

Evaluation of Yield and Quality Performance of Bread Wheat (*Triticum aestivum* L.) Genotypes Across Diverse Environments

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ABSTRACT

The study was conducted in Adıyaman Province under rainfed and supplementary irrigation conditions, using a randomized block design with four replications. The aim of the study was to determine the productive, high quality and stable breeding material suitable for the regional conditions using the GGE (genotype, genotype x environment) biplot technique. The twenty-five spring bread wheat genotypes were the experiment material. According to the ANOVA (analysis of variance) analysis results, there was significant variation at $p \leq 0.01$ level among the genotypes in all examined traits. It was determined that there was a 22.3-41.3% increase in grain yield in supplementary irrigation conditions compared to rainfall-based conditions. Particularly, G2 showed the highest positive response to supplementary irrigation with 41.3% yield increase. Protein ratio, 0.7-18.5% higher protein values were observed in rainfall-dependent conditions. The G14 genotype gave the highest grain yields under based on rainfed conditions, while the G22, G4 and Dinç genotypes gave the highest grain yields under supplementary irrigation conditions. In terms of quality traits, G6, G7, G17, G24 and Tekin genotypes attracted attention with their high quality values. The biplot analysis results showed that G22 was the most ideal and stable genotype for both environments in terms of grain yield.

Keywords: Wheat, yield, quality, GGE-biplot, stability

Farklı Çevrelerde Yetiştirilen Bazı Ekmeklik Buğday (*Triticum aestivum* L.) Genotiplerinin Verim Ve Kalite Özellikleri Bakımından Karşılaştırılması

ÖZ

Çalışma, yağışa dayalı ve destek sulama koşullarında, tesadüf blokları deneme deseninde 4 tekrarlamalı olarak yürütülmüştür. Amaç; bölge koşullarına uygun, verimli, kaliteli ve stabil ıslah materyalini GGE (genotip, genotip x çevre) biplot tekniği ile belirlemektir. Yirmi beş yazlık ekmeklik buğday genotipi deneme materyalini oluşturmuştur. ANOVA (varyans analizi) analizi sonuçlarına göre, incelenen tüm özelliklerde genotipler arasında $p \leq 0,01$ düzeyinde önemli varyasyon olduğu belirlenmiştir. Destek sulama koşullarında, yağışa dayalı koşullara göre %22.3-41.3 arasında tane verimi artışı olduğu tespit edilmiştir. Özellikle G2 genotipi, %41.3 verim artışı ile destek sulamaya en yüksek olumlu yanıtı vermiştir. Protein oranı bakımından, yağışa dayalı koşullarda %0.7-18.5 daha yüksek protein değerleri gözlenmiştir. G14 genotipi, yağışa dayalı koşullarda, G22, G4 ile Dinç genotipleri ise destek sulama koşullarında en yüksek tane verimlerini vermiştir. Kalite özellikleri açısından G6, G7, G17, G24 ve Tekin genotipleri yüksek kalite değerleriyle dikkat çekmiştir. Biplot analiz sonuçları, tane verimi açısından her iki ortamda da G22'nin en ideal ve stabil genotip olduğunu göstermiştir.

Keywords: Buğday, verim, kalite, GGE-biplot, stabilize

INTRODUCTION

Wheat has been cultivated for millennia, is essential for nutrition, widely used in bread making, and holds cultural and strategic importance worldwide [1, 2]. It has been emphasized that the unit area grain yields have increased extraordinarily through effective strategies followed in the wheat breeding process [3], but it has

been reported that additional increases in the unit area yield of wheat are needed, considering the ever-increasing world population [4]. Genotype x environment interaction is one of the most important issues that challenge breeders in selecting the correct genotype or genotypes for the desired trait in breeding experiments conducted under different environmental conditions [5, 6].

The aim of breeding programs in developing varieties is that the developed variety has the potential to yield high grain yields under good conditions, as well as economically acceptable grain yields per unit area even when exposed to adverse environmental conditions [7, 8]. Quality genotypes in wheat breeding emerge after evaluation across multiple quality parameters [9, 6]. Significant differences detected between environments in terms of the traits examined in bread wheat indicate a complex situation such as ecological conditions, genetic factors and their interactions [10, 11, 12].

Quality in wheat is a guide in deciding which product the wheat grain will be processed into, and is one of the quantitative characters controlled by many genes. In addition, these characters are shaped under the influence of variety, climate and soil structure [13,14,15]. The wheat industry prefers varieties that are stable in terms of hectolitre weight and protein content. Wheat quality may vary over time depending on consumer preferences

and market demands [16, 17]. In GGE (genotype, genotype x environment) biplot analysis, both genotype and genotype and environment interaction are evaluated simultaneously, thus explaining genotype-environment interaction in detail. GGE biplot technique uses visual plots to determine the best genotypes in general [18]. The aim of this study was to determine breeding materials that were highly adaptable, high-yielding, and of acceptable quality. Additionally, it was to test the usability of GGE technique in the selection stage of breeding material.

MATERIALS AND METHODS

This study was conducted in Adıyaman Province during the 2016-2017 growing season under both rainfed and supplementary irrigation conditions, following a randomized block design with four replications.

