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Comparison of the Agricultural Characteristics of Bread Wheat *(Triticum aestivum* L.*)* Genotypes based on Irrigated Conditions in Different Locations

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ABSTRACT

This study was performed under irrigated condition of Diyarbakir and Sanliurfa provinces, Turkey in the 2013-2014 production season to determine superior wheat genotypes for irrigated or high rainfall areas and contribute breeding programs. Experiments was designed according to the random blocks trial pattern with four replications. Performance of genotypes for examined traits was found statically different at level of $p \leq 0.01$. According to ranking biplot analyse G9 was the most stable genotype for grain yield and G11 for seed protein content. Advansed lines, G9, G11 and G17 were determined as supeior genotypes for grain yield and quality traits compare to cultivars that used as a national checks. These advanced lines could be used as genitor in breeding programs to improve high quality and yielding varieties for irrigated conditions.

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INTRODUCTION

Wheat is the raw material of many foods that are important in human life. The adaptability of wheat is higher than other plant types, and it can be grown in different conditions. According to the researches, wheat was domesticated between the Euphrates and Tigris rivers (Mesopotamia) where located in Southeast of Turkey, part of the Fertile Crescent (Mizrak 2018). Wheat (*Triticum aestivum L.*) is important for daily nutrition because of contents protein, mineral substances and vitamins. Approximately 60% of the daily protein need of a normal person is met from wheat, and it is reported that wheat contributes more calories to diet programs in the world (Khatri et al. 2019). Quality traits of the wheat also should be considered by breeders to improve high nutrional genotypes.

Test weight and thousand grain weight are important technological quality parameters. It has been reported that the test weight changed depending on the shape, density and size of the grain. It was emphasized that test weight is beneficial in estimating the wheat weight per unit area and there is an increase in test weight of the wheat varieties have been increased with plant breeding (Protic et al. 2007). Thousand grain weight has a impact on flour yield, seed sprouting, seedling growth, plant performance during growth stages (Deivasigamani and Swaminathan 2018; Afshari et al. 2011). The value of a thousand grain weight varies depending on the volume of the embryo used for the sprouting of the plant and the amount of endosperm separated (Deivasigamani and Swaminathan 2018; Ebadi and Hisoriev 2011; Cao et al. 2011). Several statica method are used to evalaute performance of genotypes that used in multi environments. Last years GGE biplot analyse method has been used by plant breeder to evaluate multi environments experiments more effective and easily.

The GGE biplot model visually presents the adaptability of genotypes, the ideal genotype or the ideal environment in a given environment or in multiple environments. It also clearly displays the stability of the genotypes to determine the performance of the genotypes too (Kadir et al. 2018; Susanto et al. 2015; Fashadfar and Sadegi 2014). Thus, the GGE biplot model facilitates plant breeders to determine the ideal genotype or ideal environment. Visualization of GGE-biplot analysis is able to explain the genotype x interaction in an environment. (Singh et al. 2019; Yan and Kang 2002). GGE-biplot displays graphic visualization to describe the appearance of genotypes in a specific environment, adaptability of genotypes in several different environments, identify the best genotypes in each environment, visualize mega environment, and average performance of genotype and stability. GGE-biplot also displays best genotypes with the highest yield potential in each mega-environment and able to show genotype and ideal environment among all environments where plants are planted (Singh et al. 2019; Sharifi et al. 2017; Susanto et al., 2015; Fashadfar and Sadegi, 2014).

The aim of this study is to determine suitable wheat genotypes for irrigated conditions and evaluate yield and some quality traits stability of some wheat genotypes based GGE-biplot method.

MATERIALS AND METHODS

Study was conducted, Diyarbakir (DB) (37° 56 'N, 40° 15' E; 599 m) and Sanliurfa (37º12 'N; 38º70' E; 402 m) (SU) provinces of Turkey in 2013-2014 growing season in the irrigated conditions (Figure1, 2). Experiments were designed according to random blocks trial pattern with four replications. 5 national checks and 20 advansed lines were used as a plant material.

