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RELATIONSHIP BETWEEN PHYSIOLOGICAL CHARACTERISTICS AND GRAIN YIELD OF BARLEY *(HORDEUM VULGARE* L.) CULTIVARS

MEHMET KARAMAN*

Mus Alparslan University, Faculty of Applied Sciences
Department of Plant Production and Technologies. Mus, Turkey

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Abstract

The present study was carried out to determine the relationship between physiological characteristics with grain yield (GY) in barley cultivars. In this study, significant differences were found between varieties ($p \leq 0.01$ or $p \leq 0.05$) in all the characteristics, except GS77 (late milk formation) period Normalized Difference Vegetation Index (NDVI). While Erciyes, Çatalhüyük, Asutay and Aydanhanım barley cultivars were high yielding, and Bozlak was determined to be both high yielding and the most stable barley variety. In the correlation analysis, a positive and significant relationship was found between GY and NDVI in the GS83 (early dough formation) (r = 0.298*) and GS85 (dough formation) (r = 0.366**) periods. The GGE (genotype, genotype × environment) biplot model, visually presented the negative correlation between canopy temperature (CT) and GY. It was concluded that the selection of genotypes with high biomass, high flag leaf chlorophyll content, low canopy temperature and stable at the same time is important.

Introduction

Barley *(Hordeum vulgare* L.) is an important grain in the world and in Turkey due to its high adaptability to different climatic conditions, its use as animal feed, a raw material in the malt industry and as human food. In the history of humanity, barley was used as human food at first. However, with the emergence of wheat and rice over time, its use as animal feed has gained more importance. (Baik and Ullrich 2008, Sönmez and Yüksel 2019). Turkey, meets about 5% of the world barley production, which is around 141 million tons, with 7.6 million tons of barley production (FAO 2019).

When the world barley production is evaluated; It has the highest production after wheat, corn and rice, and ranks 4th (FAO 2018). Grain yield is a complex quantitative trait that develops under the influence of morphological and physiological characters and is significantly affected by environmental conditions and is controlled by multiple genes (Poehlman and Sleper 1995, Karaman *et al.* 2012, Markova Ruzdik *et al.* 2015). The Normalized Vegetation Index (NDVI) has been widely used for nearly a quarter of a century to determine and monitor plant biomass (Leprieur *et al.* 2000, Kizilgeci *et al.* 2018).

Flag leaf chlorophyll content; It gives information about photosynthesis capacity, chloroplast development, nitrogen content in the leaf. In addition, it is a parameter that is widely measured because it gives information about the general condition of the plant as an indicator of plant health (Ling *et al.* 2011, Kizilgeci *et al.* 2018). It was emphasized that grain yield decreased in barley genotypes that matured exposure to high temperature (Tanaka and Nakano 2019). Varieties that are stable in different environmental conditions are important due to global climate change. For this reason, the GGE biplot model is a method that makes it easier to predict the different response and stability of genotypes in different environments, with genotype and genotype × environment interaction (Kadir *et al.* 2018).

*E-mail: <m.karaman@alparslan.edu.tr>.

The aim of the study is to determine the relationship between grain yield and physiological characteristics, the physiological characteristics that can be a selection tool and to contribute to breeding programs.

Materials and Methods

Mus is one of the Eastern Anatolian provinces of Turkey, located at latitude 38.7346 and longitude 41.4910. The study was carried out based on rainfed conditions of Mus province in the 2019-2020 (E1) and 2020-2021 (E2) growing seasons. 12 barley varieties, 4 of which were six-row (Asutay, Olgun, Mert and Hazar) and 8 of which were two-row (Erciyes, Tosunpaşa, Burakbey, Sabribey, Aydanhanım, Bozlak, Çatalhüyük 2001 and Sladoran), constituted the trial material (Table 1).

Table 1. Information on barley varieties included in the trial.

