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Determination of Adaptability of Advanced Bread Wheat (*Triticum aestivum* L.) Lines under Rainfed Conditions

Gözde Hafize Yıldırım[1], Fatih Öner[2]

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ABSTRACT

Background: This study was conducted during the 2021/2022 and 2022/2023 wheat growing seasons in Ordu province to determine the adaptability of 99 bread wheat (*Triticum aestivum* L.) genotypes obtained from theinternational winter wheat improvement program (IWWIP) and the international maize and wheat improvement center under rainfed conditions.

Methods: In the first year, the experiment was conducted using the augmented experimental design, while in the second year, it was conducted using the randomized complete block design with three replications. The study examined various phenological, morphological, agronomic, quality and some biochemical grain content parameters in wheat genotypes.

Result: According to the biplot analysis, significant variations were determined among the genotypes in terms of different traits. Regarding morphological and agronomic characteristics, genotypes 5, 67, 33 and 36 stood out with superior performance in traits such as plant height (10.94-66.51 cm), flag leaf length (10.74-24.04 cm), flag leaf width (0.87-2.3 cm), flag leaf area (9.53-33.6 cm^2), spike weight (0.82-2.54 g), spike length (4.79-9.66 cm), number of spikes per square meter (144.58-565.83 spikes/m^2), grain yield per spike (0.67-1.63 g), number of grains per spike (14.69-40.45), thousand kernel weight (23.01-45.84 g), grain yield per decare (186.13-348.13 kg/da) and harvest index (24.13-60.38%). In terms of quality traits, genotypes 42, 14, 11, 5, 27, 65, 73 and 36 were found to be superior for Zeleny sedimentation value (24.07-62.07 ml), delayed sedimentation value (10-72.07 ml), grain protein content (10.01-16.71%), grain moisture content (11.73-14.63%), wet gluten content (17.67-40.07%) and gluten index (24.07-98.07%). Additionally, in terms of biochemical content, genotypes 33, 65, 93, 24 and 42 were notable.

Key words: APX, Bread wheat, CAT, MDA, Proline.

INTRODUCTION

Wheat (*Triticum* L.), a member of the Poaceae family, is an annual plant species that grows, develops and can be harvested in a short period. In general, it can be cultivated in almost every part of the world (Özkan, 2022). Due to its high adaptability, it has spread over vast areas worldwide. It can be easily cultivated in regions where there are no extreme temperatures or excessive rainfall. Moreover, breeding studies have made it possible to grow wheat in areas with various soil structures (Okhan, 2022; Kumar and Brar, 2021; Ghedabna *et al*., 2023).

In addition to the negative impact of decreasing agricultural lands and the rapidly increasing population, the rapidly changing climate conditions lead to restrictions on demanded food products. In this regard, high-yield varieties developed to meet these challenges are of great importance (Güngör *et al*., 2022). Therefore, yield studies compatible with changing climate conditions continue. The impact of the environment on wheat genotypes is closely related to its yield and quality traits. Since many characteristics such as tillering (fertile tillers), spike yield values and 1000 kernel weight are directly associated with yield (Li *et al*., 2020; Wato, 2021; Joy *et al*., 2021), any adverse environmental conditions and stress factors will lead to significant losses.

The main objectives of this study are as follows

The bread wheat lines used in this study already have characteristics that allow them to adapt to rainfed conditions. In the first phase, the aim is to determine the adaptation abilities of these lines, collected from different climatic regions of the world, specifically to the ecological conditions of Ordu in the Central Black Sea Region. Later, they can be evaluated as research materials for different and similar regions, thus gradually improving their adaptation abilities. Globally, regions with excessive rainfall or humidity pose a risk for bread wheat cultivation. These risks result in yield losses and economic losses for farmers. This study also aims to reduce the risks associated with bread wheat cultivation in agricultural areas located in humid or rainy regions of the world. For this purpose, this study has been established to determine the

[1]Department of Field Crops, Faculty of Agriculture, Recep Tayyip Erdoğan University, Rize/Turkey.
[2]Department of Field Crops, Faculty of Agriculture, Ordu University, Ordu/Turkey.

Corresponding Author: Gözde Hafize Yıldırım, Department of Field Crops, Faculty of Agriculture, Recep Tayyip Erdoğan University, Rize/Turkey. Email: gozdehafize@hotmail.com

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adaptation characteristics of bread wheat lines and varieties under the ecological conditions of Ordu.

MATERIALS AND METHODS

Plant material and experimental design

This study was conducted during the 2021-2022 and 2022-2023 wheat production seasons at the experimental field of the Field Crops Department, Faculty of Agriculture, Ordu University. The experimental site is referred to as the Ordu Organized Industrial Zone. This region is located in the Altınordu district of Ordu province, on the coast of the Black Sea. The area's elevation reaches up to 10 meters above sea level. The Black Sea climate prevails in this region, characterized by mild and rainy winters and cool, rainy summers. During the experimental period, the region's long-term average temperature was 12.68°C. The warmest month is July, with an average temperature of 23.2°C, while the coldest month is January, with an average temperature of 7°C. The average precipitation for the same period is 84.81 mm, with higher precipitation occurring in the winter months. The average humidity level of the region is 76.56%

Table 1: Variance analysis results and details of bread wheat lines and varieties.

