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RELATIONSHIP BETWEEN PHYSIOLOGICAL CHARACTERISTICS AND GRAIN YIELD OF TRITICALE GENOTYPES

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Abstract

Triticale is an important cool seasons cereal that can be used as human food and animal feed. In the present study relationship between physiological characteristics and grain yield in 18 triticale genotypes were determined. In terms of average grain yield were TBT16-11 (3597 kg/ha), Alperbey (3536 kg/ha) and Ayşehanım (3472 kg/ha) genotypes, respectively which were in the front row. According to the heatmap graph, it was determined that the traits were in two different clusters and that normalized difference vegetation index (NDVI), especially in the GS49 and GS60 stages, which gave a high correlation with the grain yield (GY). A strong similarity was seen between the Karma-Presto and Alperbey-TBT-16-11 triticale genotypes. Finally, it was determined that physiological properties are related to GY in triticale cultivation.

Introduction

Triticale *(xTriticosecale wittmack)*, grown in many countries of the world, is an artificial cereal obtained by crossing wheat and rye, combining high grain yield and quality characteristics of wheat and tolerance of rye to biotic and abiotic stress factors (Oettler 2005, Güngör *et al.* 2022). Triticale, which is seen as an alternative plant to solve the nutritional problem of the increasing world population is known to be tolerant in conditions where organic matter is low, partially acidic and salty soils, frost and drought problems (Carikci *et al.* 2017, Ozturk *et al.* 2019).

In terms of triticale production in the world; Germany, Poland, Belarus, France, Russia, Romania, China, Hungary, Serbia, Austria, Lithuania and the Czech Republic are at the forefront. World triticale cultivation is 3.81 million ha and its production is 12.8 million tons. In addition, it was reported that the sowing amount in Türkiye is 64.1 thousand ha, the production is 215.1 thousand tons and the yield per hectare is 3360 kg (Sirat *et al.* 2020).

Triticale, which has a lower grain quality than wheat and barley, is generally consumed as animal feed in developed countries and as human food in developing countries. In addition, cereals such as wheat and barley are used as blends in different proportions in order to increase the quality of foods obtained from triticale (Muluken *et al.* 2014, Bezabih *et al.* 2019). Triticale, in terms of unit area yield**;** Kucukozdemir (2016); 2199-4666 kg/ha, Kendal *et al.* (2019); 4984-6022 kg/ha, Sirat *et al.* (2020); 4189-5463 kg/ha reported that it.

The aim of the research was to determine whether there is a relationship between physiological characteristics and grain yield in triticale plant. If there is a relationship, it is to determine the plant development periods that confirm this relationship.

Materials and Methods

The research was carried out in the rainfed conditions of Mus province in 2019-2020 (E1) and 2020-2021 (E2) growing seasons. Mus province is located in the Eastern Anatolia Region of Türkiye. It is a province with an altitude of 1350 m and continental climate conditions. Triticale

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genotypes used in the study were obtained from universities, research institutes and private sector seed companies (Table 1). The experiment was conducted in a randomized experiment block design with 18 triticale genotypes thought to be morphologically and phenological different. In the study; the trial plots were created by sowing between 15 October-01 November, 5 m long, 1.2 m wide, in each plot 6 rows and 6 m^2 net to area. The sowing norm was calculated so that four hundred and fifty seeds were sown per square meter. According to the results of soil analysis; 60 kg/ha of phosphorus (P_2O_5) and 90 kg/ha of nitrogen (N) were applied on the basis of pure substance. 30 kg of nitrogen was applied with planting and the remaining 60 kg was applied during tillering (GS23) (Zadoks *et al.* 1974). Harvesting was completed between 01-15 July with a Wintersteiger parcel combine.

Table 1. Information for triticale genotypes used in the study.