Figure 1. The Fertile Crescent (Mesopotamia), the map showing the area covering Turkey

Figure 2. Map of Turkey showing the trials areas

Sowing was made by planting machine in both environments in the first week of November. Seed density in the unit area was 450 seeds and each plot was 6 meters long, 6 rows and 20 cm between rows. Harvest was done with Hege 140 parcel combine harvester on 6 square meters area after the edge effects were discarded. In the experiment, 300 kg ha^{-1} composite (20-20-0) fertilizer was used in sowing time, and 174 kg ha^{-1} URE (%46) during tillering stage. Experiments were irrigated two times (100 mm each time) in Zadoks 53 and 73 periods (heading time and milk stage) (Zadoks 1974).

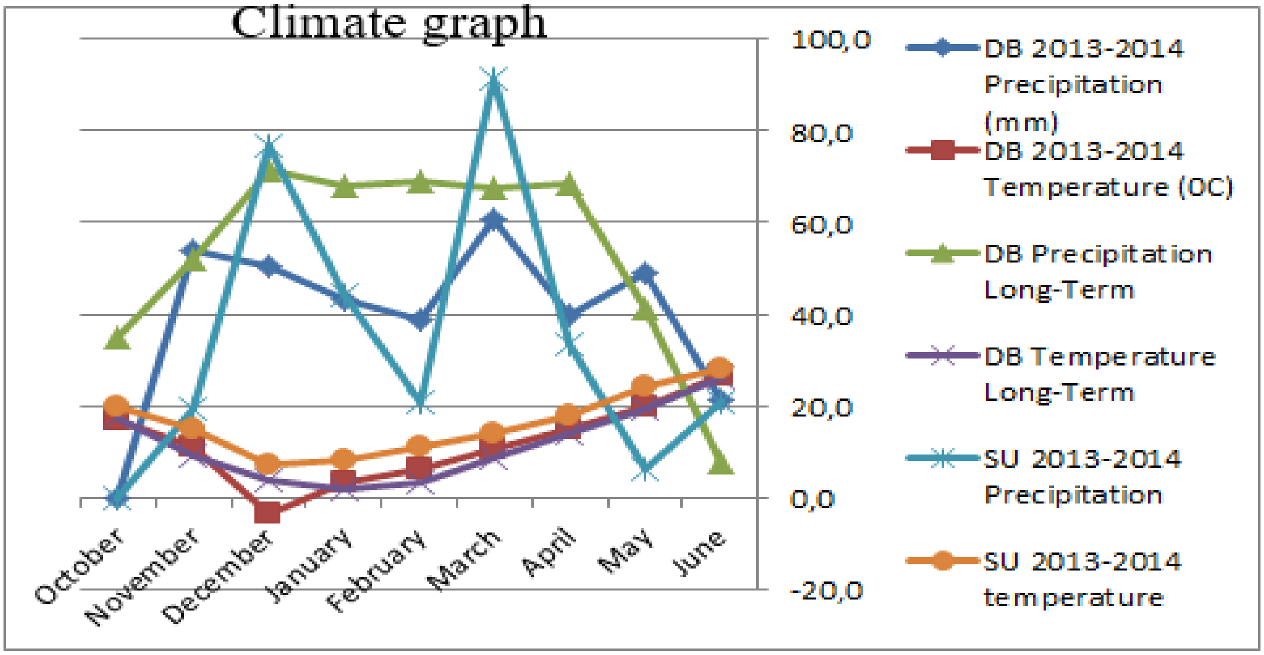

Figure 3. Climate graph of locations

For weeds control herbisite was applied when plant reach 2-4 leaves, chemical. In Diyarbakır province, precipitation average is 480.0 mm for long terms and 356.0 mm of occurred in 2013-2014 production season (Figure 3). When the precipitation graph of Diyarbakır Province is analyzed, it will be seen that precipitation is below the average of long term years in other months except May (Figure 3). Average temperature of Diyarbakır Province for long term years has been reported to be 12.2 ^{0}C, relative humidity 52.7% (Anonymous 2014a).

Temperature values of the Diyarbakir location was parallel with the average temperatures for long terms. However, the temperature in December seems to be very low compared to long term years. (Figure 3).

