype pointers drawn vertical to AEC apsis may be different from each other. The distance of genotypes to AEC is an indicator of stability in genotype performance along AEC, which is an indicator also of yield potential of the environments. For instance, while G13 was positioned almost over the AEC apsis, G2 was positioned quite far from AEC. Actual yield performances of genotypes are provided in Table 4. G2 had the largest grain yield performance in E2 and the second largest performance in E7. On the other hand, it was among the genotypes with the least grain yield in

E1, E3, E5 and E6 environments. G13 was quite close to AEC apsis, thus exhibited a stable performance just around or slightly over the environment averages (Table 4). The largest grain yield performance was observed in G14 (Figure 3). Additionally, G14 was positioned close to AEC apsis. Following G14, the genotypes G18 and G10 had the second largest yield performance, they were positioned further from the AEC apsis. Such a case indicated that G18 and G10 were not as much stable as G14, in other words, they were not able to sustain their performance against the varying environment averages all the time.

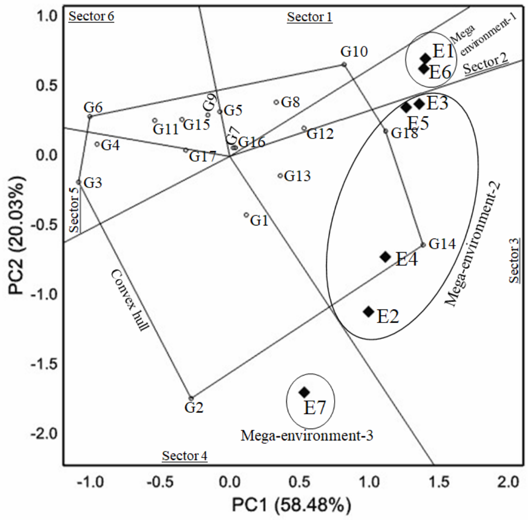


Figure 2. Hexagonal polygon of GGE-biplot graph, sectors and mega-environments. Positions of trial environments and genotypes on the graph explain which-won-where model

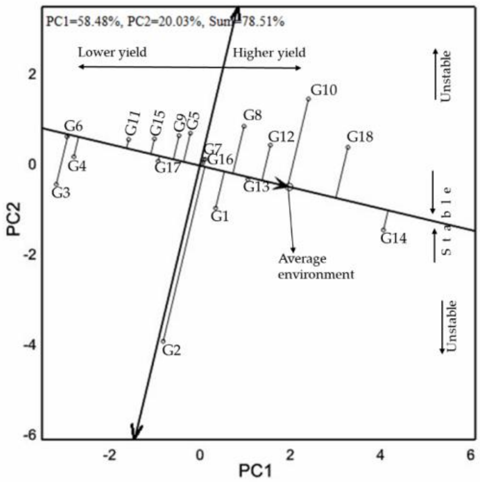
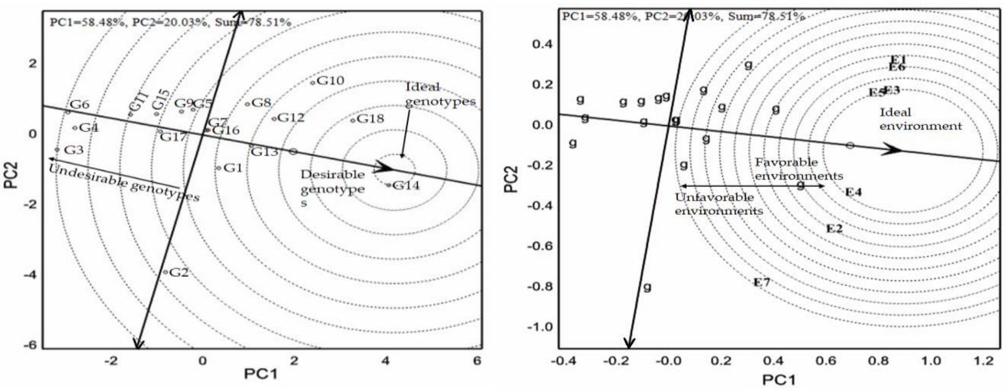