Lines and varieties	F	p	Mean	S.D.	Varyans	Minimum	Maximum
P.H.**	127.06	<0.001	80.31	8.53	72.68	66.03	100.63
F.L.L.**	388.030	<0.001	14.81	2.75	7.59	10.55	24.44
F.L.W.**	3.280	<0.001	1.41	0.38	0.14	66.03	100.63
F.L.A.**	7.720	<0.001	17.17	6.29	39.50	5.42	39.95
S.E.P.M.**	63.710	<0.001	308.30	99.70	9946.30	128.80	590.00
E.W.**	6.730	<0.001	1.40	0.44	0.20	0.64	2.62
E.L.**	29.920	<0.001	6.78	1.04	1.08	4.63	9.88
G.W.P.E.**	3.010	<0.001	1.11	0.33	0.11	0.54	2.05
G.N.P.E.**	884.270	<0.001	24.52	5.94	35.32	14.30	40.95
T.G.W.**	648.330	<0.001	31.70	5.09	25.92	22.90	46.10
T.P.C.**	6693.960	<0.001	203.61	37.12	1378.25	130.00	281.02
T.F.C.**	3.050	<0.001	119.53	35.81	1282.35	73.34	210.38
T.A.C.**	2243.760	<0.001	88.67	4.35	18.96	79.57	96.00
PR.**	15.790	<0.001	83.18	4.83	23.28	71.76	93.11
CAT**	172.680	<0.001	16.28	9.94	98.85	2.28	52.50
AS.**	2364.000	<0.001	0.70	1.15	1.32	0.12	6.58
L.P.A.**	6123.090	<0.001	1.47	0.45	0.20	1.00	3.21
T.CH.**	10608.770	<0.001	5.59	0.59	0.35	4.11	7.30
CHL-A**	5852.190	<0.001	2.83	0.44	0.19	1.80	3.85
CHL-B**	5.480	<0.001	2.65	0.33	0.11	0.36	3.47
T.C.**	402.830	<0.001	1.04	0.11	0.01	0.79	1.38
H.W.**	389.940	<0.001	69.69	4.63	21.45	60.70	79.70
Z.S.V.**	2099.120	<0.001	38.43	8.58	73.52	23.00	62.70
D.S.**	1372.930	<0.001	34.45	14.99	224.78	8.70	72.70
G.P.C.**	4.780	<0.001	13.97	1.82	3.32	8.79	17.93
W.G.C.**	717.950	<0.001	25.30	5.38	28.95	16.60	40.70
G.I.**	10840.490	<0.001	55.31	25.69	660.03	23.00	98.70
G.M.C.**	1.210	0.259	12.83	1.28	1.65	10.48	15.86
Y.P.H.**	124.140	<0.001	282.22	48.88	2389.07	184.00	350.50
H.I.**	20.780	<0.001	32.94	8.34	69.61	22.50	64.03

*N.S.: Not significant. : Significant at the 0.01 level. Mean: Average, S.D: Standard deviation, AS: Ascorbate peroxidase activity (EU/mg protein), E.W.: Ear weight (g), P.H.: Plant height (cm), H.D.: Heading duration (days), T.G.W.: Thousand grain weight (g), G.W.P.E.: Grain weight per ear (g), G.N.P.E.: Grain number per ear, E.L.: Ear length (cm), F.L.A.: Flag leaf area (cm²), F.L.W.: Flag leaf width (cm), F.L.L.: Flag leaf length (cm), E.T.: Emergence time (days), Y.P.H.: Yield per hectare (kg/ha), P.M.D.: Physiological maturity duration (days), G.I.: Gluten index (%), D.S.: Delayed sedimentation (ml), H.I.: Harvest index (%), H.W.: Hectoliter weight (hl), T.I.: Tillering iterval (days), CAT: catalase activity (EU/mg protein), CHL-A: Chlorophyll-a (mg/g), CHL-B: Chlorophyll-b (mg/g), L.P.A.: Lipid peroxidase activity (µmol/gTA), S.E.P.M.: Spikelet number per square meter, Max: Maximum value, Min: Minimum value, PR.: Proline (µg/mL), S.J.: Stem jointing duration (days), S.D.: Standard deviation, T.A.C.: Total antioxidant content (%), T.P.C.: Total phenolic content (mg GAE/g), T.F.C.: Total flavonoid content (mg QE/g), T.C.: Total carotenoid content (mg/g), T.CH.: Total Chlorophyll content (mg/g), G.M.C.: Grain moisture content (%), G.P.C.: Grain protein content (%), C.V.: Coefficient of variation, W.G.C.: Wet gluten content (%), G.S.: Green stay duration (days), Z.S.V.: Zeleny sedimentation value (ml).

Table 2: Variance analysis and grouping of bread wheat lines and varieties according to agronomic traits using duncan and games-howell tests.