In Sanliurfa Province, average precipitation was 430 mm for long years and 312.8 mm of occurred in 2013-2014 growing season. Total precipitation in wheat growing season was lower than average of long term years (Figure 3).
In addition, the average temperature value for long term years in Sanliurfa Province has been reported to be 18 ^{0}C and the average relative humidity is 58.2% (Anonymous 2014b).

Table 1. *Soil properties of the trial areas*

Location	Soil texture	Total salt content (%)	PH (sc)	$CaCO_3$ (%)	P_2O_5 (kg ha^{-1})	Organic matter (%)	Saturation with water (%)
Sanliurfa	Clayey	-	7.6	-	52.0	1.1	50
Diyarbakir	Clayey	0.246	7.8	6.26	12.8	0.7	77

Locations where the current study is conducted; soil texture, PH and organic matter similar in content, partly different in terms of phosphorus content and percentage of saturation with water (Table 1).

Table 2. *Pedigree and origin of bread wheat genotypes used in the study*

Genotypes (G)	Pedigree	Breeding Organization or Origin
G1	Qamar-4 Cmss97m03159t-040y-0b-0ap-2ap-0aps-0ap-17ap-2ap-5ap-0ap	CIMMYT
G2	D67.2/Parana 66.270//Ae.Squarrosa (320)/3/Cunningham/4/Vorb Cmsa06m00431s-040ztm-040zty-31ztm-04y-0b	CIMMYT
G3	Cno79//Pf70354/Mus/3/Pastor/4/Bav92/5/Milan/Kauz//Prinia/3/Bav92 Cmsa06y00093s-040ztp0y-040ztm-040sy-5ztm-0y-0b	CIMMYT
G4	Babax/Ks93u76//Babax/3/2*SokollCmsa06m00008t-024(Pinbd1bhet)Y-040ztm-026(Pinbd1bpos)Zty-20ztm-0y	CIMMYT
G5 (Dinç)	Standard	GAP UTAEM
G6	D67.2/Parana66.270//Ae.Squarrosa(320)/3/Cunningham/4/Skauz/Bav92 Cmsa06m00430s-040ztm-040zty-22ztm-0y-0b	CIMMYT
G7	Krichauff/2*Pastor/4/Milan/Kauz//Prinia/3/Bav92 Cmsa06y00337s-040ztp0y-040ztm-040p0y-4ztm-0y-0b	CIMMYT
G8	Heilo//Sunco/2*Pastor Cmsa06y00492s-040zty-040ztm-040sy-2ztm-0y-0b	CIMMYT
G9	Chih95.7.4//Inqalab 91*2/Kukuna Ptss06ghb00007s-0y-040ztm-040zty-11ztm-0y-0b	CIMMYT
G10 (Pehlivan)	Standard	TTAEM
G11	Kachu #1/Kiritati//Kachu Cmss06y00778t-099topm-099y-099ztm-099nj-099nj-6wgy-0b	CIMMYT
G12	Saual/Yanac//Saual Cmss06y00783t-099topm-099y-099ztm-099nj-099nj-14wgy-0b	CIMMYT
G13	Prl/2*Pastor*2//Fh6-1-7 Cmss06y00793t-099topm-099y-099ztm-099y-099m-3wgy-0b	CIMMYT
G14	Frncln/Rolf07cmss06b00013s-0y-099ztm-099y-099m-2wgy	CIMMYT
G15(Cemre)	Standard	GAP UTAEM
G16	Becard/Kachu Cmss06b00169s-0y-099ztm-099y-099m-28wgy-0b	CIMMYT
G17	Becard/Akurı Cmss06b00411s-0y-099ztm-099y-099m-12wgy-0b	CIMMYT
G18	Rolf07*2/5/Reh/Hare//2*Bcn/3/Croc_1/Ae.Squarrosa (213)//Pgo/4/Hutes Cmss06b00704t-099topy-099ztm-099y-099m-23wgy-0b	CIMMYT
G19	Usher-16 Crow's'/Bow's'-1994/95//Asfoor-5 Icw01-00257-0ap-8ap-0ap/0ts-0ap-12ap-0ap	CIMMYT
G20 (Sagittario)	Standard	TASACO TARM
G21	Croc_1/Ae.Squarrosa (213)//Pgo/3/Cmh81.38/2*Kauz/4/Berkut Cmsa02y00059s-040p0y-040ztm-040sy-040m-7zty-03m-0y	CIMMYT
G22	Chen/Aegılops Squarrosa (Taus)//Bcn/3/Bav92/4/Berkut Cmsa02y00104s-040p0y-040ztm-040sy-040m-8zty-02m-0y	CIMMYT
G23	Mısket-12-Btı735/Achtar//Asfoor-1 Icw01-00164-0ap-1ap-0ap-0ap-4ap-0ap-0sd	CIMMYT
G24	Rebwah-12/Zemamra-8-Rebwah-12/Zemamra-8 Icw01-00193-0ap-16ap-0ap-0ap-1ap-0ap-0sd	CIMMYT
G25 (Adana-99)	Standard	DATAE