Figure 3. Average environment coordinate, grain yield performance of the cultivars, vectors to AEC

GGE-biplot analysis allows user to visually assess the genotypes and environments. Ideal genotype-focused biplot graph is presented in Figure 4a. Ideal genotypes are able to present the largest performance in all environments (YAN, 2014). Maintenance of such a performance in varying environments indicates the stability of ideal genotypes. G14 was positioned within the ideal genotype zone and was quite close to AEC apsis. Enlarging circles around the center of ideal genotype visualize the positions of the other genotypes with respect to G14 or ideal genotype zone. Close position of a genotype to ideal genotypes center and AEC apsis indicates the stability of that genotype. For instance, although G2 had larger grain yield performance than some others, it had the least stability. While G6 was placed in the furthest circle to ideal genotype center, it was among the genotypes positioned the closest to AEC. Such a case indicated that G6 always had low performance both in the best and the worst environments. Coefficient of variation is an indicator of reliability of field experiments. Despite the reasonable or acceptable coefficient of variation levels, as it was in G2 genotype, presence of extreme deviation of a genotype from the AEC apsis should be well-assessed by the breeders or researchers. In Turkey, climate conditions are the primary factors influencing yield and quality in bread wheat. The sensitivity of genotype to diseases is another important factor. The tendency of genotypes to lodging may also be effective on yield and quality (BERRY and SPINK, 2012; MUT *et al.*, 2017). AKTAS (2010) conducted a study for characterization of bread wheat genotypes and reported that Gun 91 cultivar had the least yield in the first growing season, but had the largest increase in yield in the second growing season and explained such a low yield levels of Gun 91 in the first growing season with the spikelet sterility on ears.



(a) (b)

Figure 4. (a) Ideal genotype-focused comparison of 18 bread wheat cultivars on GGE-biplot graph; (b) Ideal environment-focused comparison of 7 trial environments on GGE-biplot graph

The ideal genotype perspective was applied based on trial environments (Figure 4b). E3, E4 and E5 were positioned the closest to ideal environment zone. E7 was the furthest environment from the ideal environment zone. E7 was alone positioned within the third mega-environment as shown Figure 2. E7 had the lowest PC1 score and the largest PC2 score (absolute value). Such attributes indicated E7 as the environment with the least genotype separation power

(YAN, 2014). High PC1 score and low absolute PC2 score indicate the high genotype separation power of the environments. Vector lengths of the environments to biplot origin are presented in Figure 1. When the environments were compared with respect to standard deviation, it was observed that E7 had the lowest value and E1 (1.16) and E3 (1.15) had the largest values. The length of the environment vectors to biplot origin approximates the standard deviation within each environment (YAN and TINKER, 2006).

Plant height

According to the results of variance analysis, the differences between genotypes were statistically significant ($p \leq 0.01$) for all traits (Table 5). Plant heights of bread wheat genotypes varied between 84.3 and 113.7 cm. The genotypes G17, G16 and G18 had the lowest plant heights below 90 cm. Of 18 bread wheat cultivars, 9 (G11, G13, G1, G15, G7, G5, G3, G12 and G8) had plant heights of between 90 and 100 cm. The genotypes G4, G6 and G9 had plant heights of between 100 and 110 cm; the genotypes G14, G2 and G10 had the largest plant heights over 110 cm.