Genotype	Variety/ Line	Origin	Characteristics
Mehmetbey	Variety	East Mediterranean Transitional Zone Agricultural Res. Inst.	spring
Özer	Variety	Bahri Dagdas International Agricultural Res. Inst.	alternative
Esin	Variety	GAP International Agricultural Research and Training Center	spring
Tatlıcak-97	Variety	Bahri Dagdas International Agricultural Res. Inst.	winter
Ayşehanım	Variety	East Mediterranean Transitional Zone Agricultural Res. Inst.	spring
Ümranhanım	Variety	East Anatolian Agricultural Research Institute	winter
Alperbey	Variety	Bahri Dagdas International Agricultural Res. Inst.	winter
Mikham-2002	Variety	Bahri Dagdas International Agricultural Res. Inst.	winter and alternative
Karma	Variety	Transitional Zone Agricultural Research Institute	winter and alternative
DZ-9-06	Line	Dicle University Faculty of Agriculture	spring and alternative
DZ-20-01	Line	Dicle University Faculty of Agriculture	spring
DZ-01-01	Line	Dicle University Faculty of Agriculture	spring and alternative
TBT16-11	Line	Dicle University Faculty of Agriculture	spring and alternative
Melihbey	Variety	Olgunlar Tour. Agric. Energy Produc. Trade. Mark. Lim. Comp.	spring
Bc Goran	Variety	BC Institute Agric. Produc. Auto Industry and Trade Lim. Comp.	winter
Bera	Variety	Yonca Agric. Produc. Engin. and Exp. Mat. Trade Lim.Comp.	spring and alternative
TRT8	Line	GAP International Agricultural Research and Training Center	Spring and alternative
Presto	Variety	Transitional Zone Agricultural Research Institute	winter and alternative

It was determined that salt-free, slightly alkaline, phosphorus and organic matter content was insufficient and boron content was very high (Table 2). Although the total precipitation amount in the first year of the study (E1) is similar to the long-term average, it is seen that the precipitation distribution is irregular on a monthly basis (Table 3). In the second year of the study, the total amount of precipitation and the distribution of precipitation on a monthlies based were below the long-term average in all months except January and March (Table 3). It can be said that plants are exposed to drought stress especially in the generative period. In terms of average temperature values, values close to the long-term average were observed in E1 in all months except December (well above the long-term) and June (well below the long-term). In E2, temperature values above the values of long-terms have occurred, especially from stem elongation to physiological maturity (April, May and June). For this reason, harvesting was done approximately 7-10 days more earlier in E2 than E1.

Table 2. Soil analysis results for the experiment area.

Soil structure	Total Salt (%)	pH	Lime (kg/ha)	Phosphorus (kg/ha)	Organic matter (%)	Bor (kg/ha)
Clayey	0.25	8.0	57.4	31.3	1.92	40.8

Table 3. Climate data of Mus province for 2019-2021 and long-term average.

Months	Precipitation of mus (mm)			Temperature of mus (^{0}C)		
	E1	E2	Long-term	E1	E2	Long-term
September	0.0	1.2	14.7	19.9	23.8	21.0
October	37.0	0.0	63.5	16.7	16.2	15.3
November	27.2	38.2	94.1	6.9	9.8	6.7
December	74.4	16.6	89.7	4.2	-2.3	-0.7
January	36.8	94.0	86.0	-7.7	-8.1	-7.3
February	89.2	49.8	100.4	-3.8	2.7	-3.4
March	198.0	166.4	103.3	3.7	3.9	4.1
April	117.0	7.8	107.4	11.2	14.6	11.4
May	113.2	11.6	69.0	17.6	19.1	16.8
June	29.0	0.6	28.2	20.5	23.0	21.8
July	27.8	0.4	6.6	25.4	27.5	25.6
Total	749.6	386.6	762.9	-	-	-

E1: 2019-2020 sezonu, E2: 2020-2021 sezonu.

Grain yield, after the parcels were harvested and threshed separately, the weight of the product obtained was determined on a 0.001 g precision scale and the result obtained was converted to kg/ha. All plant growth stages (GS) at which physiological measurements were made according to Zadoks *et al.* (1974). Chlorophyll content measurements; using the SPAD (Soil Plant Analysis Development) 502 meter device, was taken from the middle of the flag leaf without damaging the leaf, in the GS70.1, GS83 and GS85 stages between 10.00-12.00 when the weather was clear and windless. Normalized difference vegetation index (NDVI) measurements, using the Trimple Greenseeker device; It was take during the GS49, GS60, GS70.1, GS83 and GS85 plant growth stages during the hours of 11.00-15.00, when it is clear and sunny without precipitation (Babar *et al.* 2006, Reynolds *et al.* 2012). To determine the canopy temperature; it was determined by taking the average of at least two readings at different points of the parcel, taking into account the maximum canopy temperature in open, windless weather between 12.00-14.00 hrs of the day in the GS70.1 and GS85 periods (Reynolds *et al.* 2001).