G: Genotypes, CIMMYT: International Maize and Wheat Improvement Center, GAP UTAEM: GAP International Agricultural Research and Training Center, DATAE: Eastern Mediterranean Agricultural Research Institute, TASACO TARM.: Tasaco Agriculture, TTAEM: Directorate of Trakya Agricultural Research Institute

Data collection procedures for the features examined

Heading time (HT): Heading day was calculated when 50% of each plot plants have spike.

Grain yield (GY): Harvested each plot of seed by scale (0.01 sensitive) converted to kg ha^{-1}.

Test weight (HW) and Protein ratio (PR): Test weight and seed protein content were calculated by NIT (Model 6500, Perten device).

Thousand grain weight (TGW): 400 seeds was used to calculate TGW then obtained value was multiplied by 2.5.

Statistical analysis of data

One-way analysis of variance was performed with ANOVA. In the study, years were analyzed both individually and by combining. To visually confirm the results of ANOVA analysis, variety-feature and stability biplot graphs were presented visually using the GenStat 12th edition program (GenStat 2009). Differences between means were expressed by LSD test (p≤0.01 or p≤0.05) (Gomez and Gomez 1984). In study, grain yield analyzes were made on 4 replications. However, the remaining features were performed on 2 replications due to the high workload and cost in the laboratory.

RESULTS AND DISCUSSION

Significant differences observed (p≤0.01) between genotypes for all examined traits.

Table 3. *Variance analysis table showing the mean of squares of the investigated features*

		Average of squares					
Variance resources	DF1	GY	DF2	HT	TW	TGW	PR
Location	1	641278.0**	1	784.0**	11.1^{NS}	259.4^{NS}	34.9^{NS}
Genotype	24	16674.3**	24	44.8**	6.8**	31.2**	2.6**
Location*Genotype	24	10209.5**	24	10.1^{NS}	1.8**	15.8**	1.8**
Hata	6	12480.3	2	6.1	10.2	67.1	5.8
CV (%)		11.8		1.6	0.9	4.5	6.3

**: Statistically significant at the 0.01 level, DF1: Degree of freedom for grain yield, DF2: Degree of freedom for other properties other than grain yield, NS: not significant

Average the heading time ranged between 153.5-166.8 days. The earliest heading was seen in G16 (153.5 days), and the latest in Cemre (166.8 days) variety (Table 4). It was reported that heading time was affected due to the different effects of environmental conditions on the development periods of genotypes (Karaman 2020; Rahman et al. 2009a; Araus et al. 2007).