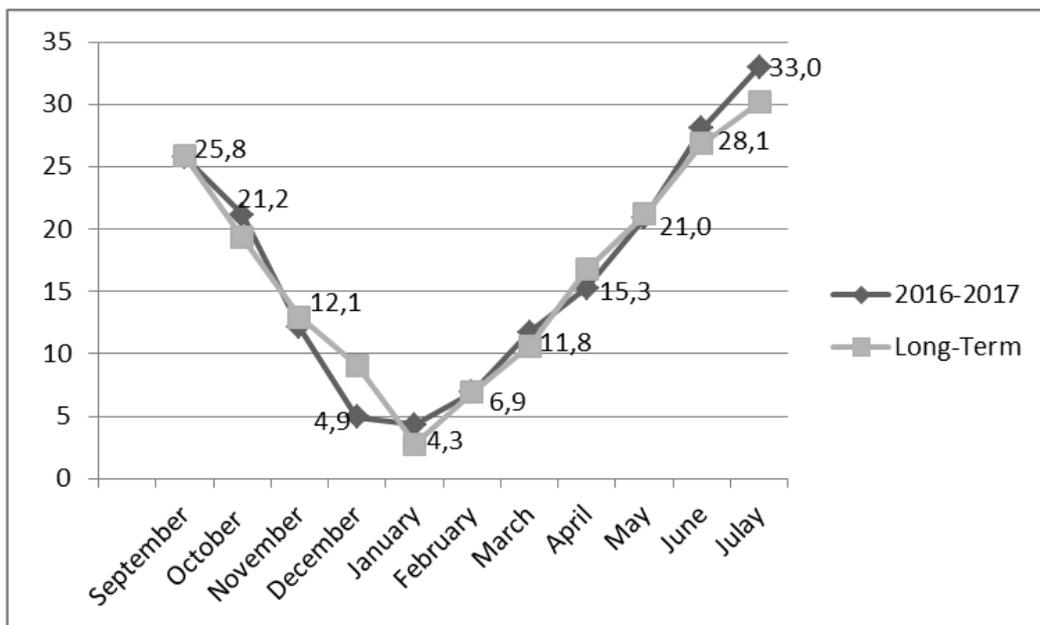


Figure 1. Mean Temperature Graph for Season and Long Years (°C)

Adıyaman province is located between 37° 25' and 38°11' north latitude, 37° and 39° east longitude, and its altitude is 669 m. In the study, when the temperature values related to the season were compared with the long-term averages, December was low and the other months had similar temperature values with the long-

term averages (Fig. 1). Average based on months rainfall, it was observed that the distribution of rainfall was irregular, and rainfall was well above the average to long years in December, and well below the average to long years in January and February.

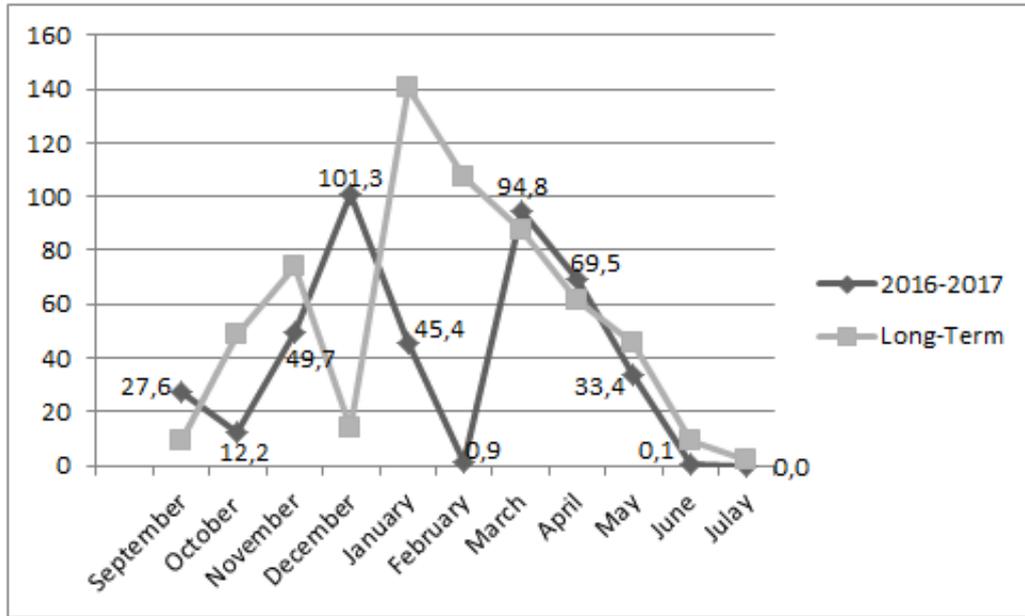


Figure 2. Precipitation Graph for the Working Season and Long Years (mm)