One-way analysis of variance of the data was done in the JMP 5.0 package program. The differences between the groups were determined according to the LSD ($p \leq 0.01$ and $p \leq 0.05$) test (Gomez and Gomez 1984). In addition, due to the varieties and especially high number of the investigated parameters principal component analysis (PCA) (XLSTAT, 2021) was applied in order to disable the inter-parameter dependency structure and reduce the size of data. Heatmap clustering (ClustVis) was performed with the help of heatmap in order to visualize and differentiate the examined genotypes and traits and to determine the correlation between them.

Results and Discussion

According to the combined analysis results for genotypes, except for the GS70.1 stage in canopy temperature, significant differences were determined between the environments and genotypes at level $p \leq 0.01$ or $p \leq 0.05$ in all the traits examined. Environments*genotype interaction was found to be important in all traits except canopy temperature. This result shows that the response of genotypes to different environments is not the same (Table 4).

Table 4. Sources of variance and significance levels for the analyzed features.

		Mean of squares					
Variance sources	df	GY	NDVI (GS49)	NDVI (GS60)	NDVI (GS70.1)	NDVI (GS83)	NDVI (GS85)
Environment	1	27574.2*	0.28418**	0.16646**	0.03778**	0.27806**	0.24845**
Replication[Env.]	4	2996.2	0.00081	0.00372	0.00039	0.00066	0.00021
Genotype	17	7540.3**	0.00301**	0.0069**	0.00458**	0.00451**	0.00604**
Env.*Genotype	17	5364.6**	0.00240**	0.00477**	0.00218**	0.00243**	0.00338**
Error	68	2081.3	0.00047	0.00072	0.00040	0.00063	0.0007
General total	107	3742.7	34.97851	0.00400	0.00169	0.00412	0.00427
CV (%)		15.3	3.4	4.4	3.3	4.6	5.2
		SPAD (GS70.1)	SPAD (GS83)	SPAD (GS85)	CT (GS70.1)	CT (GS85)	
Environment	1	850.532**	255.148**	506.134**	141.934**	169.501**	
Replication[Env.]	4	1.1436	3.067	11.229	5.579	1.238	
Genotype	17	46.4713**	26.201**	46.751*	1.15 N.S	1.157*	
Env.*Genotype	17	11.3103**	6.86**	43.995*	0.565 N.S	0.993N.S	
Error	68	2.1116	2.310	24.199	0.744	0.622	
General total	107	18.5139	9.220	34.947	2.281	2.367	
CV (%)		2.7	2.8	9.5	2.8	2.6	

Env.: environment, GY: grain yield; NDVI: normalized difference vegetation index; SPAD: soil plant analysis development; CT: canopy temperature; GS: growth stage; GS49: end of the booting stage, GS60: beginning of flowering stage, GS70.1: beginning of milk formation stage, GS83: early dough formation stage, GS85: dough formation stage, df: degrees of freedom, *: $p \leq 0.05$; **: $p \leq 0.01$; N.S: not significant.

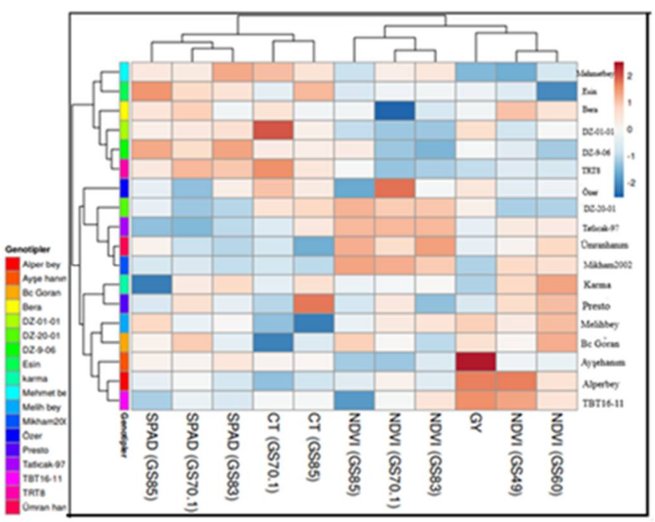
In the present study, TBT16-11 (3597 kg/ha) triticale line gave the highest average grain yield. Alperbey (3536 kg/ha) and Ayşehanım (3472 kg/ha) triticale varieties followed with high grain yields. In the triticale study conducted in Çanakkale province Biga conditions, it was reported that the average grain yield ranged between 2779-3671 kg/ha and the highest grain yield was obtained from the Alperbey variety (Tayyar and Kahriman 2016). In the present study, the range of average grain yield was 2423-3597 kg/ha and Alperbey cultivar was in the foreground. It was seen that TBT16-11 and Alperbey genotypes, which stand out with their high grain yields, were in the forefront in terms of NDVI (GS49) (Table 5). When the grain yields of the genotypes in the E1 and E2 environments were examined the grain yields of TBT16-11, Alperbey, Mehmetbey and DZ-9-06 genotypes did not change much. It was understood that the general adaptability of these genotypes in different environmental conditions were high (Table 5). It was emphasized that grain yield in genotypes was significantly affected by environmental conditions and this effect level was determinant on adaptation and stability (Karaman *et al.* 2023).

