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DETERMINATION OF THE RELATIONSHIP OF HARMONIZATION RATIO AND SOME YIELD CHARACTERISTICS WITH GRAIN YIELD IN BARLEY

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Abstract: In this study, it was aimed to calculate the harmonization ratio before and after the flowering period (GFP_{tt}/VP_{tt}) in barley depending on thermal times, to determine the vegetative period (VP) and grain filling period (GFP) values for higher grain yield (GY) capacity and the possibility of using these qualities as adaptation and selection criteria and to determine the relationship between HR and GY calculated according to phenological periods depending on thermal times under Kahramanmaraş conditions. The experiments were carried out between 2014 and 2016 for 2 successive years with 3 replicates according to the randomized completed block design with 9 genotypes. Phenological traits such as VP, GFP, GY and days to maturity (DM) were measured in relation to thermal times. According to the results, genotypes were found to be significantly different in terms of harmonization ratio in barley. Considering the two-year averages, the highest grain yields were determined as Samyeli (534.3 kg da^{-1}) and Şahin-91 (532.8 kg da^{-1}). The lowest grain yields were determined as Kendal (404.9 kg da^{-1}) and Sur-93 (416.9 kg da^{-1}). The highest harmonization ratios were determined as Samyeli (0.753) and Kendal (0.672), the lowest harmonization ratios were determined as Şahin-91 (0.486) and Athena*Yabani (0.558). Although there was a general relationship between grain yield and harmonization ratio, some genotypes had values outside this trend.

Keywords: Harmonization ratio, Vegetative period, Grain filling period, Yield, Barley

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1. Introduction

Barley, which was previously used directly in human nutrition, is now cultivated and bred for two main purposes in the world and in our country: as a feed for animal nutrition and for malt-beer production in the industry (Kılınç et al., 1992).

In Türkiye, there is 3 million hectares of cultivation and 8.3 million tons of production in 2020 (TUIK, 2021a) and the most barley production are Konya, Ankara, Afyonkarahisar, Aksaray, respectively (TUIK, 2021b). In 2022, barley cultivation area was 3.2 million ha, production was 8.5 million tons and yield was 266 kg da^{-1} (Anonymous, 2022).

With a production of 157 million tons and a cultivation area of 51 million hectares, barley ranks 4th among cereals in the world after wheat, maize and rice, with a share of 3.5% in agricultural areas, 17.4% in cool climate cereals and 7% in total cereal areas (FAO, 2020).

About half of the increase in yield per unit area was due to genetic improvement and the other half to improvements in breeding technique in all grains. Genetic improvement has been made possible by the improvement of agronomic characters that increase yield potential or tolerance to stresses. Increases in yield potential have also led to changes in phenological periods. Determining the effects of phenological periods on yield will allow the development of new high-yielding varieties. In addition, knowing how phenological periods affect yield will help to make more realistic yield predictions. For the first time, the effects of VP (vegetative period), GFP (grain filling period) and DM (days to maturity) on grain yield were evaluated together for durum wheat cultivars GFP_{tt}/VP_{tt} and it was revealed that the harmonization ratio (HR) obtained by proportioning them was significantly related to grain yield (Akkaya et al., 2006).

The relationship between growing-degree-days (GDD) and the time of peak tassel emergence in maize varieties, GDD index values were calculated by taking max. and min. temperature values for each day of the period from sowing to peak tassel emergence, using the formula (equation 1)

$$GDD = \text{Daily max. temperature} + \text{Daily min. temperature}/2-10 \quad (1)$$

The peak tassel emergence time shortened with the increase in air temperatures, and that the delay in sowing time and the earliness characteristics of the varieties also played a role in this decrease. The fact that the GDD value started to decrease from the beginning of July revealed that the planting time should not be delayed further (Choelho and Dale, 1980). It was reported that barley varieties with short heading time had long heading-maturity duration, varieties with high grain yields had high harvest indexes, varieties with low grain yields had low harvest indexes, and varieties with high yields were generally two-rowed in terms of thousand grain and hectoliter weight (Kırtok and Genç, 1979), (Choelho and Dale, 1980), the time of peak tassel emergence in maize is also related to temperature totals and the method used to determine this is GDD (Kiniry and Keener, 1982), in a study investigating the direct effects of temperature on developmental stages in soybean, thermal time provides a better determination of dry matter accumulation (Mayers et al., 1991) aimed to observe the development rate of barley, bread wheat, durum wheat, triticale and oat cereal varieties grown in 5 different locations with rainfed cereals, especially with flowering, and barley varieties matured earlier, barley tillered more, flowered earlier, had higher grain yield than other cereals, matured as barley, bread wheat, triticale, durum wheat and oat, respectively, and barley reached physiological maturity 10 days earlier than other species (Lopez and Richards, 1994) was determined.