A total of 434.9 mm of precipitation occurred during the season, compared to a long-term average of 599.1 mm (Fig. 2). The research material consisted of 19 advanced stage lines originating from CIMMYT (International Maize and Wheat Improvement Center), 1 registration candidate (Aday-12) and 5 registered bread wheat varieties. In the experiment, each plot was 5 m long and 1.2 m wide, consisting of 6 rows with 20 cm spacing between rows. The harvested area was 6 m². The planting process was carried out on 05.11.2016 with a trial drill, with 450 seeds per square meter in both trials. According to the soil analysis results, the experimental area soils were clayey-loamy, had insufficient phosphorus content and poor organic matter ratio. In this context, 14 kg nitrogen (N) was applied per decare for based on rainfall conditions and 16 kg nitrogen (N)

for supplementary irrigation conditions, while phosphorus (P₂O₅) was applied as 6 kg in both environments. In the experiments, all phosphorus and 6 kg of nitrogen were applied at planting, and the remaining nitrogen was applied at the end of the tillering period. In the trial conducted under supplementary irrigation conditions, irrigation was performed during the heading stage and continued until the soil in each plot reached full saturation. In the experiment, 452.42 g l⁻¹ 2,4-d 2-ethylhexyl ester+6.25 g l⁻¹ florasulam and 50 g l⁻¹ pinoxaden+12.5 g l⁻¹ cloquintocet-mexyl were used against narrow and broad-leaved weeds when the weeds had 2-4 leaves. The names/pedigrees of the genotypes included in the study and where they were obtained were given in Table 1.

Table 1. Pedigree and Origin of Bread Wheat Genotypes Used in the Study

Genotipler	Pedigri	Breeding Organization or Origin
G1	WORRAKATTA/2*PASTOR//DANPHE #1 CMSA07M00403S-040ZTM	CIMMYT
G2	KA/NAC//TRCH/3/DANPHE #1 CMSA07M00445S-040M-0	CIMMYT
G3	BAV92//IRENA/KAUZ/3/HUITES/4/2*ROLF07 CMSS06Y00875T-099	CIMMYT
G4	FRET2/TUKURU//FRET2/3/MUNIA/CHTO//AMSEL/4/FRET2/TUKURU	CIMMYT
Dinç	Kontrol	GAP UTAEM
G6	WBLL1/FRET2//PASTOR*2/3/MURGA CMSS06Y00937T-	CIMMYT
G7	FRNCLN*2/TECUE #1 CMSS07Y00941T-099TOPM-099Y-	CIMMYT
G8	CEYHAN99//TUJ"S"/ONELTO SEE06032	CIMMYT
G9	BAV92//IRENA/KAUZ/3/HUITES/4/DOLL	CIMMYT
Pehlivan	Kontrol	TTAEM
G11	ATTILA/BAV92//PASTOR/3/ATTILA*2/PBW65	CIMMYT
G12	CUNNINGHAM/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ	CIMMYT
G13	SOKOLL/EXCALIBUR CMSA04Y00612S-25ZTP0Y-010M-	CIMMYT
G14	WBLL1*2/KKTS//PASTOR/KUKUNACMSS05B00525S	CIMMYT
Aday-12	Kontrol	GAP UTAEM
G16	KACHU/5/NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR	CIMMYT
G17	B.HASHI+B764TA/5/DOVE/INIA/4/4777/(2)//FKN/GB/3/PVN SEE060	CIMMYT
G18	KRICHAUFF/2*PASTOR/4/MILAN/KAUZ//PRINIA/3/BAV92	CIMMYT
G19	HEILO//SUNCO/2*PASTORCMSA06Y00492S-040ZTY	CIMMYT
Tekin	Kontrol	GAP UTEAM.
G21	FRNCLN/ROLF07CMSS06B00013S-0Y-099ZTM-099Y	CIMMYT

G22	BECARD/KACHU CMSS06B00169S-0Y-099ZTM-099Y-09	CIMMYT
G23	ROLF07*2/5/REH/HARE/2*BCN/3/CROC_1/AE.SQUARROSA (213)	CIMMYT
G24	USHER-16 CROW'S/BOW'S-1994/95//ASFOOR-5 ICW01	CIMMYT
Ceyhan-99	Kontrol	DATAE

CIMMYT: International Maize and Wheat Improvement Center, GAP UTAEM: Directorate of GAP International Agricultural Research and Education Center, TTAEM : Thrace Agricultural Research Institute Directorate, DATAE: Eastern Mediterranean Agricultural Research Institute

In the study, grain yield was evaluated over 4 replications, while quality analyses were evaluated over 3 replications due to workload and cost. To determine the grain yield, after the harvest-threshing process was completed separately in each plot, the product obtained was weighed on a ± 0.001 precision scale and the grain yield was recorded in kg da^{-1} . thousand-grain weight was determined by counting 4×100 seeds and weighing them and multiplying the average by 10 [19]. Test weight and protein ratio were determined by reading the grain surface with the NIT (model 6500) device. The amount of zeleny sedimentation was measured according to the method recommended by the International Association of Cereal Science and Technology [20].

Variance analysis of the features examined in the research was performed in the JMP 13.0.1 pro package program. Differences between genotypes in the examined traits and the resulting groups were determined at $p \leq 0.01$ level according to the Least Significant Difference (LSD) test [21]. In addition, visual graphics showing the relationships between traits, genotype-trait relationships and stability of genotypes were created using the Genstat 12th package program [22].