Lines and varieties	[1]Plant height (cm)	[1] Flag leaf length (cm)	[1]Flag leaf width (cm)	[2]Flag leaf area (cm²)	[1]Number of spikes per square meter	[2]Spike weight (g)	[1]Spike length (cm)	[2]Grain weight per spike (g)	[2]Number of grains per spike
1	91.78 bc	17.91 öp	1.34 cdef	20.90 -	209.17 bcd	1.22 ab	7.12 def	1.24 -	31.57 b
4	90.87 bc	11.84 p	1.21 def	11.25 -	308.33 hi	1.26 ab	7.80 b	0.98 -	25.85 f
5	100.9 4a	12.48 c	1.37 cdef	14.12 -	299.17 ij	0.97 ab	7.06 d-g	0.78 -	31.26 b
11	88.40 b-e	12.27 no	1.24 def	11.97 -	347.08 fgh	1.89 ab	7.64 bcd	1.18 -	27.28 ef
14	76.11 a-j	14.32 e-h	1.33 cdef	16.58 -	197.92 bc	1.26 ab	6.50 g-k	0.83 -	26.73 ef
16	84.18 d-g	13.09 f-h	1.23 cdef	13.49 -	144.58 o	1.56 ab	7.96 b	1.15 -	17.11 mno
21	87.74 b-f	17.66 n	1.04 de	14.71 -	301.67 ij	1.34 ab	6.01 jkl	1.08 -	27.34 c-f
22	77.22 d-j	13.68 gh	1.33 cdef	14.64 -	329.17 ghi	1.61 ab	6.40 i-l	1.05 -	22.40 ghı
24	66.59 j	16.38 a	1.33 cdef	18.24 -	335.42 g-f	0.95 ab	5.07 m	0.77 -	16.22 no
26	74.62 b-j	15.36 n	1.52 cd	20.56 -	214.17 lmn	1.82 ab	7.19 c-f	1.39 -	30.72 b
27	80.07 c-j	12.50 öp	1.33 cdef	13.79 -	206.25 lmn	1.27 ab	6.02 jkl	1.19 -	16.20 m-p
33	82.70 d-ı	19.48 oö	2.13 ab	33.60 -	317.08 hi	2.55 ab	9.66 a	1.63 -	40.45 a
34	81.26 d-ı	16.12 b	1.63 bcd	21.45 -	470.42 b	1.62 ab	5.98 kl	1.12 -	21.27 hýj
36	90.70 a-d	14.72 c	2.38 a	26.03 -	256.67 k	2.10 ab	7.77 bc	1.55 -	30.46 b
37	75.83 e-j	13.89 d	1.18 def	13.58 -	230.83 klm	1.54 ab	7.03 e-h	1.49 -	27.59 de
41	83.77 d-h	12.99 m	0.93 f	9.53 -	342.08 fgh	1.19 ab	7.15 def	0.98 -	22.73 gh
42	83.54 b-ı	14.19 lm	1.25 cdef	15.67 -	213.75 lmn	1.45 ab	6.60 f-j	1.38 -	28.91 bcd
62	74.80 e-j	12.89 ef	1.31 cdef	14.29 -	408.75 cd	1.02 ab	5.84 l	0.80 -	18.61 k-n
65	79.33 d-j	15.29 e	1.29 cdef	17.33 -	370.83 ef	2.02 ab	6.90 f-i	1.08 -	22.71 gh
67	95.45 ab	24.04 d	1.46 cdef	28.16 -	240.00 kl	1.52 ab	7.65 bcd	1.14 -	29.12 bc
70	71.43 ij	12.24 r	1.14 def	11.98 -	202.50 lmn	0.82 ab	6.09 jkl	0.68 -	19.89 jkl
73	79.52 d-j	10.74 jk	1.18 def	10.21 -	364.17 efg	1.50 a	6.46 h-l	1.57 -	26.91 ef
75	76.97 d-j	14.80 oö	1.74 abc	22.22 -	361.25 efg	1.53 ab	7.67 bcd	1.27 -	28.77 b-e
82	78.10 d-j	15.49 n	1.68 bcd	21.34 -	565.83 a	1.30 ab	6.20 jkl	1.02 -	28.90 bcd
83	90.50 b-d	19.53 hi	1.58 cde	24.48 -	441.67 bc	1.29 ab	7.86 b	1.26 -	23.69 g
85	66.51 j	15.01 öp	1.39 cdef	16.47 -	186.25 n	1.19 b	7.52 b-e	1.13 -	20.62 ijk
87	69.77 ij	14.86 b	1.20 cdef	15.64 -	261.25 k	0.96 ab	4.79 m	1.00 -	14.69 p
90	68.60 j	13.08 e-g	1.23 def	13.32 -	269.17 jk	1.05 ab	6.12 jkl	0.75 -	19.01 klm
93	79.34 d-j	15.15 h	1.51 cdef	17.55 -	386.67 de	1.17 ab	6.21 jkl	0.92 -	23.66 g
96	75.91 h-j	12.23 ij	1.24 def	11.84 -	467.08 b	0.92 ab	5.26 m	0.85 -	14.86 op
Mean	80.75	14.81	1.39	17.1	308.31	1.40	6.78	1.11	24.52
C.V. (%)	10.62	18.60	26.84	36.62	32.35	31.65	15.35	29.77	24.24

1: Duncan test, 2: Games-Howell, a–x: Means followed by the same letters in the same column are not significantly different at the 5% significance level. C.V.: Coefficient of variation (%).

Table 3: Variance analysis and statistical grouping of bread wheat lines based on biochemical traits.

Lines and varieties	[2]Thousand kernel weight (G)		[1]Total phenolic content (mg GAE/g)		[2]Total flavonoid content (mgQE/g)		[1]Total antioxidant content (%)		[1]Proline (µg/mL)		[1]Catalase activity (EU/ mg protein)		[1]Ascorbat peroxidase activity (EU/mg protein)		[1]Lipid peroxidation activity (µmol/ g FW or TA) (µmol/ g TA)		[1]Total Chlorophyll content (mg/g)	
1	31.93	ef	193.00	l	86.30	-	86.00	hi	82.00	g-j	16.25	hi	0.36	m	1.03	u	5.19	r
4	23.01	m	208.06	g	84.79	-	84.90	ijk	80.35	h-l	17.71	gh	0.40	l	1.59	f	5.18	s
5	24.28	m	191.00	mn	114.70	-	85.74	hi	81.28	k-j	6.57	n	0.64	g	1.08	s	5.94	f
11	33.86	e	205.67	hi	95.30	-	91.00	e	80.00	i-l	16.56	hi	0.54	h	1.45	ij	5.89	g
14	29.18	fgh	248.58	d	134.93	-	92.05	cde	86.49	j-m	20.30	f	0.73	f	1.43	kl	5.19	t
16	40.64	b	224.40	e	141.20	-	85.17	ij	78.18	k-j	8.43	f	0.73	f	1.07	s	5.64	l
21	31.70	ef	171.46	r	100.37	-	93.47	a-d	88.91	f-i	14.94	ef	0.86	d	1.03	u	6.32	b
22	23.82	m	196.00	k	97.43	-	87.00	gh	87.00	n	10.25	de	0.65	g	1.05	t	6.21	e
24	33.23	e	193.16	l	88.97	-	91.69	de	86.28	lmn	10.92	o	1.45	a	1.74	d	5.67	k
26	37.90	cd	249.50	d	90.08	-	84.93	ijk	80.54	b-f	17.00	m	0.24	qr	1.01	v	5.69	j
27	34.22	de	174.61	p	137.05	-	88.76	h	82.39	c-g	5.68	i	0.14	u	1.32	o	5.04	u
33	31.77	ef	280.02	a	154.60	-	80.57	m	73.76	k-j	3.91	i-l	0.45	j	1.54	q	6.26	d
34	27.79	g-l	203.42	j	127.75	-	83.18	kl	76.73	j-m	8.38	jk	0.17	t	1.21	r	5.37	n
36	45.84	a	253.81	c	111.29	-	94.31	ba	89.67	mn	3.28	b	1.26	b	1.77	c	6.32	c
37	27.69	ýkl	174.33	p	98.06	-	91.16	e	85.80	i-l	22.61	gh	0.43	k	1.28	p	4.88	y
41	31.19	ef	204.33	ij	156.52	-	91.07	e	85.55	b-f	21.50	n	0.22	s	1.39	m	5.96	f
42	36.67	d	210.93	f	115.20	-	85.74	hi	81.07	d-h	16.02	o	0.33	no	3.20	a	5.91	f
62	25.72	lm	207.27	gh	96.31	-	92.56	b-e	87.15	g-j	23.60	f	0.83	e	1.45	j	5.73	i
65	28.68	f-k	159.17	t	113.44	-	94.91	a	91.11	e-i	8.63	klm	0.13	u	2.59	b	5.78	h
67	38.80	bc	131.00	v	152.16	-	92.53	b-e	87.32	klm	16.40	ef	0.18	t	1.42	l	5.79	i
70	34.15	e	191.33	m	125.97	-	83.66	jkl	78.29	b-e	20.21	m	0.51	i	1.39	m	5.38	o
73	36.23	d	277.60	b	177.30	-	82.25	l	75.09	b-e	3.94	o	0.85	d	1.44	jk	7.29	a
75	29.03	f-ý	145.71	u	140.22	-	93.69	cba	88.62	bcd	22.44	g	0.23	rs	1.48	h	4.81	y
82	33.71	e	222.83	e	164.44	-	84.67	ijk	80.03	bcd	11.32	de	1.07	c	1.34	n	4.12	z
83	28.99	f-j	276.29	b	173.80	-	92.15	cde	86.00	bcd	21.52	a	0.33	no	1.46	i	4.94	v
85	29.75	fg	195.05	k	102.10	-	93.39	a-d	88.87	abc	21.31	c	0.34	n	1.72	e	5.34	o
87	33.59	e	178.00	o	98.00	-	87.00	gh	84.00	abc	18.50	hi	0.25	q	1.25	q	5.31	p
90	31.41	ef	189.30	n	109.20	-	95.00	a	82.00	abc	25.30	d	0.32	g	1.78	c	5.32	q
93	30.01	f	190.02	mn	121.34	-	88.48	fg	83.19	ab	35.39	lm	0.17	t	1.43	kl	5.40	m
96	25.54	h-m	162.50	s	76.79	-	82.91	l	77.67	a	9.42	hi	0.30	p	1.28	p	5.82	g
Mean	31.68		203.61	1	19.52		88.66		83.18		15.28		0.50		1.47		5.59	
C.V. (%)	16.06		18.23		29.96		4.91		5.80		61.08		163.59		30.32		10.52	