Table 4. *Values of the properties examined in the study*

Genotypes	**HT (day)**			**GY (kg ha^{-1})**			**TW (kg hl^{-1})**		
	DB	SU	Average	DB	SU	Average	DB	SU	Average
G1	161.0	154.0	157.5	5077	4042	4559	82.8	83.4	83.1
G2	163.0	160.0	161.5	4956	3259	4108	83.9	83.9	83.9
G3	162.5	153.5	158.0	5218	3612	4415	84.7	82.1	83.4
G4	162.0	158.0	160.0	5303	4167	4735	83.4	82.7	83.1
G5 (Dinç)	161.5	155.5	158.5	6096	3872	4984	83.4	84.0	83.7
G6	162.0	155.0	158.5	4915	4533	4724	84.2	81.9	83.0
G7	163.0	154.0	158.5	5095	2917	4006	85.9	84.4	85.1
G8	165.5	163.0	164.3	5462	5783	5622	85.3	84.7	85.0
G9	164.0	160.0	162.0	5548	5034	5291	84.1	83.6	83.9
G10 (Pehlivan	168.0	163.5	165.8	4608	5093	4850	84.6	82.5	83.5
G11	157.5	150.0	153.8	4364	3321	3842	81.7	81.7	81.7
G12	160.0	152.0	156.0	4897	3683	4290	80.0	81.9	80.9
G13	162.5	153.0	157.8	5342	3882	4612	80.6	82.0	81.3
G14	162.0	153.0	157.5	5588	4109	4848	80.5	81.5	81.0
G15 (Cemre)	169.0	164.5	166.8	4521	4851	4686	82.5	82.1	82.3
G16	157.5	149.5	153.5	4688	3415	4051	82.7	81.5	82.1
G17	164.0	153.0	158.5	4931	3285	4108	80.9	82.1	81.5
G18	163.5	155.0	159.3	5196	3417	4306	82.1	80.5	81.3
G19	161.0	159.5	160.3	5766	4358	5062	81.9	79.0	80.5
G20 (Sagittario)	165.0	165.0	165.0	4872	3415	4143	83.2	81.8	82.5
G21	162.0	155.5	158.8	5233	3708	4470	85.1	82.6	83.8
G22	163.0	159.5	161.3	5525	4335	4930	82.9	82.2	82.6
G23	162.0	159.5	160.8	4922	3471	4196	81.2	81.2	81.2
G24	162.0	163.5	162.8	4140	3468	3804	82.7	82.6	82.6
G25 (Adana-99)	164.0	158.5	161.3	4923	3841	4382	85.1	83.4	84.2
Average	162.7	157.1	159.9	5087	3955	4521	83.0	82.4	82.7
LSD (0.05)	1.8**	7.2**	3.6**	835**	670**	531**	1.7**	1.5**	1.1**

**: significant at the 1% level, DB: Diyarbakir, SU: Sanliurfa

It was observed that the grain yield ranged between 3804-5622 kg ha^{-1}. The highest grain yield was obtained from G8 (5622 kg ha^{-1}) and the lowest from G24 (3804 kg ha^{-1}) (Table 4). Grain yield is controled by many genes, also it is affected by several factors such as year, environment and amount of precipitation (Aktas et al. 2017; Kaydan and Yağmur 2008; Mut et al. 2005).
Test weight ranged between 80.5-85.1 kg hl^{-1}. The highest test weight was obtained from G7 (85.1 kg hl^{-1}) and the lowest value from G19 (80.5 kg hl^{-1}) (Table 4). When the amount of water is limited, the weight of tests decreases (Aguirre et al. 2002). It was reported that the test weight is significantly affected by kernel plumpness (Aktas 2017; Aguirre et al. 2002). Kernel plumpness reflects the environment in which the grain was grown and is dependent upon the effectiveness of grain filling (Kelly et al. 1995)

Table 5. *Values of the properties examined in the study*

Genotype (G)	TGW (g)			PR (%)		
	DB	SU	Av.	DB	SU	Av.
G1	33.6	37.9	35.8	14.0	10.3	12.1
G2	37.6	44.3	40.9	15.4	12.4	13.9
G3	40.4	39.5	39.9	13.5	13.6	13.6
G4	33.7	37.5	35.6	13.8	11.1	12.5
G5 (Dinç)	31.9	35.3	33.6	14.3	14.4	14.3
G6	38.9	39.8	39.3	14.6	12.8	13.7
G7	38.9	37.9	38.4	15.3	13.3	14.3
G8	32.6	33.5	33.1	14.6	12.2	13.4
G9	35.5	38.4	36.9	14.7	14.2	14.4
G10 (Pehlivan	40.9	41.6	41.3	14.7	13.6	14.2
G11	36.1	42.5	39.3	15.3	15.8	15.6
G12	36.5	48.3	42.4	15.0	13.9	14.4
G13	37.6	48.0	42.8	14.8	12.8	13.8
G14	33.0	41.8	37.4	14.8	14.8	14.8
G15 (Cemre)	36.8	37.9	37.3	15.7	13.0	14.3
G16	37.6	43.0	40.3	14.7	14.5	14.6
G17	34.1	39.5	36.8	15.5	14.8	15.1
G18	38.6	35.6	37.1	14.3	13.5	13.9
G19	34.1	31.5	32.8	14.4	14.0	14.2
G20 (Sagittario)	38.1	35.8	36.9	14.7	15.3	15.0
G21	38.4	41.6	40.0	13.9	14.8	14.4
G22	38.5	42.5	40.5	13.9	13.2	13.5
G23	34.5	41.4	37.9	14.9	14.9	14.9
G24	36.1	40.8	38.4	14.9	12.3	13.6
G25 (Adana-99)	34.5	33.6	34.1	14.6	11.4	13.0
Average	36.3	39.6	38.0	14.7	13.5	14.1
LSD (0.05)	3.2**	3.8**	2.4**	NS	2.1**	1.3**