RESULTS AND DISCUSSION

The average values and importance groups of the features examined in the study were given in Tables 2 and 3. According to the results of variance analysis (ANOVA) obtained by combining the environments, there were significant differences at the level of $p \leq 0.01$ in genotype, environment and genotype*environment interaction (except zeleny sedimentation). The statistical significance of the environments indicates that the results obtained based on the environments are not the same, and the interaction indicates that the genotypes respond differently based on the environments in terms of the examined traits.

Grain Yield (kg da^{-1}): In the study, G14 (654.8 kg da^{-1}) and G22 (642.7 kg da^{-1}) genotypes gave the highest grain yield in based on rainfall conditions, and G22 (875.0 kg da^{-1}) and Dinç (874.7 kg da^{-1}) genotypes in the same group gave the highest grain yield in supplementary irrigation conditions (Table 2). When the based on rainfed conditions were compared with supplementary irrigation conditions, 22.3-41.3% loss in grain yield was found.

It was determined that the highest yield loss was in G2 and the lowest yield loss was in G14. According to the combined years, G14 (748.5 kg da^{-1}), G22 (758.8 kg da^{-1}) and Dinç (720.9 kg da^{-1}) genotypes were the most

productive. It has been emphasized that the increase in the unit area yield of wheat is related to the improvement in some factors that contribute to yield (spike length, thousand-grain weight, biological yield, etc.) [23, 24].

Test Weight (hl kg^{-1}): In rainfed conditions, G3 (81.6 kg hl^{-1}) and Tekin (81.5 kg hl^{-1}), and in supplementary irrigation conditions, G18 (83.4 kg hl^{-1}) and Tekin (83.6 kg hl^{-1}) were in the same group and gave the highest test weight (Table 2). A decrease in test weight was found between 0.6% and 10.9% under based on rainfed conditions compared to supplementary irrigation conditions. The highest test loss was in G21 and the lowest loss was in G7.

According to the combined environments, G3 (81.83 kg hl^{-1}), G18 (81.78 kg hl^{-1}) and Tekin (82.55 kg hl^{-1}) genotypes shared the same group and gave the highest test weight values (Table 2). The test weight is one of the basic technological quality parameters in the classification of wheat. It has been reported that test weight, which is an indicator of grain density, may vary depending on environmental conditions, grain structure and genetic structure of the genotype [25, 26].

Thousand-Grain Weight (g): Based on rainfall conditions, Aday-12 (36.6 g) and Pehlivan (35.1 g), in supplementary irrigation conditions, G22 (42.5 g) and Pehlivan (41.6) shared the same group and had the largest grains. When rainfed conditions were compared with supplementary irrigation conditions, 2.6-26.8% decrease in thousand-grain weight was found. The highest thousand-grain weight loss was in G24 and the lowest loss was in G12. According to the combined environments, Pehlivan (38.38 g), Aday-12 (38.63 g) and G22 (38.81 g) genotypes gave the highest thousand-grain weight value.

In wheat cultivation, soil structure and cultivation techniques, as well as climate and genotypic effects during flowering and grain filling periods, have a significant effect on thousand-grain weight (grain size) [26]. While it was emphasized that the thousand-grain weight, which is one of the technological quality parameters, showed a parallel change with the grain size, it was the feature that directly affected the grain flour yield [27, 28].

Protein Ratio (%): In rainfed conditions, G16 (16.90%), G19 (17.05%) and G24 (17.60%), and in supplementary irrigation conditions, G7 (15.22%), G13 (15.15%) and G17 (15.50%) gave the highest protein ratio values. When rainfed conditions were compared with supplementary irrigation conditions, an increase in protein ratio between 0.7-18.5% was found, except for G3 (-2.4%) and G7 (-0.6%). Under supplementary irrigation conditions, the highest protein ratio loss was

found in Ceyhan-99, while the highest increase was found in G3.

According to the combined years; the highest protein ratio was obtained from the genotypes G1 (15.65%), G16 (15.73%), G17 (15.70%), G19 (15.73%), Tekin (15.65%) and G24 (16.08%). Although heredity is important in the protein ratio of wheat, the protein ratio is mostly affected by climate, soil structure and applied fertilizer [29].

Zeleny Sedimentation (ml): In rainfed conditions, G6 (48.50 ml), G17 (47.00 ml), Tekin (46.33 ml) and G23 (45.50 ml), and in supplementary irrigation conditions, G7 (45.00 ml), G17 (45.50 ml) and Tekin (44.00 ml) gave the highest amount of zeleny sedimentation. When rainfed conditions were compared with supplementary irrigation conditions, the amount of zeleny sedimentation increased between 0.0-23.2% except for G7 (-3.4%).

When the supplementary irrigation conditions were compared with based on the rainfall conditions, the highest zeleny sedimentation loss was found in G24 and the lowest loss was found in G7. According to the combined-year data, zeleny sedimentation values ranged from 28.17 ml to 46.50 ml. It has been emphasized that the amount of zeleny sedimentation is one of the important analyses in determining gluten quality, and that high zeleny sedimentation amount indicates high gluten quality and quantity [30, 28].

In the GGE biplot technique, the relationship between features is explained by the angle between the vectors representing both features. It has been reported by many researchers in different studies that there is a positive relationship as the angle value ($>0^{\circ}$ -- $<90^{\circ}$) between the vectors of two features narrows, a negative relationship as the angle value (90° -- $<180^{\circ}$) increases, and there is no relationship when the angle value $=90^{\circ}$ [31, 32, 33, 34].