The thermal time from sowing to harvest was reported to be 1808 (± 23) GDD at 3 main temperatures (9 - 29 - 39^{o}C) used in the maturity estimation of peanut (Bell and Wright, 1998), while leaf formation at different sowing times in triticale, except when the photoperiod was below 11 hours, (above 0^{o}C) (Naylor and Su, 1998), the number of fully developed leaves on the main stem is directly related to thermal time from sowing onwards in the development of photoperiod sensitive sorghum in Mali (Vaksmann et al., 1998).

In this study, it was aimed to evaluate barley genotypes in terms of phenological periods (VP, GFP, DM) in barley genotypes grown in Kahramanmaraş conditions, to examine their relationships with GY and to calculate the harmonization ratios evaluating GFP_{tt} /VP_{tt} = HR_{tt} together with phenological traits and to determine the traits that can be used as selection criteria for this region.

2. Materials and Methods

In this research, genotypes belonging to barley species (Kendal, Samyeli, Promesa*Yabani, Eralam*Yabani, Şahin-91, Efes-98, Sur-93, Athena*Yabani, Altıkat) were used in Kahramanmaraş conditions in the growing periods of 2014 - 2015 and 2015 - 2016 with 3 replications according to the randomised completed block design.

When the 2-year growing period was analyzed, the lowest temperature was realized in January with 1.6^{o}C in 2015-2016 period and the highest temperature was realized in June with 33.7^{o}C in the same period (Anonymous, 2016). The Mediterranean climate is effective in the region and the temperature difference between seasons is high. Winters are generally warm and rainy, and summers are hot and dry (Figure 1 and Figure 2). In the soil of the experiment, phosphorus and potassium from macro plant nutrients were moderately sufficient, calcium was too much, magnesium was too much, micronutrients except manganese were low or insufficient, organic matter coverage was low, lime coverage was high, and it was slightly alkaline (Anonymous, 2015).

Sowing was carried out on December 5, 2014 in the first year and on December 28, 2015 in the second year with a 6-row plot seeder with a spacing of 20 cm on plots of 8.30 meters in length and 400 grains per/m^2 in barley. Sowing depth was 3 - 4 cm and plot size was 1.2 m x 8.3 m = 9.96 m^2 in both years.

Fertilization was completed with 20-20-0 (compound) commercial fertilizer at 7 kg da^{-1} of pure N and 7 kg of pure P_2O_5 as base fertilizer at sowing in both years, and with 33% Ammonium Nitrate (NH_4NO_3) at 7 kg da^{-1} of pure N at the end of tillering in the second part and 35 kg da^{-1} in the second part.

In the rain-fed study, weeds were controlled manually and narrow and broad-leaved weeds were controlled with selective herbicide (2.4 - D Amine) in the spring season.

Near the harvest time, 1.15 meters from the beginning and end of each plots and 1 row from the edges of the plots were removed as edge effect, and the remaining part (0.8 m x 6 m = 4.8 m^2) was left. In addition, during the ripening period of the plants, the plots were mowed with a sickle for 1 meter each, the mowed plants were dried for 2-3 days and then weighed and biomass yields were determined. Then the parcels were threshed with a threshing machine.

HR (Harmonization ratio) values were calculated with the formula $HR_{tt} = GFP_{tt} / VP_{tt}$ (Harmonization ratio $_{thermal\ times}$= Grain Filling Period $_{thermal\ times}$ / Vegetative Period $_{thermal\ times}$) depending on thermal times. Days to maturity (DM), grain filling period (GFP), vegetative period (VP) were evaluated by Gebeyehou et al. (1982) and Lopez Castaneda and Richards (1994). Celsius scale was used with a base 0^{o}C for thermal time calculations for VP, DM, and GFP. The analysis of variance of the data belonging to the mentioned characters was performed using SAS package program (SAS, 1999) and Duncan multiple comparison test was used to compare the means.