1: Duncan test, 2: Games-Howell, a–x: Means followed by the same letters in the same column are not significantly different at the 5% significance level. C.V.: Coefficient of Variation (%).

(Turkish State Meteorological Service, 2023). Winds generally blow from the northeast in this region. During the study period, the average monthly temperature for the 2021-2022 season was 11.05°C, while for the 2022-2023 season, it was 13.79°C.

Lines and varieties used in the experiment

In the first year of the study, 99 different bread wheat lines and varieties were tested. In the second year, 29 selected lines and varieties from the first year were included in the trial, along with the Dimenit bread wheat variety. The study material was obtained through the International Winter Wheat Improvement Program (IWWIP) in collaboration with the International Maize and Wheat Improvement Center (CIMMYT).

Experimental design, sowing, maintenance and harvesting procedures

Since the number of materials exceeded 50, the experiment was conducted according to the Augmented experimental design in the first year. Based on this design, 99 plots were prepared, with each plot containing three rows of 1-meter length. The row spacing was set at 20 cm (plot size: 100 × 60 cm) and seeds were sown in straight lines. A 1-meter distance was maintained between the plots.

In the second year of the experiment, 29 selected lines from the first year and one local variety (Dimenit) were included, making a total of 30 lines and varieties. This year, the study was conducted using the randomized complete block design (RCBD) with three replications. Accordingly, 90 plots were prepared, with each plot containing five rows of 1-meter length and a 20 cm row spacing (plot size: 100 × 80 cm).

Data collection and measurement methods

quality analyses

Zeleny sedimentation value and delayed sedimentation were determined using a 3.2 g sample (adjusted to 14% moisture) and bromophenol blue solution, with shaking and resting steps performed in a Zeleny sedimentation device (Erkaya Zeleny 120, Turkey). For delayed sedimentation, an additional incubation at 37°C for 2 hours was included. Wet gluten content was measured using a gluten washing device (Erkaya GI2030, Turkey) by forming dough with 2% NaCl solution and calculating the remaining gluten after washing. Gluten index was determined by centrifuging wet gluten at 6000 rpm (Erkaya GW2200, Turkey), where the percentage of gluten retained on the sieve indicated gluten strength. Grain protein content was analyzed following AACC Method 39-10, using the PERTEN IM 9500 device and Kjeldahl method with a nitrogen-to-protein conversion factor of 5.7.

Pigment, proline, lipid peroxidation and enzyme analyses

Total chlorophyll and carotenoid contents were determined spectrophotometrically according to Arnon (1949) by measuring absorbance at 645, 663 and 470 nm. Proline content was analyzed using the method of Bates (1973), with absorbance measured at 520 nm and results expressed as µmol/g fresh weight. Lipid peroxidation (MDA) was assessed following the method of Çakmak and Horst (1991) by measuring absorbance at 532 and 600 nm and expressed as nmol/g. Ascorbate peroxidase (APX) and catalase enzyme activities were determined using the methods of Nakano and Asada (1981) and Cho *et al*. (2000), respectively, based on absorbance readings at 290 nm and 240 nm and expressed as EU/mg protein.

Statistical analysis

The first-year data were analyzed using the R project program and evaluated through biplot analysis. Principal component analysis was used to interpret the results (Table 2, 3 and Fig 1, 2, 3, 4, 5). The second-year data were analyzed using Minitab V14 and IBM SPSS V23 software. The normality of the data distribution was tested using the Shapiro-Wilk test. Normally distributed data by lines and blocks were compared using Generalized Linear Models (GLM), with multiple comparisons conducted *via* the Duncan and Games-Howell tests. For non-normally distributed data, the Kruskal-Wallis test was applied and multiple comparisons were made using Dunn's test.