The feature with longer vector length is more discriminative than the feature with shorter vector length. Low-level features are uninformative and misleading [18, 34]. In the study, it was observed that the zeleny sedimentation feature was the most effective feature in distinguishing the genotypes in based on rainfed conditions (Fig. 3).

In the experiment carried out in both environments, a positive relationship was observed between test weight and thousand-grain weight and protein content and zeleny sedimentation amount, while grain yield was found to be negatively related to protein content and zeleny sedimentation amount (Fig. 3 and 4).

Table 2. Average Values and Groups Formed for Grain Yield and Technological Quality Traits (**: Significant at 1% Level)

Genotype	Grain yield (kg da ⁻¹)				Test weight (kg hl ⁻¹)				Thousand-grain weight (g)												
	Irrigated	Rainfed	Loss (%)	Mean	Irrigated	Rainfed	Loss (%)	Mean	Irrigated	Rainfed	Loss (%)	Mean									
G1	774.9	def	503.8	g-j	35.0	639.3	ij	80.2	ijkl	75.5	i	5.8	77.83	lm	33.9	jk	27.3	gh	19.6	30.56	ij
G2	747.3	f	438.5	j	41.3	592.9	j	80.7	ijk	79.0	b-f	2.1	79.80	f-i	31.6	n	30.0	efg	5.1	30.81	i
G3	866.5	ab	560.4	c-h	35.3	713.5	a-e	82.1	c-f	81.6	a	0.7	81.83	ab	39.1	cd	34.1	abc	12.8	36.63	b
G4	873.0	a	528.9	d-i	39.4	701.0	b-g	82.3	c-f	80.7	ab	1.9	81.45	bc	37.9	de	34.6	ab	8.6	36.25	bc
Dinç	874.7	a	567.0	c-h	35.2	720.9	abc	82.1	c-f	79.7	b-e	2.9	80.85	b-e	31.8	mn	29.3	fg	7.9	30.50	ij
G6	772.8	def	478.3	ij	38.1	625.5	ij	82.6	bcd	78.7	c-g	4.7	80.65	c-f	37.8	def	31.3	c-f	17.2	34.50	de
G7	776.8	def	478.8	ij	38.4	627.8	ij	78.9	m	78.4	d-h	0.6	78.63	ijkl	35.0	ij	33.5	a-d	4.1	34.25	def
G8	814.6	a-e	625.2	abc	23.2	719.9	a-d	82.3	c-f	79.9	a-d	2.9	81.05	bcd	37.5	efg	32.8	b-e	12.7	35.13	bcd
G9	769.8	def	577.3	b-g	25.0	673.5	c-i	81.8	d-g	80.1	a-d	2.1	80.93	bcd	35.0	ij	33.2	bcd	5.2	34.13	def
Pehlivan	823.3	a-d	555.0	c-h	32.6	689.2	c-h	81.0	hij	78.8	c-g	2.7	79.85	fgh	41.6	ab	35.1	ab	15.6	38.38	a
G11	789.6	c-f	545.4	d-i	30.9	667.5	e-i	82.2	c-f	78.8	c-g	4.2	80.48	c-g	32.0	lmn	29.3	fg	8.5	30.69	ij
G12	815.0	a-e	594.8	a-d	27.0	704.9	b-f	81.1	ghı	78.0	e-h	3.9	79.53	g-j	33.8	jk	32.9	b-e	2.6	33.31	efg
G13	767.3	def	580.0	b-f	24.4	673.7	c-i	80.2	ijkl	78.5	d-g	2.1	79.30	hij	36.1	ghı	34.0	abc	5.9	35.06	bcd
G14	842.3	abc	654.8	a	22.3	748.5	ab	81.8	e-h	79.1	b-f	3.3	80.40	d-g	36.8	e-h	33.4	bcd	9.2	35.06	bcd
Aday-12	792.5	c-f	534.0	d-i	32.6	663.3	f-i	80.0	kl	76.6	hı	4.3	78.30	kl	40.6	bc	36.6	a	9.8	38.63	a
G16	811.5	a-f	621.5	abc	23.4	716.5	a-d	82.7	bc	77.1	ghı	6.8	79.88	e-h	36.9	e-h	30.8	def	16.6	33.81	def
G17	789.8	c-f	510.7	e-j	35.3	650.2	hı	81.5	fgh	77.7	fgh	4.7	79.60	g-j	33.4	kl	30.6	def	8.2	32.00	ghı
G18	752.4	ef	581.7	a-e	22.7	667.1	e-i	83.4	ab	80.2	a-d	3.8	81.78	ab	36.9	e-h	33.1	be	10.2	35.00	b-e
G19	769.0	def	502.4	hij	34.7	635.7	ij	81.1	ghı	76.6	hı	5.5	78.85	ijk	31.0	n	27.0	gh	12.9	29.00	jk
Tekin	807.4	b-f	535.5	d-i	33.7	671.4	d-i	83.6	a	81.5	a	2.5	82.55	a	36.3	f-i	33.4	bcd	7.9	34.81	cde
G21	803.0	b-f	506.3	f-j	37.0	654.6	ghı	79.6	lm	70.9	k	10.9	75.20	o	35.5	hı	27.4	gh	22.9	31.44	hı
G22	875.0	a	642.7	ab	26.5	758.8	a	82.4	cde	80.5	abc	2.3	81.40	bc	42.5	a	35.1	ab	17.3	38.81	a
G23	827.9	a-d	498.1	hij	39.8	663.0	f-i	80.1	kl	73.2	j	8.6	76.60	n	36.1	ghı	29.4	fg	18.7	32.75	fgh
G24	814.8	a-e	510.1	e-j	37.4	662.4	f-i	77.7	n	71.0	k	8.6	74.35	o	31.8	mn	23.3	i	26.8	27.50	k
Ceyhan-99	866.7	ab	520.8	e-i	39.9	693.7	c-h	81.2	ghı	73.3	j	9.7	77.25	mn	33.3	klm	24.9	hı	25.2	29.06	jk
Environment LSD (0.05)	-	-	-	-	18.4**	-	-	-	0.3**	-	-	-	-	-	-	-	-	-	-	1.0**	-
Genotype LSD (0.05)	64.6**	73.8**	-	48.6**	0.9**	1.8**	-	1.0**	1.5**	3.1**	-	1.7**	-	-	-	-	-	-	-	-	-
Environment *Genotype LSD (0.05)	-	-	-	68.8**	-	-	-	-	1.4**	-	-	-	-	-	-	-	-	-	-	-	2.4**
CV (%)	5.7	9.6	-	7.3	0.6	1.4	-	1.1	2.6	6.1	-	4.5	-	-	-	-	-	-	-	-	-