Table 5. Agronomic traits of 18 bread wheat cultivars

Genotypes	Plant height (cm)	Number of days to heading[1]	1000 kernel weight (g)	Test weight (kg hl^{-1})	Protein content (%)	Zeleny Sedimentation (ml)
G1	95.1 cd	114.9 hi	34.2 def	77.9 abc	13.4 efg	45.4 b-e
G2	111.0 ab	113.4 i	34.0 def	78.2 ab	13.6 efg	37.7 de
G3	98.3 c	116.4 fgh	35.2 cde	78.3 ab	13.8 ef	43.6 cde
G4	107.0 b	118.3 c-f	40.5 a	78.6 ab	13.7 ef	37.7 de
G5	97.9 c	119.0 bcd	33.9 def	76.3 ef	13.9 def	57.0 a
G6	108.3 ab	121.9 a	39.1 ab	78.4 ab	15.9 a	50.6 abc
G7	97.6 c	120.4 ab	36.3 cd	76.4 def	13.4 efg	36.7 e
G8	99.7 c	115.9 gh	32.3 fg	76.4 def	13.8 ef	39.3 de
G9	109.3 ab	116.6 fgh	33.1 efg	76.7 c-f	15.0 b	49.9 abc
G10	113.7 a	120.1 abc	35.5 cde	78.0 abc	15.2 ab	49.6 abc
G11	91.1 de	116.7 fgh	34.6 c-f	77.5 b-e	13.0 g	38.3 de
G12	98.7 c	118.0 def	34.5 def	75.5 f	13.3 fg	45.9 bcd
G13	91.7 de	118.7 b-e	32.2 fg	77.8 a-d	14.1 cde	54.1 ab
G14	110.4 ab	117.0 efg	37.1 bc	79.1 a	13.1 g	46.4 bcd
G15	95.1 cd	119.6 bcd	35.4 cde	76.7 c-f	13.3 fg	50.1 abc
G16	86.1 ef	116.9 efg	29.4 h	78.0 abc	14.7 bc	51.7 abc
G17	84.3 f	120.3 ab	30.7 gh	75.7 f	14.6 bcd	51.4 abc
G18	86.3 ef	118.3 c-f	35.1 cde	75.4 f	14.8 b	42.9 cde
F	20.65**	10.40**	9.13**	5.43**	11.02**	3.70**
CV (%)	5.41	1.49	6.81	1.69	4.60	18.63
$LSD_{0.05}$	5.68	1.87	2.50	1.39	0.69	9.09

[1]1st January to heading; **Significant at $p \leq 0.01$; Values with the same letter are not significantly different

Figure 5a presents the position of genotypes with respect to AEC apsis and ordinate. Biplot analysis was able to explain 87.23% of total variation (78.43% on PC1 and 8.80% on PC2). G12 was placed quite close to biplot origin, thus had the least sensitivity to environment. G2 and G1 had the longest vector lengths to AEC apsis. With regard to plant heights, genotypes were positioned closer to AEC apsis than the other traits. The genotypes placed in left section of AEC ordinate, in other words, the ones with low PC1 scores, are preferred more because of ecological conditions of Thrace Region.

Plant height indicates adaptation of genotypes to environments and have indirect effects on yield and quality, thus it is used as a significant selection criterion in breeding programs (DOGAN and KENDAL, 2013). Quite dry and highly precipitated ecologies of Turkey increase the significance of plant height. In 2017 with lower precipitation than the long-term averages, the largest and the lowest precipitation varied between 359.8 and 686.5 mm in Turkey (RAR, 2018). Besides annual total precipitation, seasonal distribution of the precipitations is also a significant issue. Generally, rain-fed wheat cultivation is practiced in Turkey. Thrace region has sufficient precipitation levels, thus generally has high yields. OZTURK and AVCI (2014) indicated that the varieties with plant heights of between 85 and 90 cm and strong stalk were appropriate for Thrace region and longer varieties had lodging problems in rainy years.