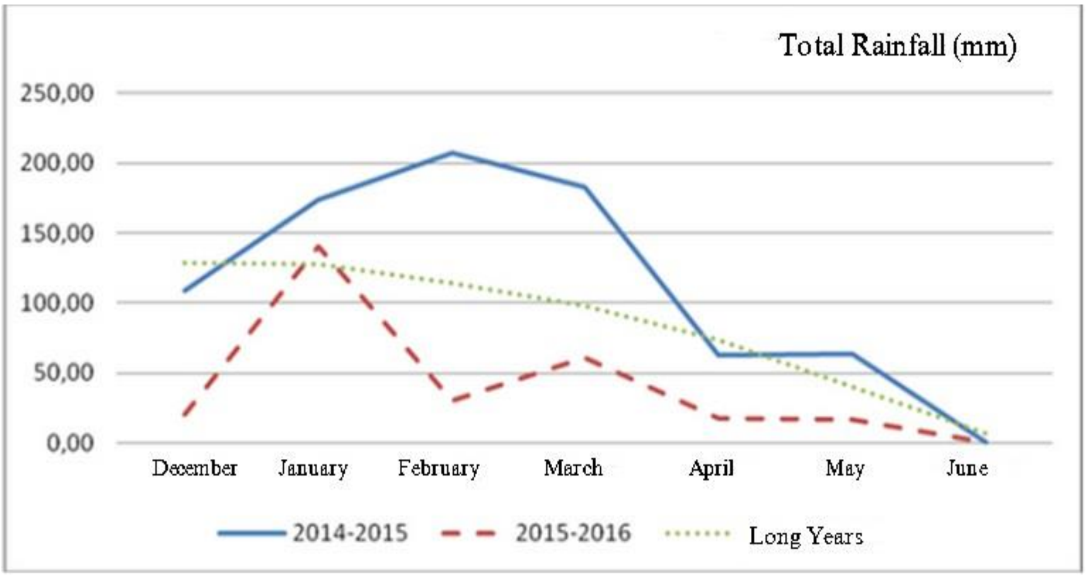

Figure 1. Graph of total rainfall (mm) data for the experimental years and long years (1960 - 2015).

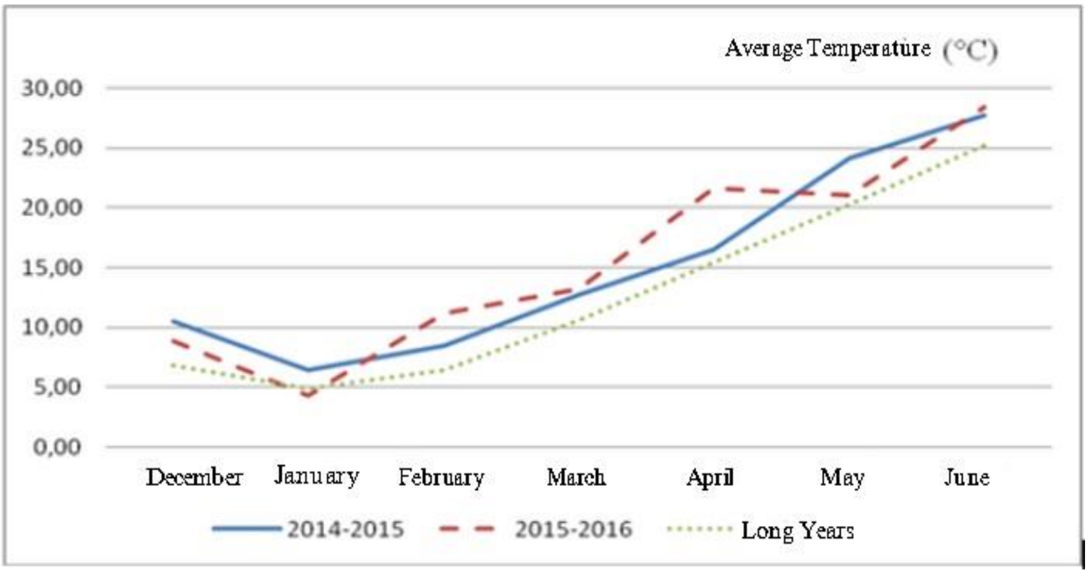

Figure 2. Graph of average temperature (°C) data for the trial years and long years (1960 - 2015).