Variety	Number of row	Origin
Erciyes	2 row	Anadolu Efes Brewing and Malt Industry Inc.
Tosunpaşa	2 row	Field Crops Central Research Institute Directorate
Asutay	6 row	Olgunlar Tourism Agriculture Energy Production Trade. Marketing Ltd. Sti.
Burakbey	2 row	Field Crops Central Research Institute Directorate
Olgun	6 row	Eastern Anatolia Agricultural Research Institute Directorate
Sabribey	2 row	Transitional Zone Agricultural Research Institute
Aydanhanım	2 row	Field Crops Central Research Institute Directorate
Bozlak	2 row	Field Crops Central Research Institute Directorate
Çatalhüyük 2001	2 row	Anadolu Efes Brewing and Malt Industry Inc.
Mert	6 row	Olgunlar Tourism Agriculture Energy Production Trade. Marketing Ltd. Sti.
Sladoran	2 row	Thrace Agricultural Research Institute Directorate
Hazar	6 row	Thrace Agricultural Research Institute Directorate

Trial plots; It was planned as 6 rows, 20 cm between rows and 6 m plot length. Four hundred fifty seeds were planted per square meter. The seeds were sown with trial seeder in the last week of October with 3 replications according to the randomized blocks design. It was determined that the soil structure of the experimental area was clayey, slightly alkaline and poor in organic matter (Table 2). In order to complete the nutrient deficiency of the soil, a total of 60 kg/ha phosphorus (P_2O_5) and 90 kg/ha nitrogen (N) were given over the pure substance. All the phosphorus and 25 kg N were used during planting, the remaining (65 kg) N amount was applied during tillering period. Harvesting was done with a parcel combine harvester in a net 6 m^2 area between June 20 and July 01, after this 0.5 m was cut from the northern and southern parts of each parcel. Since the E2 production season was drought, the harvest was done 1 week earlier than the E1 season (Table 3).

In the first year of study, approximately twice precipitation according to long-term average precipitation occurred in March and May (Table 3). It is thought that during the months in question, the plants were periodically exposed to the stress of flooding due to excessive precipitation. Therefore, the average yield was lower than in the second year, although the amount of precipitation was much higher in the first year of the study (Table 5).

Grain yield (GY); After each parcel was harvested and threshed, the product obtained from the unit area was weighed on a precision balance of 0.001 g and then determined by converting to kg/ha. In the study, plant development periods (GS) for all physiological observations were determined with reference to Zadoks *et al.* (1974).

Table 2. Some physical and chemical properties of trial area soils.

Soil structure	Total salt (%)	Ph (sç)	Lime (%)	Phosphorus (kg/ha)	Organic matter (%)	Saturation with water (%)
Clayey	0.2	8.2	7.96	32.1	1.74	77.0

Table 3. Climatic data of the experimental area for the 2019-2021 seasons and the 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	20.0
October	37.0	0.0	63.5	16.7	16.2	12.6
November	27.2	38.2	94.1	6.9	9.8	4.5
December	74.4	16.6	89.7	4.2	-2.3	3.0
January	36.8	94.0	86.0	-7.7	-8.1	-7.4
February	89.2	49.8	100.4	-3.8	2.7	-6.1
March	198.0	166.4	103.3	3.7	3.9	0.6
April	117.0	7.8	107.4	11.2	14.6	9.0
May	113.2	11.6	69.0	17.6	19.1	14.9
June	29.0	0.6	28.2	20.5	23.0	20.2
July	27.8	0.4	6.6	25.4	27.5	25.3
Total	749.6	386.6	762.9	-	-	-

Source: Anonymous (2022).

Chlorophyll content measurements; It was carried out at the GS85 stage between 10.00-12.00 with the SPAD (Soil Plant Analysis Development) 502 meter device, which allows to measure the chlorophyll content of the flag leaf accurately, quickly and without damaging the leaf. NDVI measurements were made in four different growth periods (GS73: early milk formation, GS77: late milk formation, GS83: early dough formation and GS85: dough formation) (Reynolds *et al.* 2012). Canopy temperature (CT) was determined over the average temperature by making at least two readings for each plot, from the north and south, between 12.00-14.00 in clear and sunny weather during the GS83 period (Reynolds *et al.* 2001).

Statistical analyzes were made with JMP 13.0 pro package program. Significance levels between groups were determined according to the LSD test ($p \leq 0.01$ and $p \leq 0.05$) (Gomez and Gomez 1984, Kalaycı 2005). Genstat 12th program was used for GGE biplot analysis.

Results and Discussion

In the current study; except at the GS77 period of NDVI, statistically highly significant ($p \leq 0.01$) or significant ($p \leq 0.05$) differences were determined among the varieties in all the traits examined (Table 4). In addition, interaction was found to be insignificant in all properties except grain yield.

Table 4. Results of variance analysis.