RESULTS AND DISCUSSION

Plant height showed statistically significant variation among lines ($p<0.001$), ranging from 66.51 cm (line 85) to 100.94 cm (line 5), which is consistent with the findings of Mut *et al*. (2017). Flag leaf length ranged from 10.74 cm (line 73) to 24.04 cm (line 67), in line with the values reported by Þengün (2006). Flag leaf width differed significantly ($p<0.001$), varying between 0.87 cm (line 41) and 2.3 cm (line 36) and aligns with the results of Çekiç (2008). Flag leaf area ranged from 9.53 cm^2 (line 41) to 33.6 cm^2 (line 33), which corresponds with the data presented by Mucuk (2022). Number of spikes per square meter varied significantly among lines ($p<0.001$), with values between 144.58 (line 16) and 565.83 (line 82), supporting the findings of Sakin *et al*. (2015). Spike length ranged from 4.79 cm (line 87) to 9.66 cm (line 33). Grain weight per spike showed significant variation, ranging from 0.67 g (line 71) to 1.63 g (line 33), similar to the values reported by Yiğit (2019). Number of grains per spike significantly differed among lines, ranging from 14.69 (line 87) to 40.45 (line 33), aligning with the findings of Güngör *et al*. (2019) (Table 1, 2).

In this study, significant differences ($p<0.001$) were observed among lines and varieties in terms of catalase (CAT) activity, proline content, total antioxidant and phenolic compounds, as well as technological quality parameters.

Catalase activity (CAT)

The highest mean CAT activity was recorded in line 93 (35.39 EU/mg protein) and the lowest in line 36 (3.28 EU/mg protein). Oğuz (2019) reported that CAT activity in Karahan-99 and Kınacı-97 wheat seedlings increased by 95.19% and 72.09% respectively under salt stress, while

the addition of jasmonic acid (JA) reduced these increases to 69.02% and 43.25%. These findings suggest that JA suppresses CAT activity. In line with this, our study revealed variety-dependent variations in stress response, emphasizing the importance of genetic diversity in antioxidant enzyme regulation.

Proline (µg/mL)

The highest proline content was found in line 65 (91.11 µg/mL), while the lowest was in line 33 (73.76 µg/mL). Studies by Öncel and Keleş (2002) and Yakıt and Tuna (2006) reported increased proline accumulation under stress in wheat and maize, respectively. Proline functions as an osmoprotectant, stabilizing cellular structures by attracting water, particularly under salt stress. The proline increases observed in this study are consistent with its protective role in abiotic stress tolerance.

Total antioxidant content (%)

The highest antioxidant content was found in line 91 (95%) and the lowest in line 33 (80.57%). According to Yıldır (2018),

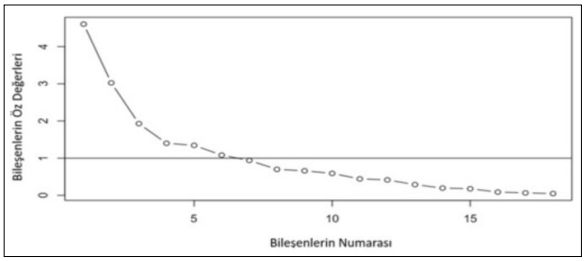


Fig 1: Scree plot.

antioxidants play a critical role in neutralizing free radicals and preventing cell damage, thereby enhancing stress resilience. The observed differences among genotypes may stem from genetic variation affecting antioxidant defense mechanisms.

Total flavonoid content

Flavonoids contribute to plant defense, growth and biological regulation. Şenlik and Alkan (2021) highlighted the importance of isoflavonoids in stress adaptation, especially in legumes and vegetables. The variation among lines in this study reflects the genetic potential for metabolite-based stress tolerance.

Total phenolic content (mg GAE/g)

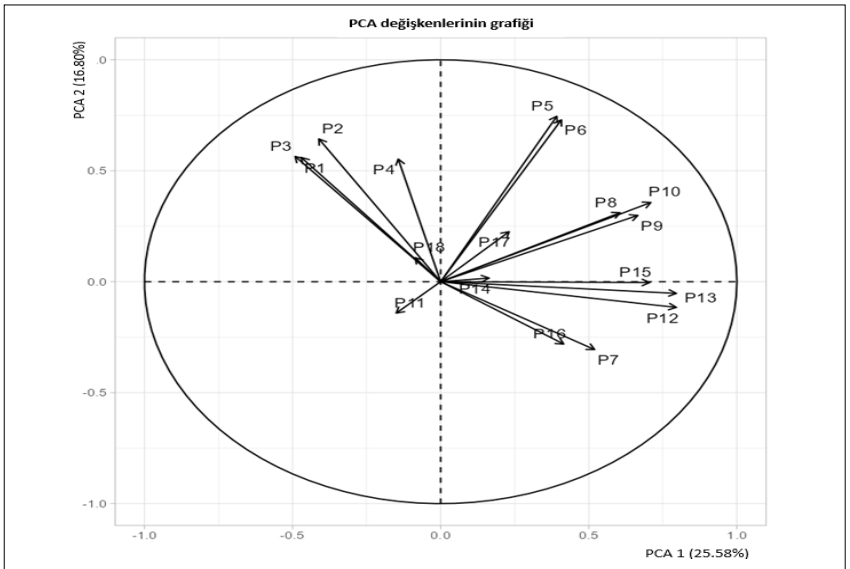
The highest phenolic content was observed in line 33 (280.02 mg GAE/g) and the lowest in line 67 (131 mg GAE/g). Phenolic compounds, besides contributing to color and aroma, play a crucial role in enhancing plant resistance against environmental stressors (Şenlik and Alkan, 2021). Therefore, lines with high phenolic content may possess stronger stress tolerance.

Zeleny sedimentation value (ml)

Line 42 had the highest sedimentation value (62.07 ml), while line 73 had the lowest (24.07 ml). These values are consistent with those reported by Enes and Ünsal (2021), Baparan *et al*. (2020) and others, indicating alignment with previously established ranges.