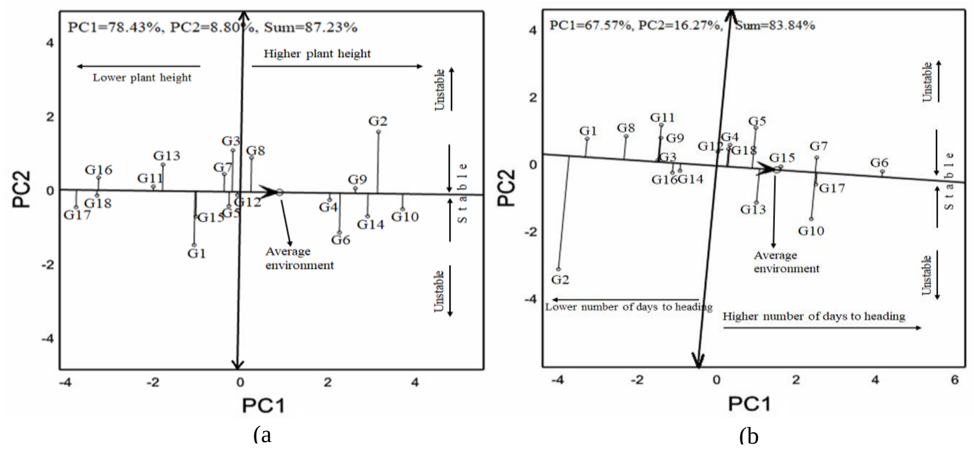


Figure 5. (a) Plant height and (b) number of days to heading of the cultivars, vectors to AEC on GGE-biplot graph

Number of days to heading

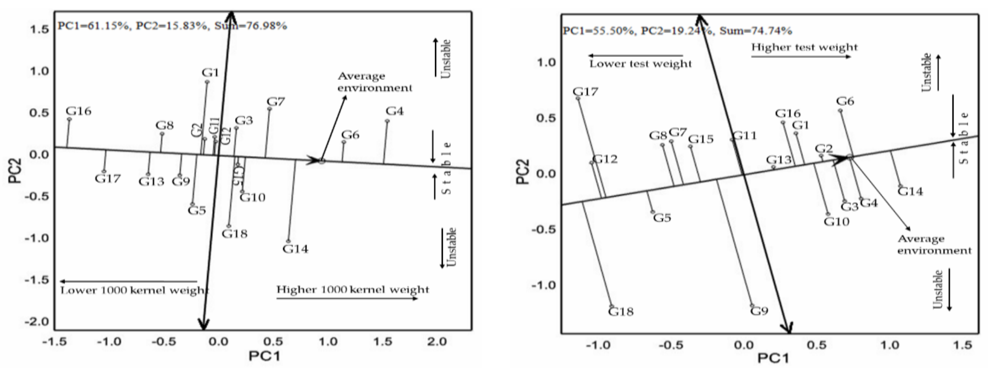
Number of days to heading values of the cultivars varied between 113.4 (G2) and 121.9 (G6) days (Table 5). Two cultivars had a value below 115 days and 4 cultivars had a value larger than 120 days. Majority of the cultivars (12 of them) had values of between 115 and 120 days.

In terms of number of days to heading, biplot analysis explained 83.84% of total variation (Figure 5b). The genotype G2 with the lowest number of days to heading was placed at the furthest position to AEC apsis and had the longest vector length. The genotype G6 with the greatest number of days to heading was among the genotypes with the least grain yields.

Low values are generally desired by the breeders because of drought tolerance and prolonged grain-fill periods (DOGAN and KENDAL, 2013). The difference in number of days to heading values of the earliest (G2) and the latest (G6) cultivars were 8.5 days. Average of cultivars was 117.9 days and cultivars exhibited 4.0-4.5 days earlier or later heading than the average. Especially the precipitation of May and deviations from the averages largely influence late genotypes (OZTURK and AVCI, 2014).

Thousand-kernel weight

Thousand-kernel weights of the cultivars varied between 29.4 and 40.5 g (Table 5). Position of genotypes with respect to AEC apsis and ordinate are presented in Figure 6a. The arrow over the AEC apsis indicates larger genotypic effect. Then from this point of view, cultivars ordered along the AEC apsis from G16 with the lowest 1000-kernel weight to G4 with the largest 1000-kernel weight. However, distances of cultivars from the AEC apsis were different (Figure 6a). Bidirectional arrows along the AEC ordinate indicate decreasing stability and increasing GEI. The genotypes G4, G6, G14, G7, G10, G15, G3 and G18 had positive PC1 scores. Of these genotypes, G15 had the shortest and G14 and G18 had the longest vector lengths to AEC apsis. G4 and G6 had the largest 1000-kernel weight performance and they were placed further above the others. It is a significant genotype-specific physical quality parameter and largely influenced by the environments (ZHANG *et al*., 2013).