NS.: not significant, **: significant at the 1% level, Av.: average

Thousand grain weight ranged between 32.8-42.8 g and average was 38.0 g. G13 (42.8 g) had the highest value and G19 had the lowest value (32.8 g) (Table 5). Previous study conducted in Turkey Diyarbakir province in bread wheat has been reported that an average of a thousand grain weight was 32.5 g (Aktas 2017). Although a thousand grain weight is a genetic feature, TGW affected by ecological factors, precipitation, temperature, humidity etc. (Rahman et al. 2009b). Seed protein content is one of most the important quality parameters. Seed protein content ranged between 12.1-15.6%. The highest protein value was obtained from G11 (15.6%) and the lowest value was obtained from G1 (12.1%) (Table 5). In breeding programs, it was emphasized that irrigated experiments or environments with high precipitation will give more accurate results in the selection made to determine the protein capacities of wheat genotypes (Akram et al. 2010).

GGE biplot model showing the genotype-feature relationship

GGE biplot is two-way analysis model that provides visual presentation of ideal genotype or ideal environment also show genotype-traits relation, stability of genotypes. In this study, the genotype-traits relationship was shown with scatter plot and stability was shown with ranking biplot. Also, ideal genotypes and environments are shown with comparison biplot models. (Figure 6, 7, 8, 9, 10 and 11).

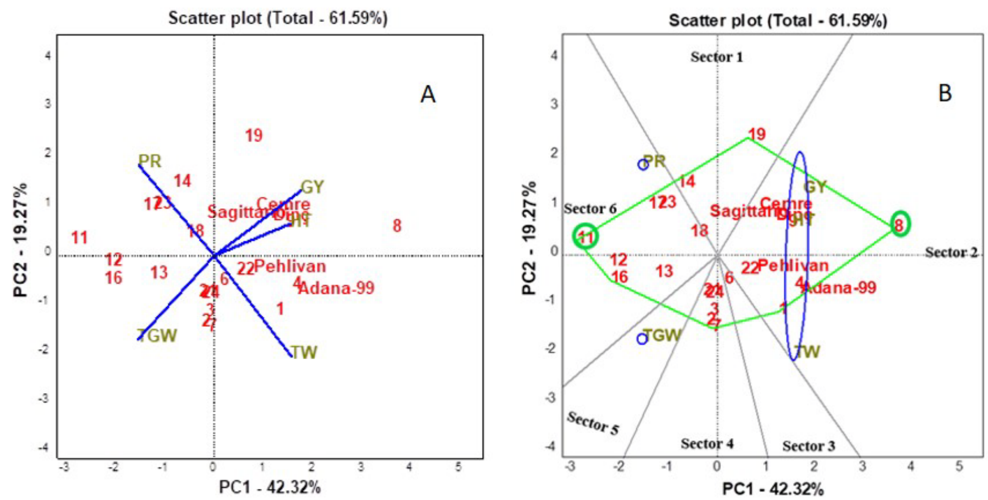

Figure 6. (A) GGE biplot graph showing the genotype-feature relationship, (B) Representation of genotype-feature relationship with polygon