		Squares means						
Variance Resources	df	GY	NDVI (GS73)	NDVI (GS77)	NDVI (GS83)	NDVI (GS85)	CT (GS83)	SPAD (GS85)
Environment	1	722.2 n.s	0.3314**	0.141**	0.067*	0.0008	306.3**	119.1*
Replication [Environment]	4	515.4	0.0096	0.006	0.008	0.0060	5.5	11.9
Variety	11	22691.4**	0.0029**	0.002 n.s	0.005**	0.0110**	2.9*	20.6**
Environmentx variety	11	8254.3**	0.0015n.s	0.003 n.s	0.002 n.s	0.0030 n.s.	0.8 n.s.	11.6 n.s
Error	44	721.6	0.0009	0.001	0.002	0.0016	1.2	6.2
General total	71	5280.8	0.0065	0.004	0.003	0.0035	5.9	11.2
CV (%)		13.1	4.6	5.5	5.9	6.5	3.6	5.0

GY: Grain yield, NDVI: Normalized Vegetation Index, SPAD: Soil Plant Analysis Development, GS: Growt Stage, CT: Conapy Temperature, df: Degree of freedom, *: Statistically significant at 0.05, **: Statistically significant at 0.01, n.s: not significant, CV: Coefficient of variation.

Interpretation of Grain Yield and Physiological Characteristics by GGE Biplot Analysis

GGE biplot model provides convenience to researchers by visually presenting the relationships between genotype-trait and traits. In this model; The relationship between features is interpreted by considering the angle between the vectors representing each feature. As the angle value (>0---<90^o) between the vectors of two features decreases, it is interpreted as positive relationship, as the angle value (90^o>-<180^o) increases, it is interpreted as negative relationship. In addition, if the angle value = 90^o, it is said that there is no relationship (Yan and Tinker 2006, Kendal 2019, Karaman, 2021).

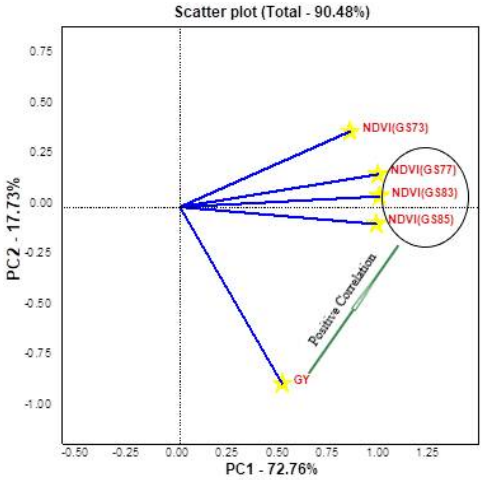

Fig. 1. GGE biplot graph showing NDVI and GY relationship

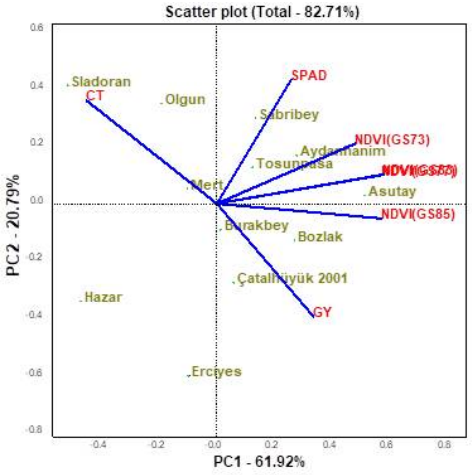

Fig. 2. GGE biplot graph showing variety-trait relationship

In this study, Fig. 1 showing the relationship between features is examined, PC1; 72.76%, PC2; 17.73% and PC1+PC2; 90.48% with ratio explained the relationship between GY and NDVI. When the graph is examined, it is seen that NDVI is positively related to each other in all GS

periods. Positive correlation between GY with GS77, GS83 and GS85 NDVI was visually presented (Fig. 1). In addition, it was understood that there was a significant and positive relationship was obtained between GY and GS83, and a highly significant and positive relationship between GS85 (Fig. 1 and Table 7). According to the graphic that visually presents the variety-feature relationship; PC1; 61.92%, PC2; 20.79% and PC1+PC2; It explained the variety-trait relationship with an accuracy rate of 82.71% (Fig. 2). The graph showed a positive correlation between SPAD readings and all NDVI periods. In particular, a positive and highly significant relationship was determined between SPAD readings and GS73, GS77 and GS83 periods NDVI. In addition, there was a negative correlation between GY and CT (Fig. 2). In this case, it can be interpreted that the grain yield decreases as the canopy temperature rises.