(a (b

Figure 6. (a) 1000-kernel weight and (b) test weight performance of the cultivars, vectors to AEC on GGE-biplot graph

Test weight

Hectolitre weight or test weight is also a significant physical quality attribute for the industry and positively correlated with floor yield and protein content (KARADUMAN *et al.*, 2015; BULUT, 2012). G14, G6, G4, G3, G2, G10, G1, G16 and G13 had values larger than the average and also had high PC1 scores (Figure 6b). G2 and G13 had the shortest vector lengths to AEC apsis. The genotype G14 with a high 1000-kernel weigh also had the best hectolitre weight performance. The genotypes G9, G17 and G18 with low PC1 scores were positioned the furthest from the AEC apsis. In other words, in addition to low PC1 scores, they were the furthest cultivars from the origin either in negative or positive direction.

Protein content and Zeleny sedimentation values

Protein content and Zeleny sedimentation values are among the significant quality criteria in bread wheat (KARADUMAN, 2020; KARADUMAN *et al.*, 2019). Biplot graphs generated for protein content and sedimentation values are presented in Figure 7a,b. In Figure 7a, 11 of 18 cultivars were placed beneath the AEC ordinate, in other words, had low PC1 scores. The genotype G6 with the least grain yield had quite larger protein content than the others. G9 was positioned the closest to AEC apsis. G6, G10, G9, G18, G16, G17 and G13 had values larger than the average and positive PC1 scores. The standard cultivar G5 had the largest Zeleny sedimentation value (Figure 7b) and it was respectively followed by G13, G17, G16, G6, G10 and G15. The genotype G9 was positioned the furthest from the AEC apsis. Sedimentation values are largely influenced by cultural practices and climate conditions (EREKUL *et al.*, 2012; SAVASLI *et al.*, 2019; BARUT *et al.*, 2019). The vector lengths of the cultivars to the AEC apsis indicate that the responses of the cultivars to different environments are also variable.

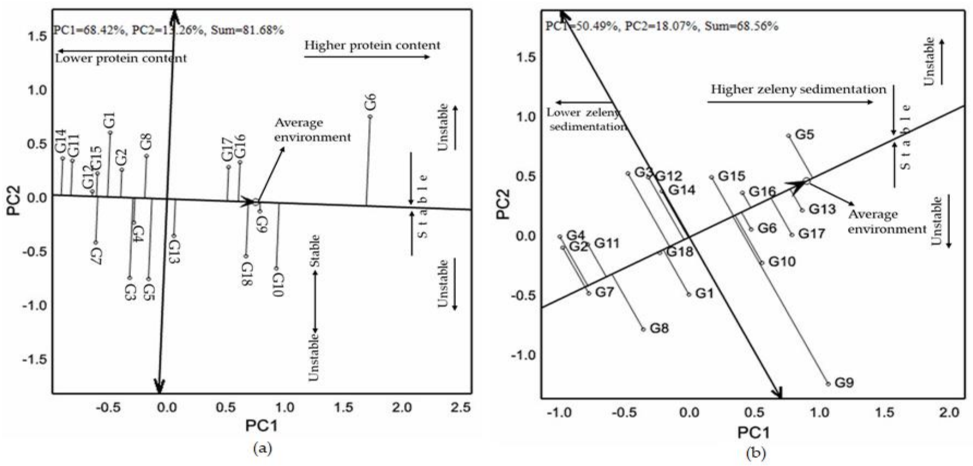


Figure 7. (a) Protein content and (b) Zeleny sedimentation performance of the cultivars, vectors to AEC on GGE-biplot graph