Delayed sedimentation value (ml)

The highest delayed sedimentation value was recorded in line 14 (72.07 ml) and the lowest in line 16 (10 ml). These



Variables: P1: Emergence time, P2: Tillering time, P3: Stem elongation time, P4: Heading time, P5: Stay-green duration, P6: Physiological maturity time, P7: Plant height, P8: Flag leaf length, P9: Flag leaf width, P10: Flag leaf area, P11: Number of spikes per square meter, P12: Spike weight, P13: Spike length, P14: Grain weight per spike, P15: Number of grains per spike, P16: Thousand kernel weight, P17: Grain protein content, P18: Grain moisture content.

Fig 2: Visualization of variables in principal component space and their vectorial relationships.

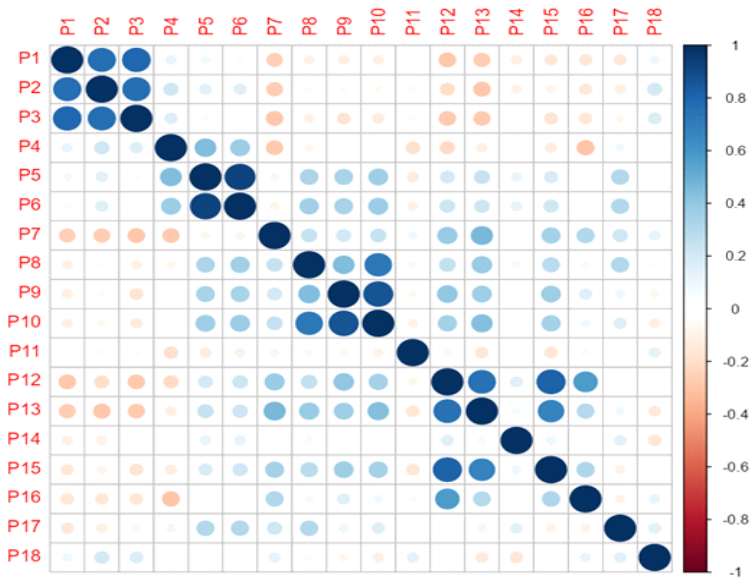
findings are in agreement with earlier studies by Balkan *et al*. (2006); Kurt (2012) and Kınabaş and Yağdı (2013), confirming the reliability of the results.

Grain protein content (%)

Line 11 exhibited the highest protein content (16.71%), while line 73 had the lowest (10.01%). These results are in line with values reported by Baykara *et al*. (2022), which ranged between 13.96% and 11.02%.

Wet gluten content (%)

The highest wet gluten content was found in line 5 (40.07%) and the lowest in line 82 (17.67%). Our findings are supported by previous studies (Baykara *et al*. 2022; Enes and Ünsal (2021),



Variables: P1: Emergence time, P2: Tillering time, P3: Stem elongation time, P4: Heading time, P5: Stay-green duration, P6: Physiological maturity time, P7: Plant height, P8: Flag leaf length, P9: Flag leaf width, P10: Flag leaf area, P11: Number of spikes per square meter, P12: Spike weight, P13: Spike length, P14: Grain weight per spike, P15: Number of grains per spike, P16: Thousand kernel weight, P17: Grain protein content, P18: Grain moisture content.

Fig 3: Correlation graph representing the relationships between principal components and variables.

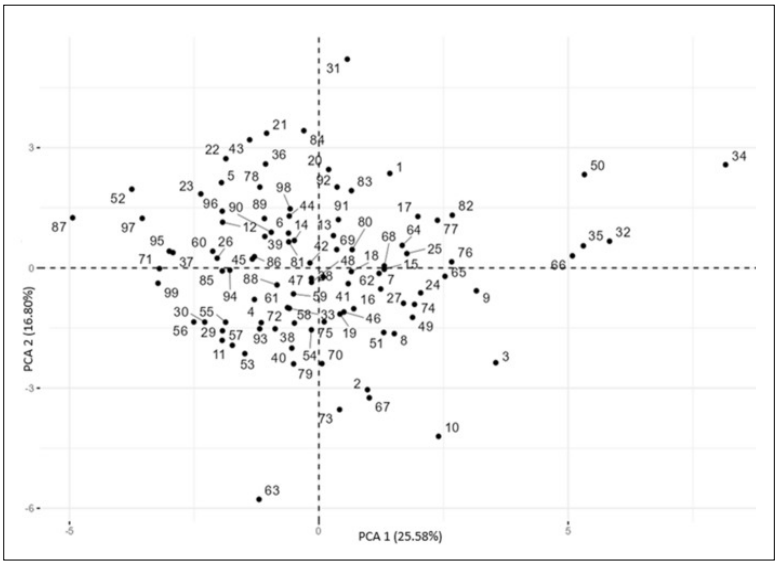
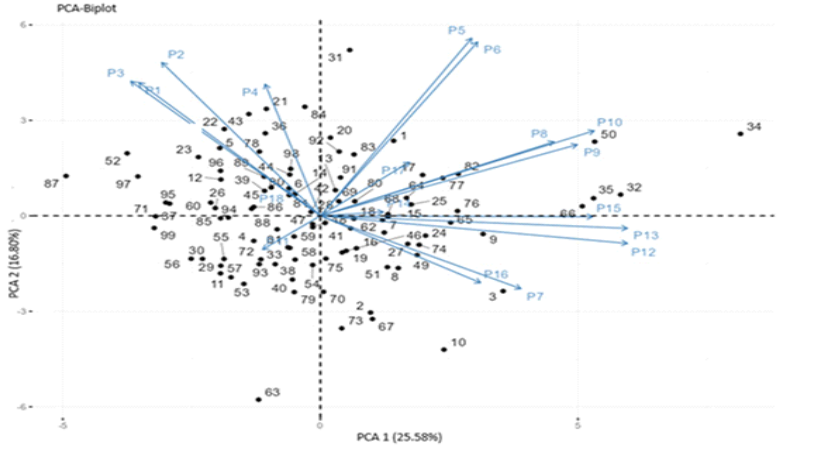


Fig 4: Positions of lines and varieties in the principal component space.