Ayşehanım and Melihbey varieties, on the other hand, were evaluated as varieties that are highly affected by environmental conditions and can be recommended for special environments, despite their high grain yields (Table 5). In addition, although arid climatic conditions occurred in the second year of the study, it was observed that the yields of the Karma, DZ-20-01, DZ-01-01 and TRT8 genotypes increased compared to the first year (Table 5). It has been reported that triticale is more drought resistant than other cereals due to features such as leaf area, stomata number and low flag leaf angle (Lonbani and Arzani 2011, Ozturk *et al.* 2019).

In terms of NDVI, respectively, GS49; TBT16-11 (0.667) and Alperbey (0.667), GS60; Melihbey (0.652) and Bc Goran (0.660), GS70.1; Tatlıcak-97 (0.627) and Mikham-2002 (0.645), in GS83 and GS85 periods; Ümranhanım (0.592-0.552) and Mikham-2002 (0.585-0.568) genotypes took the first place. In SPAD readings made at different periods to determine the chlorophyll content of genotypes, GS70.1; Esin (56.9) and TRT8 (57.4), GS83; Mehmetbey (57.0) and DZ-9-06 (57.1), GS85; Esin (58.2) and DZ-9-06 (56.4) genotypes were determined to be in the front row (Table 6). It was determined that Ümranhanım (30.0 and 29.8) and Melihbey (30.0 and 29.9) cultivars were in the front row in all plant canopy temperature readings made at different developmental stages of plants to determine the ability of the genotypes to keep the plant canopy cool (Table 6).

In the present study, a heatmap graph was created in order to interpret the relationships between the examined traits and the similarity between genotypes (Fig. 1). A heatmap is a data matrix that visually presents the data in cells using a color scale. Often the rows and/or columns of the matrix are clustered, researchers can easily interpret clusters of rows or columns instead of evaluating cells individually. In addition, the clear display of colors in the color scheme is of great importance in terms of interpretation. In the heatmap color scheme, red indicates an increase and blue indicates a decrease (Metsalu and Vilo 2015, Stavridou *et al.* 2021).

It has been determined that there are two different main clusters related to the examined traits and each main cluster contains sub-clusters. In the first main cluster; CT (GS70.1), CT (GS85), SPAD (GS83), SPAD (GS70.1) and SPAD (GS85) were in cluded and, in the second main cluster; GY, NDVI (GS49), NDVI (GS60), NDVI (GS70.1), NDVI (GS83), and NDVI (GS85) were taken part (Koçak 2021).



Leader	Joiner	Distance
Karma	Presto	1.3937339
Alper bey	TBT16-11	1.5045904
Ozer	Ayşe hanım	1.6139627
Umran hanım	Mikham2002	1.6711266
Melih bey	Bc Goran	1.9611837
DZ-9-06	TRT8	1.9683532
Tatlıcak-97	Umran hanım	2.1956668
Ozer	Bera	2.4681054
Ozer	Karma	2.4995999
Alper bey	Melih bey	2.5063978
Mehmet bey	Esin	2.6730737
DZ-9-06	DZ-01-01	2.801978
Ozer	Alper bey	3.3563567
Mehmet bey	DZ-9-06	3.5331572
Tatlıcak-97	DZ-20-01	3.5732488
Ozer	Tatlıcak-97	6.1168174
Mehmet bey	Ozer	7.5699864

Fig. 1. Representation of yield and physiological characteristics with heatmap in triticale genotypes, distance and similarity between genotypes.