CONCLUSIONS

Stability of 18 bread wheat cultivars were tested in 2 growing seasons under rain-fed conditions of Thrace region. With regard to grain yield, 45.1% of total variation was resulted from the main effects of G and GEI. Test environments gathered under 3 mega-environments. All environments exhibited non-cross GEI for PC1. Genotypes exhibited both cross and non-cross GEI types. G14 had the largest average grain yield and assessed as a stable cultivar with the position close to AEC apsis. Newly registered cultivars seemed to be quite promising especially for grain yield. Of the standard cultivars, G3 and G4 had negative PC1 scores and low grain yields. G1 and G2 standard cultivars had positive PC1 scores, but G2 was assessed as instable with the furthest position from AEC apsis. In terms of plant height, 12 genotypes had values less than 100 cm. Since Thrace Region has greater precipitations and yield potential than the other regions, longer plant heights are not preferred. In terms of number of days to heading, genotypes generally distributed either below or above 4-4.5 days. Among the standard cultivars, G4 had the greatest thousand-grain weight and entire new cultivars had values below this genotype. In terms of hectoliter weights, the distances of genotypes from AEC apsis exhibited greater variation. G14 had the greatest hectoliter weight. For protein ratios, all standard cultivars were positioned behind the AEC ordinate and had negative PC1 scores. New cultivars generally had greater protein ratios than the standard cultivars. The standard cultivar G5 had the greatest Zeleny sedimentation value. However, the other standard cultivars were positioned below the AEC ordinate and had low PC1 values. Although there were not any genotypes with a Zeleny sedimentation value greater than G5 standard cultivar, new cultivars generally had equivalent or greater values than the average of standard cultivars. However, in terms of investigated parameters, biplot graphs revealed that some of new cultivars were more stable and some did not have stable performance in different environments.

Received, May20th, 2019
Accepted December 08th, 2019

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OCENA PRINOSA I AGRONOMSKIH OSOBINA NOVIH OZIMIH SORTI HLEBNE PŠENICE

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Izvod

U ovom radu utvrđeni su i upoređeni prinosi i parametri kvaliteta 13 sorti hlebne pšenice registrovanih za region Trakije i 5 standardnih sorti hlebne pšenice. Ispitivane sorte potiču iz Turske, Bugarske, Rumunije, Hrvatske, Austrije i Ukrajine. Eksperimenti su sprovedeni u vegetacionim sezonama 2015-2016 i 2016-2017. Pošto lokacije nisu podjednako raspoređene po vegrtacionim sezonama, za statističke analize prinosa i drugih parametara svaka lokacija je posmatrana kao posebna spoljašnja sredina. Stoga su procene rađene u 7 spoljašnjih sredina. Spoljašnja sredina (E) je činila 54.9% ukupne varijacije (E+G+GEI), genotip (G) i interakcija genotipa × okoline (GEI) generisali su 25.6%, odnosno 19.5%, respektivno. GGE (Genotip+ interakcija genotipa i spoljašnje sredine) biplot analiza je objasnila 78.51% varijacije u prinosu zrna. Lokacije u kojima su izvođeni ogledi grupisane su u 3 mega-spoljašnje sredine. Od sorata registrovanih u 2018. godini, Adali, Bc Anica, Topkapi, FDL Miranda, Otilia, ZT Ziiade, Viktoria i Dragana imale su vrednosti veće od proseka i tako su imale najveći PC1. Ispitivane sorte takođe su ocenjene na osnovu dužine vektora do prosečne koordinate spoljašnje sredine (AEC). Otkriveno je da je sorta Adali sa visokim PC1 i najbližim položajem do AEC apscise prilično istaknuta po prinosu zrna. U ocenama fokusiranim na spoljašnju sredinu, E3, E4 i E5 imali su poziciju najbližu idealnom krugu spoljašnje sredine. Sto se tiče atributa fizičkog kvaliteta, sorte Pehlivan, Bojana i Adali imale su visoke vrednosti. Kod sorata Bojana, Topkapi i Iveta sadržaj proteina je bio iznad 15%. Za vrednosti sedimentacije, Zeleny i Krasunia odes'ka odeska imale su najbolje performanse.

Primljeno 20.V.2019.
Odobreno 08. XII. 2019

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