3. Results and Discussion

As a result of the evaluation of the genotypes in terms of the traits examined by considering the two-year averages; they were found to be significantly different in terms of heading duration, vegetative period, grain filling period, days to maturity, harmonization ratio, grain yield, protein content, 1000-grain weight and hectoliter weight (Table 1, Table 2 and Table 3).

According to the results of correlation analysis, there is no statistically significant difference between grain yield and harmonization ratio in barley (Table 4). The reason for this is thought to be problems such as grain shedding, bird damage, not all varieties are registered and they have different genetic structure.

In terms of vegetative period values, the highest value was obtained from Şahin-91 genotype with 132.5 days, while the lowest value was obtained from Samyeli genotype with 114.1 days (Table 1). In another study, vegetative period values were 67.3 and 64.6 days and grain filling period values were 38.6 and 37.0 days, respectively (Öztürk et al., 2001). In terms of grain filling period values, the highest value was obtained from Samyeli genotype with 41.1 days, while the lowest value was obtained from Şahin-91 genotype with 31.0 days. (Table 1). In terms of days to maturity values, the highest value was obtained from Şahin-91 genotype with 163.5 days, while the lowest value was obtained from Samyeli genotype with 155.3 days (Table 1).

Table 1. Phenological characteristics of the genotypes in the years of the study

Genotypes	Vegetative Period			Grain Filling Period			Days to Maturity		
	14-15	15-16	Average	14-15	15-16	Average	14-15	15-16	Average
Kendal	130.3^{f}	108.3^{c}	119.3^{d}	41.0^{ab}	34.3^{abc}	37.6^{b}	171.3^{bc}	142.6^{de}	157.0^{de}
Samyeli	124.0^{g}	104.3^{d}	114.1^{e}	45.0^{a}	37.3^{a}	41.1^{a}	169.0^{c}	141.6^{e}	155.3^{e}
Promesa*Yabani	135.6^{d}	114.6^{b}	125.1^{b}	37.3^{bc}	32.3^{bc}	34.8^{cd}	173.0^{bc}	147.0^{b}	160.0^{bc}
Eralam*Yabani	138.0^{c}	114.3^{b}	126.1^{b}	37.0^{bc}	32.0^{bc}	34.5^{cd}	175.0^{ab}	146.3^{bc}	160.6^{b}
Şahin-91	146.0^{a}	119.0^{a}	132.5^{a}	31.6^{d}	30.3^{c}	31.0^{e}	177.6^{a}	149.3^{a}	163.5^{a}
Efes-98	139.6^{b}	113.3^{b}	126.5^{b}	34.6^{cd}	33.0^{bc}	33.8^{d}	174.3^{ab}	146.3^{bc}	160.3^{bc}
Sur-93	138.0^{c}	112.6^{b}	125.3^{b}	35.3^{cd}	34.0^{abc}	34.6^{cd}	173.3^{abc}	146.6^{bc}	160.0^{bc}
Athena*Yabani	137.3^{c}	113.3^{b}	125.3^{b}	36.3^{bc}	31.3^{bc}	33.8^{d}	173.6^{ab}	144.6^{bcd}	159.1^{bcd}
Altıkat	132.6^{e}	109.0^{c}	120.8^{c}	39.3^{bc}	35.3^{ab}	37.3^{bc}	172.0^{bc}	144.3^{cd}	158.1^{cd}
Averages	135.7^{a}	112.1^{b}	123.9	37.5^{a}	33.3^{b}	35.4	173.2^{a}	145.4^{b}	159.3