According to the heatmap graph, the features in the 2nd main cluster are related to GY, especially; NDVI (GS49) and NDVI (GS60) were found to have highest correlation with GY (Figs 1 and 2). It has been confirmed by many researchers that the leaf area reaches the maximum level around the GS60 stage in cereals and that there is a positive correlation between the NDVI measurement values made in this period and the GY (Fischer 1975, Lopresti *et al.* 2015, Karaman *et al.* 2022). Which was confirmed in the present study and additionally, GS49 stage NDVI was also found to be strongly correlated with GY.

Table 5. Average values for traits studied in different environments.

Varieties	GY (kg/ha)		Av.	NDVI (GS49)		Average	NDVI (GS60)		Average	NDVI (GS70.1)		Av.	NDVI (GS83)		Average
	E1	E2		E1	E2		E1	E2		E1	E2		E1	E2	
Mehmetbey	2440	2406	2423	0.577	0.610	0.593	0.550	0.630	0.590	0.660	0.557	0.608	0.655	0.477	0.566
Özer	3223	2711	2967	0.567	0.677	0.622	0.550	0.657	0.603	0.620	0.607	0.613	0.605	0.477	0.541
Esin	3249	2808	3028	0.557	0.697	0.627	0.467	0.627	0.547	0.660	0.547	0.603	0.645	0.467	0.556
Tatlıcak-97	3371	2269	2820	0.550	0.727	0.638	0.570	0.677	0.623	0.637	0.617	0.627	0.610	0.547	0.578
Ayşehanım	3962	2982	3472	0.597	0.657	0.627	0.597	0.613	0.605	0.607	0.540	0.573	0.580	0.490	0.535
Ümranhanım	2943	2532	2738	0.573	0.687	0.630	0.570	0.717	0.643	0.627	0.607	0.617	0.637	0.547	0.592
Alperbey	3700	3372	3536	0.620	0.713	0.667	0.610	0.667	0.638	0.607	0.607	0.607	0.580	0.507	0.543
Mikham-2002	2747	2224	2486	0.580	0.733	0.657	0.580	0.710	0.645	0.663	0.627	0.645	0.640	0.530	0.585
Karma	2421	2892	2656	0.590	0.697	0.643	0.597	0.693	0.645	0.593	0.590	0.592	0.567	0.523	0.545
DZ-9-06	3068	3059	3063	0.597	0.660	0.628	0.557	0.613	0.585	0.575	0.567	0.571	0.575	0.457	0.516
DZ-20-01	2412	3502	2957	0.507	0.677	0.592	0.470	0.643	0.557	0.643	0.600	0.622	0.630	0.520	0.575
DZ-01-01	2947	3132	3039	0.553	0.647	0.600	0.533	0.657	0.595	0.540	0.550	0.545	0.535	0.457	0.496
TBT16-11	3977	3218	3597	0.647	0.687	0.667	0.630	0.657	0.643	0.635	0.577	0.606	0.615	0.527	0.571
Melihbey	3800	2793	3296	0.590	0.690	0.640	0.637	0.667	0.652	0.610	0.607	0.608	0.600	0.527	0.563
Bc Goran	3659	2888	3273	0.597	0.687	0.642	0.680	0.640	0.660	0.660	0.557	0.608	0.620	0.460	0.540
Bera	3303	2800	3051	0.613	0.697	0.655	0.610	0.667	0.638	0.570	0.547	0.558	0.580	0.507	0.543
TRT8	2227	2818	2523	0.557	0.673	0.615	0.553	0.610	0.582	0.555	0.540	0.548	0.530	0.480	0.505
Presto	3118	2408	2763	0.587	0.690	0.638	0.617	0.647	0.632	0.625	0.573	0.599	0.580	0.460	0.520
Mean	3140	2823	2983	0.58	0.684	0.632	0.576	0.655	0.616	0.616	0.579	0.597	0.599	0.498	0.548
LSD (0.05)	87.5**	61.7**	52.6**	0.04**	0.03**	0.03**	0.05**	0.03**	0.03**	0.04**	0.02**	0.02**	0.04**	0.04**	0.03**
CV (%)	16.8	13.2	15.3	3.9	3.0	3.4	5.7	2.9	4.4	4.1	2.2	3.3	4.5	4.7	4.6

GY: grain yield, E1: 2019-2020 growth season, E2: 2020-2021 growth season, Av: average, NDVI: normalized difference vegetation index, GS: growth stage *: $p \leq 0.05$; **: $p \leq 0.01$.