Table 3. Average Values of Protein Ratio and Zeleny Sedimentation Amount

Genotype	Protein ratio (%)					Zeleny sedimentation (ml)								
	Irrigated	Rinfed	Loss (%)	Mean		Irrigated	Rainfed	Loss (%)	Mean					
G1	14.80	a-g	16.50	bcd	10.3	15.65	ab	41.00	cd	44.17	a-e	7.2	42.58	c
G2	14.88	a-f	15.22	f-1	2.2	15.05	cde	33.00	i-l	37.00	hi	10.8	35.00	fgh
G3	14.27	e-1	13.93	l	-2.4	14.10	gh	36.50	e-h	41.00	e-h	11.0	38.75	de
G4	12.98	jk	14.07	kl	7.7	13.53	h	31.50	kl	36.67	hi	14.1	34.08	h
Dinç	14.10	ghi	14.80	i-l	4.7	14.45	fg	32.00	jkl	37.00	hi	13.5	34.50	gh
G6	14.55	b-g	16.15	b-f	9.9	15.35	bc	44.50	ab	48.50	a	8.2	46.50	a
G7	15.22	ab	15.13	g-j	-0.6	15.18	b-e	45.00	a	43.50	b-f	-3.4	44.25	abc
G8	14.20	f-1	15.00	h-k	5.3	14.60	efg	34.50	g-j	40.33	e-h	14.5	37.42	def
G9	15.08	a-d	15.52	e-1	2.8	15.30	bcd	38.50	de	38.50	ghi	0.0	38.50	de
Pehlivan	14.65	b-g	16.15	b-f	9.3	15.40	bc	26.50	m	29.83	k	11.2	28.17	ı
G11	13.75	hi	15.10	g-j	8.9	14.43	fg	37.00	efg	40.33	e-h	8.3	38.67	de
G12	14.45	c-h	15.90	d-h	9.1	15.18	b-e	34.00	h-k	39.83	e-h	14.6	36.92	efg
G13	15.15	abc	15.25	f-1	0.7	15.20	bcd	36.00	e-h	41.83	d-g	13.9	38.92	de
G14	12.85	k	14.20	jkl	9.5	13.53	h	26.50	m	31.50	jk	15.9	29.00	ı
Aday-12	14.25	f-1	15.25	f-1	6.6	14.75	def	34.50	g-j	38.83	ghi	11.2	36.67	e-h
G16	14.55	b-g	16.90	abc	13.9	15.73	ab	35.50	f-1	43.67	b-f	18.7	39.58	d
G17	15.50	a	15.90	d-h	2.5	15.70	ab	45.50	a	47.00	ab	3.2	46.25	ab
G18	14.85	a-f	15.15	ghi	2.0	15.00	c-f	34.50	g-j	39.00	gh	11.5	36.75	efg
G19	14.40	d-h	17.05	ab	15.5	15.73	ab	31.00	l	39.67	fgh	21.8	35.33	fgh
Tekin	15.00	a-e	16.30	b-e	8.0	15.65	ab	44.00	ab	46.33	abc	5.0	45.17	abc
G21	14.20	f-1	16.70	a-d	15.0	15.45	bc	37.50	ef	42.00	c-g	10.7	39.75	d
G22	14.40	d-h	16.00	c-g	10.0	15.20	bcd	34.50	g-j	39.33	fgh	12.3	36.92	efg
G23	14.25	f-1	16.30	b-e	12.6	15.28	bcd	42.00	bc	45.50	a-d	7.7	43.75	bc
G24	14.55	b-g	17.60	a	17.3	16.08	a	26.50	m	34.50	ij	23.2	30.50	ı
Ceyhan-99	13.65	ij	16.75	a-d	18.5	15.20	bcd	37.00	efg	41.00	e-h	9.8	39.00	de
Environment	-	-	-	-	0.4**	-	-	-	-	-	-	-	2.2**	-
LSD (0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Genotype LSD (0.05)	0.7**	0.9**	-	0.6**	-	2.9**	4.4**	-	-	-	-	-	2.6**	-
Environment * Genotype	-	-	-	0.8**	-	-	-	-	-	-	-	-	ö.d.	-
LSD (0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CV (%)	3.1	3.6	-	3.4	-	4.9	6.6	-	-	-	-	-	5.9	-