14= 2014, 15= 2015, 16= 2016

Table 2. Traits of the genotypes in the years of the study

Genotypes	Harmonization Ratio			Grain Yield			Heading Duration		
	14-15	15-16	Average	14-15	15-16	Average	14-15	15-16	Average
Kendal	0.692^{ab}	0.652^{abc}	0.672^{b}	140.5^{c}	669.4^{ab}	404.9^{c}	133.0^{e}	110.6^{c}	121.8^{e}
Samyeli	0.764^{a}	0.741^{a}	0.753^{a}	340.0^{ab}	728.7^{a}	534.3^{a}	127.3^{f}	106.3^{d}	116.8^{f}
Promesa*Yabani	0.604^{cd}	0.530^{de}	0.567^{c}	308.8^{b}	587.9^{bc}	448.4^{bc}	141.3^{c}	117.0^{b}	129.1^{bc}
Eralam*Yabani	0.596^{cd}	0.533^{de}	0.564^{c}	334.9^{ab}	558.3^{c}	446.6^{bc}	143.6^{b}	116.0^{b}	129.8^{b}
Şahin-91	0.509^{e}	0.463^{e}	0.486^{d}	415.6^{a}	650.0^{abc}	532.8^{a}	148.6^{a}	120.6^{a}	134.6^{a}
Efes-98	0.563^{de}	0.560^{cd}	0.562^{c}	325.7^{ab}	612.9^{bc}	469.3^{abc}	143.6^{b}	116.3^{b}	130.0^{b}
Sur-93	0.568^{de}	0.588^{bcd}	0.578^{c}	275.4^{b}	558.3^{c}	416.9^{c}	142.0^{c}	106.3^{b}	128.3^{c}
Athena*Yabani	0.583^{cde}	0.534^{de}	0.558^{c}	355.5^{ab}	662.0^{ab}	508.8^{ab}	142.3^{bc}	114.6^{b}	128.8^{bc}
Altıkat	0.650^{bc}	0.660^{ab}	0.655^{b}	366.8^{ab}	579.6^{bc}	473.2^{abc}	136.0^{d}	111.3^{c}	123.6^{d}
Averages	0.614^{a}	0.584^{b}	0.599	318.1^{a}	623.0^{b}	470.6	139.7^{a}	114.2^{b}	127.0

14= 2014, 15= 2015, 16= 2016

Table 3. Quality characteristics of the genotypes in the years of the study

Genotypes	Protein Content in Grain			1000-Grain Weight			Hektoliter Weight		
	14-15	15-16	Average	14-15	15-16	Average	14-15	15-16	Average
Kendal	13.7^{c}	12.1^{ab}	12.9^{ab}	34.1^{e}	30.1^{f}	32.1^{f}	55.4^{a}	58.9^{c}	57.1^{b}
Samyeli	13.7^{c}	13.6^{a}	13.6^{a}	45.9^{ab}	50.4^{ab}	48.1^{ab}	56.9^{a}	68.9^{a}	62.9^{a}
Promesa*Yabani	13.4^{d}	12.5^{a}	13.0^{ab}	46.3^{ab}	47.0^{bcd}	46.6^{bc}	55.4^{a}	64.2^{abc}	59.8^{ab}
Eralam*Yabani	14.1^{b}	12.4^{a}	13.3^{ab}	43.7^{bc}	45.9^{cde}	44.8^{cd}	56.0^{a}	63.5^{abc}	59.7^{ab}
Şahin-91	12.7^{e}	12.4^{a}	12.6^{b}	44.1^{abc}	48.3^{bc}	46.2^{bc}	55.7^{a}	65.5^{ab}	60.6^{ab}
Efes-98	13.8^{c}	12.7^{a}	13.2^{ab}	41.9^{c}	43.9^{de}	42.9^{de}	53.0^{a}	60.9^{bc}	56.9^{b}
Sur-93	14.8^{a}	12.4^{a}	13.6^{a}	47.0^{a}	52.4^{a}	49.7^{a}	54.8^{a}	68.9^{a}	61.8^{a}
Athena*Yabani	13.8^{c}	12.1^{ab}	12.9^{ab}	39.0^{d}	42.5^{e}	40.8^{e}	56.9^{a}	62.9^{abc}	59.9^{ab}
Altıkat	12.1^{f}	10.5^{b}	11.3^{c}	33.8^{e}	31.1^{f}	32.5^{f}	53.5^{a}	49.5^{d}	51.5^{c}
Averages	13.6^{a}	12.3^{b}	12.9	41.8^{a}	43.5^{b}	42.6	55.3^{a}	62.5^{b}	58.9