Variables: P1: Emergence time, P2: Tillering time, P3: Stem elongation time, P4: Heading time, P5: Stay-green duration, P6: Physiological maturity time, P7: Plant height, P8: Flag leaf length, P9: Flag leaf width, P10: Flag leaf area, P11: Number of spikes per square meter, P12: Spike weight, P13: Spike length, P14: Grain weight per spike, P15: Number of grains per spike, P16: Thousand kernel weight, P17: Grain protein content, P18: Grain moisture content.

Fig 5: Biplot representation of variables, lines and varieties in the principal component space.

which reported similar ranges, confirming the consistency of gluten-related quality parameters across genotypes (Table 1, 3).

CONCLUSION

Based on the results obtained from the study, a statistically significant difference was found among the distributions of all parameters except for grain moisture content according to the lines ($p<0.001$). Line selection also facilitates the acquisition of genotypes with resilience, meaning that wheat plants become more resistant to environmental factors. It is believed that conducting similar studies in different locations with the same conditions could be beneficial.

The results of the study indicate that the lines exhibit different characteristics and varying levels of resilience. Therefore, selecting lines based on the intended purpose could lead to more accurate outcomes. Similarly, including different soil structures in future studies could lead to significant variations, as a uniform soil structure might hinder the proper evaluation of certain parameters. This approach would help distinguish potential errors from the genetic characteristics of the lines. Line selection plays a crucial role in obtaining higher-yielding genotypes. Hence, the findings of this study could be valuable for future research. In addition to this study, it is recommended to examine the genetic characteristics of the lines to better determine the adaptation abilities of new varieties.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Arnon, DI. (1949). Copper enzymes in isolated chloroplasts Polyphanol-oxidase in *Beta vulgaris*. *Journal of Plant Physiology*. **24:** 1-15.

Balkan, A. and Gençtan, T. (2008). Bazı ekmeklik buğday *Triticum aestivum* L. çeşitlerinde farklı sıra arası ve tohumluk miktarının tane verimi ve verim unsurlarına etkileri. *Journal of Agricultural Sciences*. **14(01):** 29-37.

Baþaran, M., Karaman, M., Mustafa, Ö. Kan, Bilge, U. and Doğan, Ö. Kur (2020). Ekmeklik buğdayda (*Triticum aestivum* L.) kalite özelliklerinin ve tane veriminin etkileþimi ve uygun genotiplerin seçimi. *ISPEC Tarım Bilimleri Dergisi*. **4(3):** 609-622.

Bates, LS, Waldren, RP. and Teare, I.D. (1973). Rapid determination of free proline for water stress studies. *Plant Soil*. **39:** 205-207.

Baykara, F., Yıldırım, M. and Mehmet, A. (2022). Diyarbakır ekolojik koþullarında bazı yerel ve güncel makarnalık buğday çeþitlerinin verim ve kalite unsurlarının belirlenmesi. *Dicle Üniversitesi Fen Bilimleri Enstitüsü Dergisi*. **11(2):** 1-1.

Boyacı, A. (2013). Bazı ekmeklik buğday (*Triticum aestivum* L.) çeşitlerinin Çukurova koşullarında verim ve bazı kalite özellikleri yönünden değerlendirilmesi. Yüksek Lisans Tezi, Mustafa Kemal Üniversitesi, Fen-Edebiyat Fakültesi, Tarla Bitkileri Anabilim Dalı, Antakya, Türkiye.

Bayraktaroğlu, M., Taner, S., Yakıþır, E., Yıldırım, T., Çayıröz, M.A., Özer, E., Yaþar, M., Çeri, S., Göçmen Akçacık, A. and Hamzaoğlu, S. (2015). Evaluation of some bread wheat (*Triticum aestivum* L.) genotypes in terms of yield and quality parameters. In Proceedings of the 11th National Field Crops Congress, 7-10 September 2015, Çanakkale, Turkey.

Cakmak, I. and Horst, W.J. (1991). Effect of aluminium on lipid peroxidation, superoxide dismutase, catalase and peroxidase activities in root tips of soybean (*Glycine max*). *Physiologia Plantarum*. **83(3):** 463-468.

Cho, Y.W., Park, E.H.; Lim, C.J. (2000). Glutathione S-transferase activities of S-type and L-type thiol transferase from Arabidopsis thaliana. *Journal of Biochemistry and Molecular Biology*. **33:** 179-183.

Çekiç, C., Savaşlı, E., Dayıoğlu, R., Önder, O., Karaduman, Y. and Avcıoğlu, R. (2008). Determination of the relationships between planting time and frequency and quality criteria in bread wheat (*Triticum aestivum* L.). Türkiye Tahıl Sempozyumu, Konya.

Enes, A., Ünsal, N. E., Ünsal, A. S. (2021). Kuru koþullarda durum buğday çeşitlerinin verim ve kalitelerini etkileyen önemli parametrelerin belirlenmesi. *ISPEC Journal of Agricultural Sciences*. **5(1):** 246-256.

Erdoğan, E. (2018). Amik Ovası, Hatay, Türkiye koþullarında bazı ekmeklik buğday (*Triticum aestivum* L.) genotiplerinin fizyolojik, morfolojik ve kalite özellikleri açısından belirlenmesi. Yüksek Lisans Tezi, Mustafa Kemal Üniversitesi, Fen-Edebiyat Fakültesi, Tarla Bitkileri Anabilim Dalı, Hatay, Türkiye.

Ghedabna, R., Kamel, B., Benmati, H., Benmati, M., Gana, M. and Kerrouche, I. (2023). Effects of organic and inorganic fertilization: Response of wheat cultivation and interaction with soil properties. *Indian Journal of Agricultural Research*. **57(3):** 312-317. doi: 10.18805/IJARe.AF-724.

Güngör, H. ve Dumlupınar, Z. (2019). Bazı ekmeklik buğday (*Triticum aestivum* L.) çeşitlerinin Bolu koşullarında verim, verim bileşenleri ve kalite yönünden değerlendirilmesi. *Türk Tarım ve Doğa Bilimleri Dergisi.* **6(1):** 44-51.

Güngör, H., Çakır, MF. and Dumlupınar, Z. (2022). İleri ekmeklik buğday (*Triticum aestivum* L.) hatlarının verim, verim unsuru ve kalite özellikleri bakımından değerlendirilmesi. *Avrupa Bilim ve Teknoloji Dergisi.* **35:** 123-127.