** %1 seviyesinde önemli

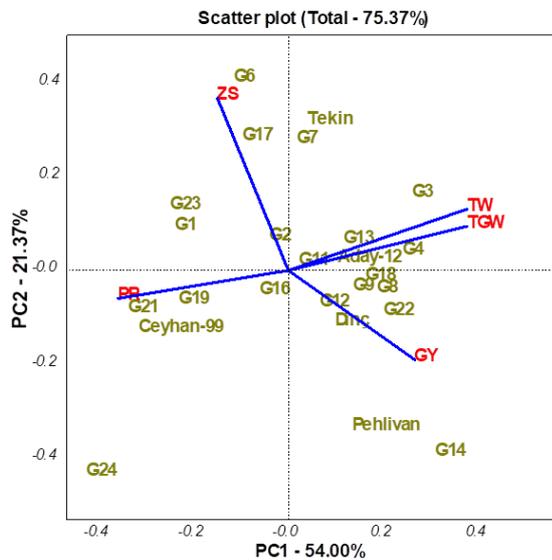


Figure 3. Genotype-Trait Relationship Based on Rainfall Conditions

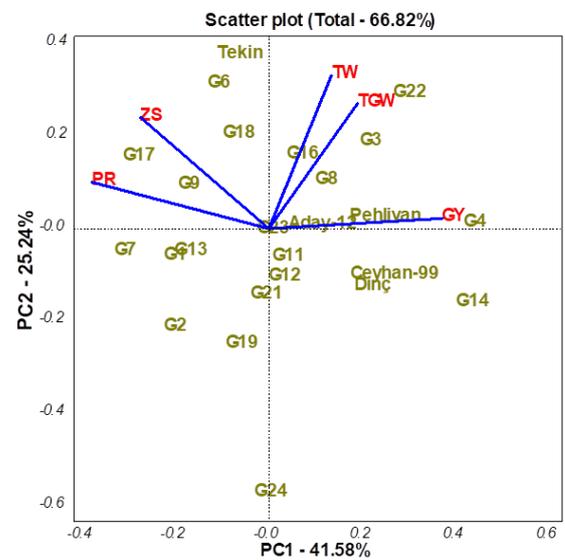


Figure 4. Genotype-Trait Relationship Under supplementary Irrigation Conditions

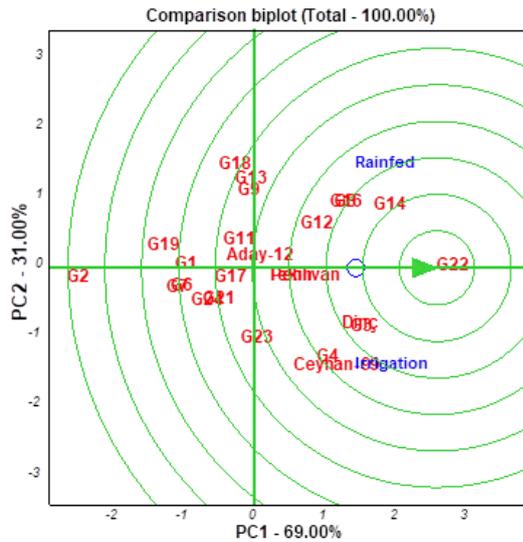


Figure 5. GGE Biplot Graph Showing Ideal Genotype

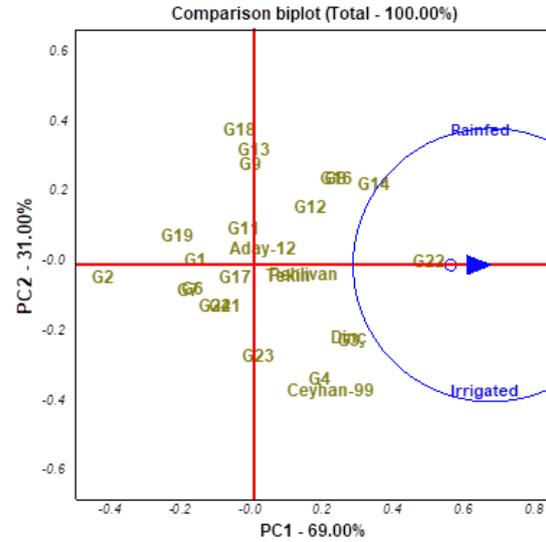


Figure 6. GGE Biplot Graph Showing Ideal Environment

When the biplot graph in Fig. 3, which visually shows the genotype-trait relationship in rainfed conditions, was examined, it was seen that G14 and G22 in grain yield, Tekin and G3 in test weight, Aday -12 and G22 in thousand-grain weight, G24 in protein ratio, G6 and G17 in zeleny sedimentation amount were in the first place. In supplementary irrigation conditions, G4 and G22 were prominent in grain yield, Tekin and G18 in test weight, G22 in thousand-grain weight, G17 in protein content, G7 and G17 in zeleny sedimentation amount were prominent (Fig. 4).