The negative and highly significant correlation was found between all periods of NDVI measurement and CT (Fig. 2 and Table 7), it means that as the biomass increases, the barley plant keeps the canopy cooler. When genotypes are evaluated on the basis of traits, in GY; Erciyes, Çatalhüyük, Bozlak and Asutay barley varieties stood out. In NDVI measurement in all GS periods; Aydanhanım, Asutay and Bozlak barley varieties took the first place (Tables 5 and 6).

Table 5. Average values for investigated features.

Varieties	GY (kg/ha)		Average	NDVI (GS73)		Average	NDVI (GS77)		Average	NDVI (GS83)		Average
	E1	E2		E1	E2		E1	E2		E1	E2	
Erciyes	2208	3575	2892	0.535	0.740	0.638	0.610	0.703	0.657	0.587	0.680	0.633
Tosunpaşa	1892	2127	2009	0.580	0.757	0.668	0.605	0.747	0.676	0.613	0.727	0.670
Asutay	2271	2200	2235	0.640	0.760	0.700	0.657	0.730	0.693	0.687	0.707	0.697
Burakbey	1721	2318	2019	0.607	0.757	0.682	0.575	0.737	0.656	0.590	0.720	0.655
Olgun	883	929	906	0.617	0.757	0.687	0.623	0.710	0.667	0.600	0.663	0.632
Sabribey	2422	1194	1808	0.617	0.757	0.687	0.650	0.710	0.680	0.660	0.677	0.668
Aydanhanım	2231	2897	2564	0.633	0.767	0.700	0.635	0.727	0.681	0.630	0.690	0.660
Bozlak	2450	2992	2721	0.627	0.753	0.690	0.605	0.743	0.674	0.630	0.720	0.675
Çatalhüyük	2954	2667	2810	0.633	0.743	0.688	0.630	0.693	0.662	0.623	0.657	0.640
Mert	2221	1021	1621	0.620	0.707	0.663	0.653	0.663	0.658	0.630	0.640	0.635
Sladoran	1463	1364	1413	0.583	0.707	0.645	0.603	0.657	0.630	0.587	0.640	0.613
Hazar	1546	1738	1642	0.587	0.703	0.645	0.593	0.683	0.638	0.573	0.623	0.598
Mean	2022	2085	2053	0.607	0.740	0.674	0.620	0.709	0.664	0.618	0.679	0.648
CV (%)	11.8	14.2	13.1	5.8	3.4	4.6	4.0	6.4	5.5	6.3	5.6	5.9
LSD (0.05)	40.5**	50.0**	31.3**	N.S	0.04*	0.04**	0.04**	N.S	N.S	N.S	0.06*	0.04**

*: 0.05, **: 0.01 significant at the level, n.s: not significant, LSD: Least Significant Differences.

In SPAD readings; Aydanhanım, Tosunpaşa, Sabribey and Asutay barley varieties ranked first in terms of flag leaf chlorophyll content (Table 6). in CT; while it was seen that Sladoran and Olgun barley varieties gave the highest canopy temperature, it was also determined that these varieties had the lowest grain yield (Fig. 2, Table 5 and 6). Ranking biplot model; provides guidance for determining the stability of varieties and the most suitable genotypes over the average of all environments or years for the traits studied (Kendal 2020). When the ranking biplot graph is examined; PC1; 75.60%, PC2; 24.40% and PC1+PC2; 100% in ratio, it explained grain yield stability (Fig. 3). In the interpretation of the ranking biplot plot, it was emphasized that the first principal component (IPCA1) represents the productivity of the varieties and the second

principal component (IPCA2) represents the stability of the varieties (Yan *et al.* 2000). This shows that the higher the IPCA1 value (towards to the right of the *y*-axis) the higher the efficiency and the closer the IPCA2 value to zero (towards the *x*-axis) the greater the stability (Hagos and Abay 2013).