Joy, J.M.M., Mitra, B. and Roy, A.K. (2021). Growth and yield performances of wheat genotypes under restricted irrigation in eastern sub-Himalayan plains. *Indian Journal of Agricultural Research*. **55(4):** 505-508. doi: 10.18805/IJARe.A-5545.

Kahrıman, F. and Egesel, C.Ö. (2011). Bazı ekmeklik buğday çeşitlerinin agronomik ve kalite özellikleri açısından değerlendirilmesi. *Ordu Üniversitesi Bilim ve Teknoloji Dergisi.* **1(1):** 22-35.

Kınabaş, S. and Yağdı, K. (2013). Ekmeklik buğday çeşitlerinde farklı tavlama rutubeti ve sürelerinin kalite özellikleri üzerine etkisi. U.Ü. Ziraat Fakültesi Dergisi. pp 33-44.

Kumar, P. and Brar, S. K. (2021). Conjugation of biofertilizers with different sources of chemical fertilizers in wheat: A review. *Agricultural Reviews*. **42(1):** 22-31. doi: 10. 18805/ag.R-2001.

Kurt, P.Ö. (2012). Bazı ileri ekmeklik buğday (*Triticum aestivum* L.) hatlarının Bursa koşullarında verim ve kalite özellikleri yönünden performansının araştırılması. Yüksek Lisans Tezi, Uludağ Üniversitesi, Fen Bilimleri Enstitüsü, Tarla Bitkileri Ana Bilim Dalı, Bursa.

Li, J., Wen, S., Fan, C., Zhang, M., Tian, S., Kang, W., Zhao, W., Bi, C., Wang, Q. and Lu, S. (2020). Characterization of a majorquantitative trait locus on the short arm of chromosome 4B for spike number per unit area in common wheat (*Triticum estivum* L.). *Theoretical Applied Genetics*. **133:** 2259-2269.

Mucuk, Ş.H. (2022). Farklı tohum oranları ve gelişme dönemlerindeki ekmeklik buğday çeşitlerinde (*Triticum aestivum* L.) tane verimi ile hafif kullanım etkinliği arasındaki ilişkiler. Yayınlanmamış yüksek lisans tezi, Uludağ Üniversitesi Fen Bilimleri Enstitüsü.

Mut, Z., Köse, Ö. and Akay, H. (2017). Bazı ekmeklik buğday (*Triticum aestivum* L.) çeşitlerinin tane verimi ve kalite özelliklerinin belirlenmesi. *Anadolu Tarım Bilimleri Dergisi*. **32(1):** 85-95.

Nakano, Y., Asada, K. (1981). Hydrogen peroxide is scavenged by ascorbate-specific peroxidase in spinach chloroplasts. *Plant Cell Physiology*. **22:** 867-880.

Oğuz, M. (2019). Buğday (*Triticum aestium* L.) fidelerinde jasmonik asit (JA) ve tuzluluk etkileşimlerinin gen ifadesi ve antioksidant enzimleri üzerine etkileri. (Yüksek lisans tezi). Selçuk Üniversitesi, Fen Bilimleri Enstitüsü, Konya.

Okhan, B. (2022). Aydın ekolojik koşullarında soğuklamanın farklı gelişme tabiatlı buğday çeşitlerinin verim ve kalitesi üzerine etkisi (Yüksek Lisans Tezi, Aydın Adnan Menderes Üniversitesi, Fen Bilimleri Enstitüsü, Aydın.

Öncel, A. and Keleş, N. (2002). Strese maruz kalan 6 buğday genotipinde serbest prolin miktarında artış. *Türkiye Tarımsal Araþtırmalar Dergisi*. **25(3):** 269-278.

Özkan, R. (2022). Diyarbakır'da yağışa dayalı koşullarda yetiştirilen ileri kademe ekmeklik buğday hatlarının değerlendirilmesi. *ISPEC Journal of Agricultural Sciences*. **6(3):** 583-590.

Sakin, M.A., Naneli, ı., Göy, A.G. and Özdemir, K. (2015). Bazı ekmeklik buğday (*Triticum aestivum* L.) çeşitlerinin Tokat-zile koşullarında verim ve verim komponentlerinin belirlenmesi. Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi. 32(3): 119-132.

Şengün, B. (2006). Ekmeklik buğday yeni ıslah hatlarında bazı agronomik ve kalite özellikleri. Yüksek Lisans Tezi, Adnan Menderes Üniversitesi, Fen Bilimleri Enstitüsü.

Şenlik, A.S. and Alkan, D. (2021). Çimlendirilmiş bazı tahıl ve baklagillerin kimyasal özellikleri ve çimlendirmeyle açığa çıkan biyoaktif bileşenlerin sağlık üzerine etkileri. *Akademik Gıda*. **19(2):** 198-207.

Wato, T. (2021). Growth and yield performance of wheat (*Triticum aestivum* L.) to under water stress conditions. *Agricultural Science Digest-A Research Journal*. **41(2):** 301-306. doi: 10.18805/ag.D-289.

Yakıt, M. and Tuna, H. (2006). Mısır bitkisinin (*Zea mays* L.) yapraklarında prolin miktarının strese bağlı olarak artması. *Ege Üniversitesi Ziraat Fakültesi Dergisi*. **44(3):** 327-333.

Yıldır, H. (2018). Buğday (*Triticum aestivum* L.) ve arpa (*Hordeum vulgare* L.) bitkilerinde kısa süreli ağır metal uygulamasının bazı antioksidan enzimlerin ekspresyon seviyeleri ve lipid peroksidasyonu üzerine etkileri. Yüksek Lisans Tezi, Trakya Üniversitesi Fen Bilimleri Enstitüsü.

Yiğit, A. (2019). Farklı ekolojik koşulların buğday genotiplerinde verim, ekmeklik buğday kalitesi ve antioksidan özellikleri üzerine etkilerinin belirlenmesi. Doktora Tezi, Aydın Adnan Menderes Üniversitesi, Fen Bilimleri Enstitüsü, Aydın.