Table 6. Average values for traits studied in different environments.

Varieties	NDVI (GS85)		Average	SPAD (GS70.1)		Average	SPAD (GS83)		Average	SPAD (GS85)		Average	CT (GS70.1)		Average	CT (GS85)		Average
	E1	E2		E1	E2		E1	E2		E1	E2		E1	E2		E1	E2	
Mehmetbey	0.535	0.423	0.479	51.7	57.8	54.7	55.9	58.2	57.0	52.5	54.4	53.4	30.2	32.1	31.2	32.5	29.7	31.1
Özer	0.517	0.437	0.477	45.4	56.3	50.8	51.9	54.7	53.3	48.9	52.6	50.7	29.8	31.5	30.7	32.1	29.4	30.7
Esin	0.570	0.427	0.498	54.5	59.4	56.9	53.9	57.8	55.9	55.6	60.8	58.2	29.5	31.6	30.5	32.5	30.7	31.6
Tatlıcak-97	0.625	0.460	0.543	44.2	53.3	48.8	51.5	51.2	51.3	42.3	53.2	47.8	28.9	31.7	30.3	32.1	29.8	30.9
Ayşehanım	0.537	0.427	0.482	53.4	52.7	53.0	52.5	55.4	53.9	52.1	51.6	51.8	29.0	32.1	30.5	32.0	29.5	30.7
Ümranhanım	0.597	0.507	0.552	48.0	50.8	49.4	49.5	51.1	50.3	50.2	53.6	51.9	28.6	31.5	30.0	31.2	28.4	29.8
Alperbey	0.570	0.437	0.503	50.7	56.7	53.7	51.1	54.4	52.8	50.4	53.1	51.8	28.8	31.6	30.2	32.1	29.1	30.6
Mikham-2002	0.597	0.540	0.568	47.6	54.5	51.0	47.6	54.4	51.0	46.9	51.9	49.4	28.9	31.4	30.1	31.1	29.4	30.2
Karma	0.527	0.473	0.500	48.7	58.2	53.5	51.7	57.3	54.5	35.7	58.7	47.2	29.0	31.8	30.4	32.1	29.7	30.9
DZ-9-06	0.570	0.487	0.528	52.4	59.6	56.0	56.4	57.9	57.1	55.9	56.8	56.4	29.5	32.1	30.8	33.0	29.1	31.0
DZ-20-01	0.590	0.507	0.548	44.2	51.4	47.8	47.9	52.4	50.1	49.1	50.3	49.7	29.6	31.8	30.7	32.5	29.7	31.1
DZ-01-01	0.465	0.450	0.458	50.0	55.8	52.9	52.1	55.7	53.9	48.5	54.0	51.2	30.4	32.2	31.3	32.0	29.3	30.6
TBT16-11	0.550	0.390	0.470	51.5	55.5	53.5	53.2	53.2	53.2	48.1	52.3	50.2	29.7	31.7	30.7	32.6	29.3	30.9
Melihbey	0.557	0.447	0.502	51.1	54.1	52.6	52.2	55.1	53.7	53.9	54.4	54.1	28.4	31.7	30.0	31.6	28.3	29.9
Bc Goran	0.630	0.453	0.542	54.7	57.7	56.2	54.2	53.4	53.8	53.8	52.9	53.3	29.1	31.0	30.1	31.6	30.0	30.8
Bera	0.530	0.500	0.515	53.6	57.9	55.7	51.4	56.7	54.0	51.1	56.3	53.7	30.5	31.2	30.8	32.2	29.5	30.9
TRT8	0.550	0.460	0.505	54.7	60.1	57.4	54.4	58.2	56.3	51.3	55.4	53.3	30.3	32.6	31.4	32.4	29.7	31.0
Presto	0.505	0.470	0.488	50.8	56.6	53.7	49.8	55.7	52.7	49.2	51.2	50.2	29.2	31.1	30.2	31.3	31.1	31.2
Mean	0.557	0.461	0.509	50.4	56.0	53.2	52.1	55.1	53.6	49.7	54.1	51.9	29.4	31.7	30.6	32.0	29.5	30.8
LSD (0.05)	0.04**	0.1**	0.03**	2.3**	2.6**	1.7**	2.9**	2.1**	1.8**	N.S	4.3**	5.7**	N.S	N.S	N.S	N.S	2.3**	0.9**
CV (%)	4.3	6.2	5.2	2.7	2.8	2.7	3.3	2.3	2.8	13.0	4.8	9.7	2.9	0.03	2.8	2.7	1.2	2.6

E1: 2019-2020 growth season, E2: 2020-2021 growth season, Av: average, NDVI: normalized difference vegetation index, SPAD: soil plant analysis development; CT: canopy temperature; GS: growth stage, *: $p \leq 0.05$; **: $p \leq 0.01$; N.S: not significant.