In Fig. 3, it is seen that Erciyes and Çatalhüyük barley varieties located on the far right of the *y*-axis (PC1 value is the highest) have the highest grain yield. However, considering the distance of these varieties to the stability line; It can be interpreted that it is unstable for Erciyes (low IPCA2 value), moderately stable (medium IPCA2 value) for Çatalhüyük barley variety. Bozlak, Aydanhanım and Asutay barley varieties stood out stable and efficient varieties. It can be said that Bozlak barley variety is the highly efficient and most stable variety. In addition, it is seen that Sabribey, Mert, Sladoran, Tosunpaşa, Hazar, Olgun and Burakbey barley varieties on the left of the *y*-axis gave grain yield below the trial average (Fig. 3). In addition, it has been visually presented that Sabribey and Mert barley varieties were low grain yield and most unstable varieties.

Grain yield, which is the final output in all crops, is influenced by the interaction of genotype (G), environment (E) and genotype*environment (GE) (Yan and Kang 2002, Singh *et al.* 2019). In the Comparison biplot chart, which compares the location of the working environments with the ideal environment, is examined, PC1; 81.13%, PC2; 18.87% and PC1+PC2; 100% in ratio, it explained the situation of E1 and E2 relative to the ideal environment (Fig. 4). Since E2 is closer to the ideal environment, it can be said that the varieties show their potential better in this environment. In addition, considering the locations of the varieties, it is seen that Çatalhüyük in E1 and Erciyes barley varieties in E2, gave the highest grain yield. Erciyes barley variety can be said to be a variety with high adaptability to special environments. It can be said that Bozlak and Aydanhanım varieties have high productivity and general adaptability in both environments. In addition, it was observed that the Asutay barley variety gave grain yield above the trial average, and it was a stable barley variety with high general adaptability (Fig. 4).

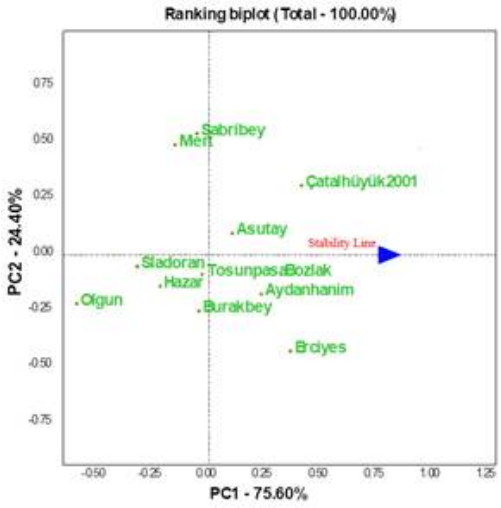

Fig. 3. GGE biplot grain yield stability biplot graph relative to the ideal environment

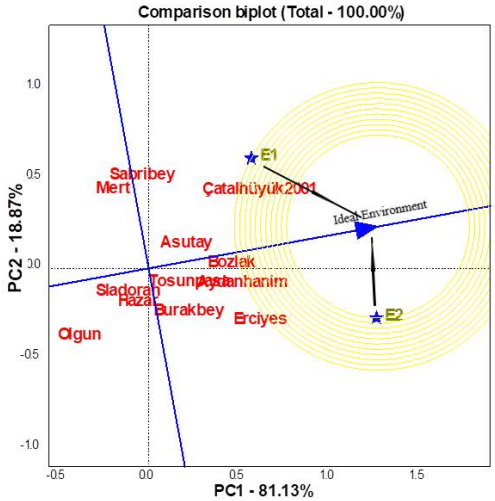

Fig. 4. Biplot graph showing the position of the environments

Table 6. Average values for investigated features.

Varieties	NDVI (GS85)		Average	CT (GS83)		Average	SPAD (GS85)		Average
	E1	E2		E1	E2		E1	E2	
Erciyes	0.587	0.630	0.608	31.5	27.6	29.5	45.4	50.6	48.0
Tosunpaşa	0.583	0.670	0.627	32.3	27.7	30.0	51.8	51.0	51.4
Asutay	0.713	0.653	0.683	30.3	27.5	28.9	50.1	52.8	51.5
Burakbey	0.610	0.633	0.622	32.0	27.8	29.9	47.8	50.3	49.1
Olgun	0.560	0.597	0.578	33.4	28.2	30.8	46.9	51.5	49.2
Sabribey	0.670	0.597	0.633	32.1	29.0	30.5	49.4	52.7	51.1
Aydanhanım	0.620	0.653	0.637	32.3	27.5	29.9	51.4	53.8	52.6
Bozlak	0.653	0.667	0.660	32.3	27.3	29.8	49.9	49.8	49.9
Çatalhüyük	0.590	0.577	0.583	31.6	27.2	29.4	47.1	52.4	49.8
Mert	0.603	0.617	0.610	31.8	28.3	30.0	49.9	50.9	50.4
Sladoran	0.537	0.520	0.528	33.5	29.5	31.5	43.6	49.8	46.7
Hazar	0.567	0.560	0.563	32.5	28.4	30.4	42.6	49.7	46.2
Mean	0.608	0.615	0.611	32.1	28.0	30.0	48.0	51.3	50.1
CV (%)	7.3	5.5	6.5	3.2	4.2	3.6	5.7	4.1	5.0
LSD (0.05)	0.08**	0.06**	0.05**	n.s	n.s	1.3*	4.8**	n.s	2.9**