In the graphs showing the genotype-feature relationship; principal component 1 (PC1) variation explains, 42.32% principal component 2 (PC2) 19.27%, and 61.59% overall, (PC1 + PC2) (Figure 6 and 7). When Figure 6 showing the genotype-feature relationship is examined; There is a positive relationship between GY and HT. In addition, there is a negative relationship between with PR and TW also between TGW and GY. For GY; G8, G9, G19 and Dinç, PR; G11, G17 and Sagittario were found to be the best genotypes (Figure 6 and 7).
According to Figure 7, which visually presents the genotype-feature relationship with polygon and sectors, 6 different sectors were formed. From these sectors; 1, 3, and 4 do not represent any of the examined traits. It has been reported that there is a strong relationship between the features in the same sector (Singh et al. 2019; Oral et al. 2018).

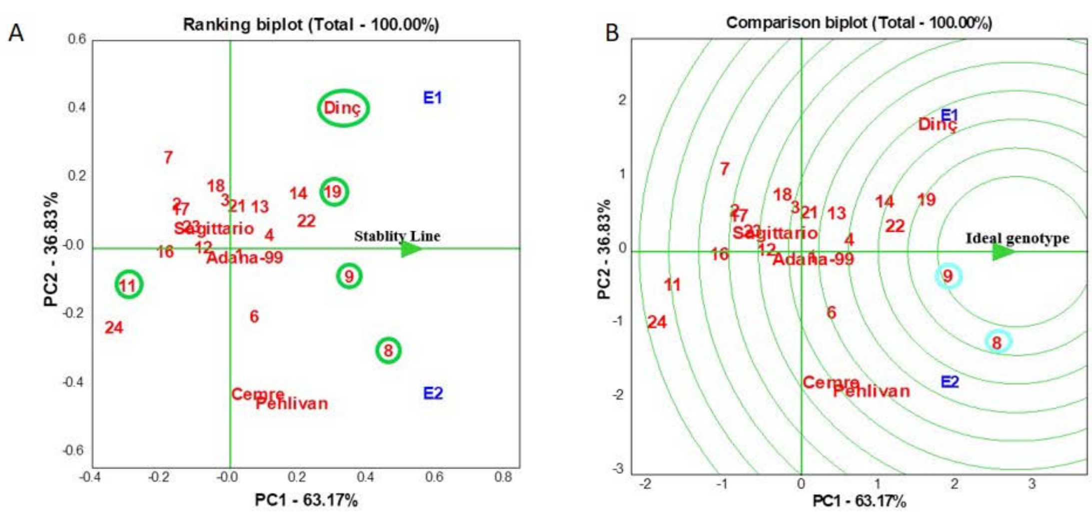

Figure 8. (A) Ranking stability biplot graph for grain yield In terms of grain yield, (B) condition of genotypes relative to the ideal genotype

GY, HT and TW are located in the same sector (Sector 2) and in the same group shows that these traits are related each other (Fig 7.). In addition, genotypes in the corners of the polygon are the best genotypes in terms of closest traits.

Accordingly, it is understood that G8 and G19 are the best genotypes for GY and G11 is the prominent genotype in terms of PR (Figure 7).

In Ranking biplot graph; PC1, 63.17% PC2 36.83%, and total (PC1 + PC2) explain 100% variation (Figure 8). Ranking biplot graph used to show the stability of genotypes, the genotypes to the right of the axis representing PC1 are desired, and the genotypes to the left are undesirable. Also, the stability increases as the genotypes approach the PC2 axis. Genotype with high grain yield and stability in any medium has been reported to be defined as the ideal genotype. It is emphasized that the genotype should show high PC1 value and low PC2 value (close to 0) in order for this to occur (Singh et al. 2019; Rakshit et al. 2014; Yan and Tinker 2006).

Therefore, genotypes with a high PC1 value and a small PC2 value are interpreted as high yield and stable genotypes. According to this comment; G8, G9, G19 and Dinç are genotypes with high grain yield. However, G9 grain yield is high but also a stable genotype (Figure 8). In this study, G11 is the best genotype in terms of quality parameters (especially for seed protein) (Table 5). However, as seen in Figure 8, G11 is moderately stable (medium distance to PC2 axis) and grain yield is below the experimental average. The GGE biplot model is useful in identifying the best genotype in different environments and visually showing the stability of the genotypes. In addition, it is a model that shows the genotypes adapted to the special environment with graphics (Oral et al. 2018; Rakshit et al. 2014).