In the heatmap graph, when the similarity of the genotypes is examined, it will be seen that two different main clusters are formed and the each main cluster is divided into 2 sub-clusters within itself (Fig. 1). Genotypes in the same cluster are similar (Koçak 2021). The first main cluster were TBT16-11, Alperbey, Ayşehanım, Bc Goran, Melihbey, Presto, Karma, Mikham 2002, Ümranhanım, Tatlıcak 97, DZ-20-01 and Özer genotypes were take part. The second main cluster in cluded TRT-8, DZ-9-06, DZ-01-01, Bera, Esin and Mehmetbey triticale genotypes.

Genotypes in the first main cluster were divided into 2 sub-clusters, in the 1st sub-cluster in cluded TBT16-11, Alperbey, Ayşehanım, Bc Goran, Melihbey, Presto and Karma; in the 2nd subset; Mikham 2002, Ümranhanım, Tatlıcak 97, DZ-20-01 and Özer genotypes were found. According to the heatmap, it can be said that the genotypes determined to be in the same cluster are similar. The distance between the dependent variables is taken into account in the interpretation of the clusters. The distance indicates the positions of the examined features and/or genotypes relative to each other. This is important when interpreting similarity and closeness. In short, for similar features and/or genotypes, the distance is small and the similarity ratio is high (Gürbüz and Karabulut 2009, Koltan Yılmaz 2011).

When the distance between genotypes is examined; It is seen that Karma-Presto and Alperbey-TBT-16-11 triticale varieties have the lowest distance (1.3937339 and 1.5045904) between them (Fig. 1). It is thought that there is a strong similarity between the Karma-Presto and Alperbey-TBT-16-11 genotypes and that the same parents may have taken part in the breeding processes of these genotypes. It can be interpreted that the similarity is low because the distance (6.1168174) between Özer and Tatlıcak-97 is large, and there is no similarity because the distance (7.5699864) between Mehmet Bey and Özer varieties is very high (Fig. 1).

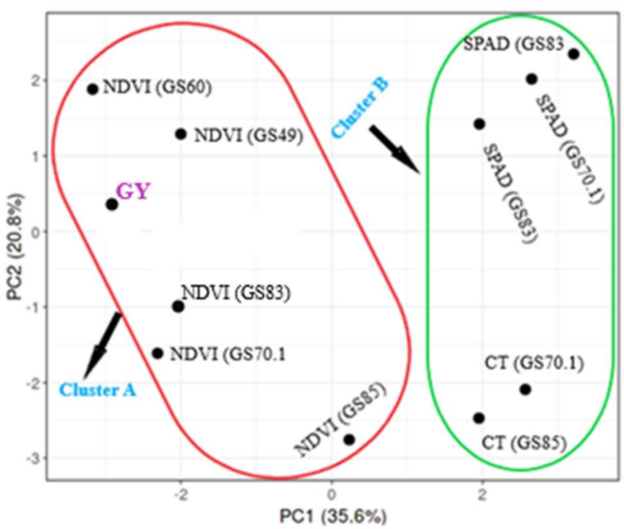


Fig. 2. Visual representation of the relationship between clusters and features.

Heatmap and Principal Component Analysis (PCA) are two popular methods used extensively by many researchers in recent years to analyze data (Metsalu and Vilo 2015). When the PCA graph is examined, it will be seen that it confirms the heatmap results and the features are located in 2 different main clusters (Cluster A and Cluster B). Also, PC1; 35.6% and PC2; 20.8% were explained the variation between traits. Visually presented that GY correlates strongly with NDVI (GS49) and NDVI (GS60) (Fig. 2). As a result; It was determined that NDVI (GS49) and NDVI

(GS60) of the investigated physiological characteristics were associated with grain yield. In addition, it is anticipated that the heatmap and PCA graphs will contribute to the researchers as they provide convenience in classifying the properties and genotypes.

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