Evaluation with Correlation Analysis of Relationships Between Characteristics

According to the results of the correlation analysis, it was observed that there was a positive and significant relationship between GY and GS83 and GS85 period NDVI (Table 7). It was determined that there was a negative and significant relationship between CT and NDVI in all periods (Table 7). This indicates that the higher the plant's biomass, the cooler it keeps the vegetation (Table 6). A positive and significant relationship was determined between NDVI values and SPAD measured in all periods, except for the GS85 (not significant) stage. In line with this result, it means that varieties with high biomass also have high chlorophyll content (Table 6). In addition, a negative and significant relationship was found between SPAD and CT. This indicates that the flag leaf chlorophyll content of varieties that keep the vegetation cool is high (Table 7).

Table 7. Correlation coefficient and significance level of the features.

Correlation	GY	NDVI (GS73)	NDVI (GS77)	NDVI (GS83)	NDVI (GS85)	CT
NDVI (GS73)	0.1401					
NDVI (GS77)	0.209	0.841**				
NDVI (GS83)	0.298*	0.698**	0.777**			
NDVI (GS85)	0.366**	0.264*	0.419**	0.676**		
CT	-0.199	-0.761**	-0.724**	-0.627**	-0.349**	
SPAD	0.020	0.401**	0.423**	0.344**	0.214	-0.415**

*: 0.05, **: 0,01 significant at the level.

The study carried out in different environmental conditions found, the positive and significant correlation of NDVI, especially GS83 and GS85 stages with grain yield of barley, shows that

NDVI readings are important in selection for barley breeders in terms of monitoring plant biomass. It was observed that the grain yield was negatively correlated with the canopy temperature and the varieties with high grain yield generally gave low canopy temperature (cool vegetation). In the present study, Çatalhüyük variety gave the highest grain yield in the season with high precipitation (E1) and Erciyes variety in the drought season (E2). However, it was determined that stability was low in Erciyes variety and medium in Çatalhüyük variety. For this reason, it can be said that Erciyes and Çatalhüyük barley varieties are more compatible with special environments. With the effect of global climate change, different conditions can be observed even in close quarters. Therefore; It is thought that the development of location-oriented varieties that are compatible with special environments is also an issue that should be considered for breeding programs. Bozlak, Asutay and Aydanhanım Barley varieties were found to be productive and stable. However, especially Bozlak barley variety can be evaluated as high yielding (high PCI1 value) and the most stable (lowest PCI2 value) variety. It has been observed that these varieties stand out in terms of all the physiological characteristics examined. As a result; It has been concluded that NDVI, SPAD and Infrared spectral readings will contribute to breeding programs and that more extensive use of these devices at different developmental stages of cereals will be beneficial for breeding programs.

Reference

Anonymous 2022. Yıldız Plant Productions, Seed, and Agricultural Industry Corp weather station records. (Date of Access: 07.01.2022).

Baik BK, Ullrich SE 2008. Barley for food: characteristics, improvement, and renewed interest. J. Cereal Sci. **48**: 233-242.

FAO 2018. Food and Agriculture Organization of the United Nations (FAOSTAT). FAO Statistical Databases, http://www.fao.org/faostat/ en/#data/QC .

FAO 2019. Food and Agriculture Organization. http://www.fao.org/faostat/en/#data/QC/ visualize Date of access: 07.10.2020.

Gomez KA and Gomez AA 1984. Statistical procedures for agricultural research. 2nd Ed. John Wiley and Sons, Inc. New York. 641 pp.

Hagos HG, Abay F 2013. AMMI and GGE biplot analysis of bread wheat genotypes in the Northern Part of Ethiopia. J. Plant Breed. Genet. **01**: 12-18.