According to the GGE biplot graph showing the ideal genotype, the genotypes closest to the center of the smallest circle are accepted as the ideal genotype [35,

36]. In this context, G22 was identified as the most ideal genotype, while G14 in rainfed conditions and G3 in supplementary irrigation conditions were the following genotypes. In the study, genotypes on the left of the y-axis (G1, G2, G17, G19 etc.) are considered as undesirable genotypes (Fig. 5).

According to the comparison biplot graph showing the situation of the environments in which the study was conducted compared to the ideal (highest PC1 and lowest PC2 value) environment, it can be said that the environments were similar because they were equidistant from the ideal environment [37]. This result shows that the genotypes responded similarly in both environments in terms of the examined traits (Fig. 6).

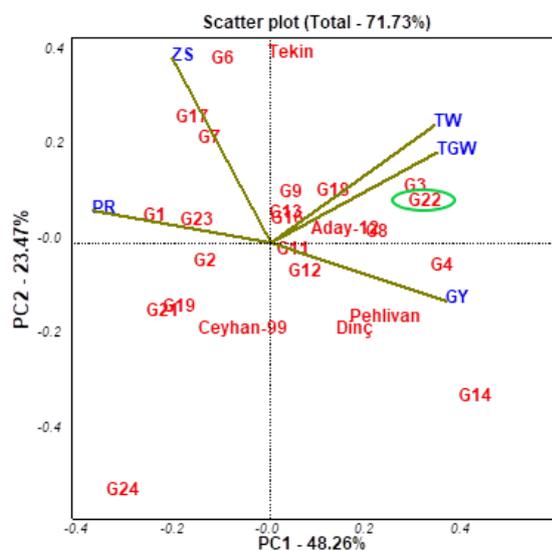


Figure 7. Contribution Levels of Traits To The Ideal Genotype According To Combined Environments

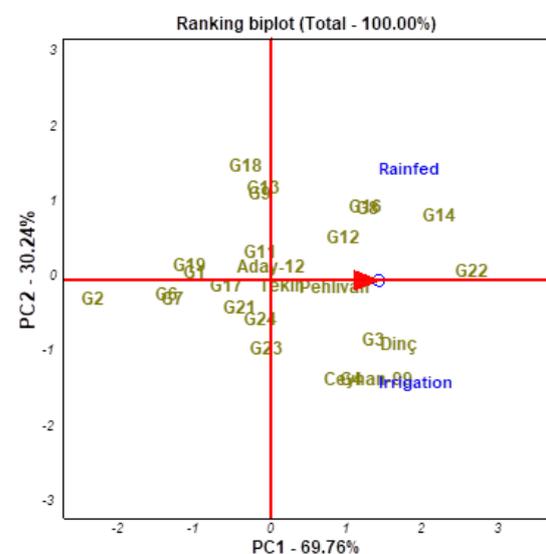


Figure 8. GGE Biplot Graph Showing the Grain Yield Stability of Genotypes

When the contribution levels of the examined traits to the ideal genotype were evaluated in the study, TGW>TW>GY>ZS>PR (Fig. 7). According to the ranking biplot graph drawn in order to determine the grain yield stability of genotypes in rainfed and supplementary irrigation conditions in the research, the principle that the yield increases as the stability line continues in the same direction and decreases as it continues in the opposite direction is accepted. It is also known that stability increases as it approaches the stability line (center of origin) and decreases as it moves away [38].

In this context, it is seen that G22>G14>Dinç>Pehlivan>Tekin>G17>G2 in terms of grain yield per unit area [39, 38, 34] (Fig. 8). In the study, the most stable genotypes were G22, Pehlivan, Tekin, Aday-12, G17 and G1, while Ceyhan-99, G18 and G23 were the most unstable and most responsive genotypes to changing environments. While G22 ranked first with high yield and stability, G14 was the following genotype in terms of grain yield (Fig. 8) [34].

CONCLUSION

It was found that, compared to rainfed conditions, a single irrigation applied at the heading stage increased grain yield by 22.3-41.3%, test weight by 0.6-10.9%, and thousand-grain weight by 2.6-26.8%, while decreasing protein ratio by 0.7-18.5% and zeleny sedimentation value by 0.0-23.2%. While the G14 genotype gave the lowest response to supplementary irrigation, the G2 genotype gave the highest response. In both environments where the study was conducted, the genotype with the highest adaptation, unit area yield and stability was G22, while G14 was the following genotype. In terms of quality traits, Aday-12, Tekin and G17 genotypes attracted attention with their high quality values. As a result of the research, it was concluded that a single irrigation during the heading period in conditions with limited irrigation opportunities caused a significant increase in yield.

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