While Comparison biplot graph presents the ideal genotype, PC1 had represent 63.17% of the variation and PC2 had represent 36.83% (Figure 9). In the Comparison biplot graph, the ideal genotype is the closest to the center of the circle. Accordingly, it is the closest G9 to the center circle where the ideal genotype is located (Figure 9). In the Comparison biplot model, the desired genotypes are those closest to the ideal genotype (the smallest central circle) (Mehari et al. 2015; Yan and Tinker 2006). Therefore, ideal genotypes are circled.

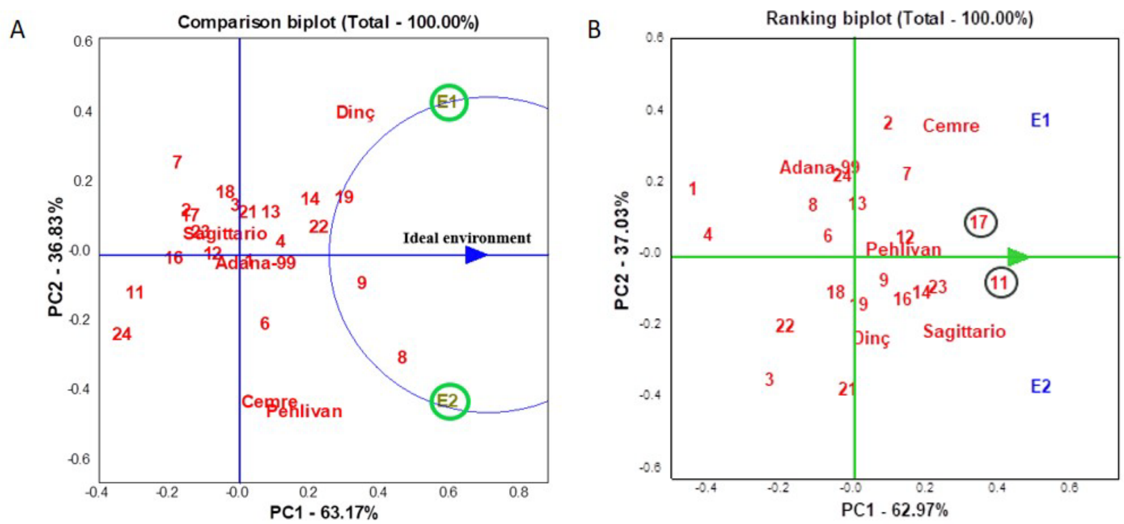

Figure 10. (A) Environments assessment based on ideal environment, (B) Visual presentation of protein stability of genotypes

In the Comparison biplot model, the ideal environment is interpreted as the environment closest to the center circle. In the current study, when the circles E1 and E2 are examined, it is seen that the distance to the center circle where the ideal environment is located is similar in both circles. In this case, it can be said that genotypes showed react similarly to the E1 and E2 environments (Figure 10).

In addition to grain yield, protein ratio from quality parameters is also an important criterion in the selection of genotypes. According to Figure 11, which shows the stability of genotypes in terms of protein ratio; PC1 value of G11 is highest (far right of the stability line) and the PC2 value is low (close to the stability line). Therefore, the best genotype in terms of protein ratio is G11. Also, it can be said that G17 is a genotype close to G11 in terms of protein ratio, too. (Figure 11).

CONCLUSION

It was concluded that G8, G9, G19 and Dinc were the best genotypes in terms of grain yield. G9 was determined as a ideal genotype because of it's stable traits and high grain yield, and it can be evaluated for national registration candidate for irrigation areas. It was determined that G11 and G17 are the best lines in terms of seed protein ratio, especially G11 has both stable and highest seed protein ratio.

It was concluded that E1 and E2 circles are not sufficient to represent the ideal environment, and different circles should be tried for yield and quality oriented selections. In addition, using G9, G11 and G17 as a genitor will contribute breeding programs to improve high quality and yield varieties.

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