Kadir M, Muddin K, Farid BM, Musa Y, Nur A, Efendi R and Seyahruddin K 2018. GGE-biplot analysis of yield stability in environment trial oftropical wheat *(Triticum aestivum* L.) genotype under dryseason in Indonesia. Research on Crop. **19**(4): 680-688.

Kalaycı M 2005. Örneklerle jump kullanımı ve tarımsal araştırma için varyans analiz modelleri. Anadolu Tarımsal Araştırma Enst. Müd. Yayınları. Yayın No: 21. Eskişehir.

Karaman M, Kendal E, Aktas H, Tekdal S and Altıkat A. 2012. Evaluationof domestic and foreign bread wheat varieties in terms of some quality parameters and grain yield. Agric. Sci. Res. J. **5**(2): 29-32.

Karaman M 2021. Analysis of different characteristic some bread wheat *(Triticum aestivum* L.) genotypes in terms of agricultural features in Diyarbakir province conditions. Euroasia J. Mat. Eng. Nat. Med. Sci. **8**(14): 24-34.

Kendal E, Tekdal S, Karaman M 2019. Proficiency of biplot methods (AMMI AND GGE) in the appraisal of triticale genotypes in multiple environments. Applied Eco. Env. Res. **17**(3): 5995-6007.

Kendal E 2020. Determination of suitable barley genotypes for diyarbakır conditions using AMMI and biplot techniques. DUFED **9**(1): 27-42.

Kizilgeci F, Yıldırım M, Akıncı C, Albayrak O, Sesiz U and Tazebay N 2018. Evaluation of relationships between yield and yield components with physiological parameters in barley *(Hordeum vulgare* L.) genotypes. DUFED **7**(2): 61-66

Leprieur C, Kerr YH, Mastorchio S and Meunier JC 2000. Monitoring vegetation cover across semi-arid regions: comparison of remote observations from various scales. Int. J. Rem. Sens. **21**(2): 281-300.

Ling Q, Huan, W and Jarvis P 2011. Use of a SPAD502 meter to measure leaf chlorophyll concentration in Arabidopsis thaliana. Photosynthesis Res. **107**(2): 209-214.

Markova Ruzdik N, Valcheva D, Vulchev D, Mihajlov, Lj, Karov I and Ilieva V 2015. Correlation between grain yield and yield components in winter barley varieties. Agric. Sci. Tech. **7**(1): 40-44.

Poehlman MJ and DA Sleper 1995. Breeding field crops. Iowa State University Press. 450 p. Ames

Reynolds MP, Nagarajan,S. Razzaque MA and Ageeb OAA 2001. Heat tolerance. In M.P. Reynolds, I. Ortiz-Monasterio & A. McNab, eds. Application of physiology in wheat breeding. Mexico. D.F., CIMMYT.

Reynolds MP, Pask AJD and Mullan D.M. (Eds.) 2012. Physiological breeding I: Interdisciplinary approaches to ımprove crop adaptation. Mexico, D.F., CIMMYT

Singh C, Gupta A, Gupta V, Kumar P, Sendhil R, Tyagi BS, Singh G, Chatrath R and Singh GP 2019. Genotype x environment interaction analysis of multi-environment wheat trials in India using AMMI and GGE biplot models. Crop Breed. Appl. Biotech. **19**(3): 309-318.

Sönmez, A.C., Yüksel, S. 2019. Determining of Grain Yield and Some Physiological Traits of Advanced Barley *(Hordeum vulgare L.)* Genotypes in Eskişehir Conditions. KSU J. Agric Nat 22 (Additional Issue 1): 61-69.

Tanaka, R., Nakano, H. 2019. Barley Yield Response to Nitrogen Application under Diferent Weather Conditions. Scientific Reports **9**: 8477.

Yan, W., L.A.Hunt, Q. Sheng, and Z. Szlavnics. 2000. Cultivar evaluation and mega-environment investigation based on the GGE biplot. Crop Sci. **40**:597-605.

Yan W, Kang MS 2002. GGE-biplot analysis: A graphical tool for breeders, geneticists, and agronomists. CRC Press, Boca Raton, 288 p.

Yan W and Tinker NA 2006. Biplot analysis of multienvironment trial data: Principles and applications. Canadian J. Plant Sci. **86**: 623-645.

Zadoks J C, Chang TT and Konzak CF 1974. A decimal code for the growth stages of cereals. Weed Res. **14**: 415-421.

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