14= 2014, 15= 2015, 16= 2016

Table 4. Correlation coefficients of investigated characteristics of the genotypes as an averages of two years of the study

Traits	PC	HD	DM	HR	VP	GFP	1000-GW	HW	GY
PC	1.000								
HD	0.513**	1.000							
DM	0.536**	0.963**	1.000						
HR	0.092	-0.174	0.073	1.000					
VP	0.498**	0.997**	0.959**	-0.195	1.000				
GFP	0.294*	0.198	0.448**	0.878**	0.178	1.000			
1000-GW	0.256	-0.032	-0.082	-0.255	-0.630	-0.189	1.000		
HW	-0.433**	-0.863**	-0.923**	-0.203	-0.855**	-0.509**	0.352**	1.000	
GY	-0.535**	-0.800**	-0.867**	-0.145	-0.797**	-0.499**	0.178	0.862**	1.000

*Significant at 5 % level, **Significant at 1 % level. PC= protein content per grain, HD= heading duration, DM= days to maturity, HR= harmonization ratio, VP= vegetative period, GFP= grain filling period, 1000-GW= 1000-grain weight, HW= hectoliter weight, GY= grain yield.

The harmonization ratios varied between 0.486 - 0.753, the highest harmonization ratios were observed in Samyeli (0.753) and Kendal (0.672) genotypes, while the lowest harmonization ratios were observed in Şahin-91 (0.486) and Athena*Yabani (0.558) genotypes, respectively (Table 2). In terms of grain yield values, the highest value was obtained from Samyeli genotype with 534.3 kg da^{-1} and the lowest value was obtained from Kendal genotype with 404.9 kg da^{-1} (Table 2). The reason why the grain yield of Kendal variety was very low in the first year of the experiment was due to bird damage to the plots of this variety in the first year. In another study, grain yield of different barley genotypes varied between 158- 458 kg da^{-1} under barren conditions and between 2.82-6.34 kg da^{-1} under irrigated conditions (Sönmez and Yüksel, 2019). When the average of two years was analyzed, the highest heading duration value was obtained from Şahin-91 genotype with 134.6 days and the lowest value was obtained from Samyeli genotype with 116.8 days (Table 2). In the studies conducted in Bafra plain, it was determined that the heading duration of the varieties used in the studies ranged between 126.0-133.5 days (Sirat and Sezer, 2017a) and the heading duration ranged between 160-170 days in Samsun (Sirat and Sezer, 2017b).

In terms of 1000-grain weight values, the highest value was obtained from Sur-93 genotype with 49.7 g and the lowest value was obtained from Kendal genotype with 32.1 g. In this study, considering the fact that the sowing was made later in the second year compared to the first year and higher 1000-grain weight was obtained in the second year, it is seen that it is in harmony with the studies of researchers such as Kandemir (2004) and Öztürk et al. (2007) who stated that high 1000-grain weight was obtained in late sowing (Table 3). In terms of hectoliter weight values, the highest value was obtained from Samyeli genotype with 72.4 kg, while the lowest value was obtained from Altıkat genotype with 61.1 kg (Table 3). These results are also in accordance with the researches indicating that hectoliter weight was 73.5 kg in the first year and 79.1 kg in the second year (Bleidere et al., 2013) and 1000-grain weight was between 24-47 g (Balouchi et al., 2005). In terms of protein content values in grain, the highest value was obtained from Samyeli genotype with 13.6% and the lowest value was obtained from Altıkat genotype with 11.3% (Table 3). Gündüzalp (1992) reported that the protein content of barley was between 8-15% and Kenar and Şehirali (2001) reported that two-row varieties had higher protein content than six-row varieties. Considering that Kendal and Altıkat varieties used in our research were six-rowed and the other genotypes were two-rowed, it is seen that these results coincide with our research results. In previous studies conducted with barley genotypes, protein content was between 6.35 and 23.4% (Wang et al., 2011).

4. Conclusion

According to the results obtained from the research; Samyeli and Şahin-91 varieties can be recommended for high grain yield under regional terms. In addition, it was determined that hectoliter weight, 1000-grain weight, days to maturity, vegetative period, heading duration, grain filling period, harmonization ratio and protein content traits can be used as selection criteria for high grain yield in the regional conditions. It is thought that all these differences between the traits and genotypes are due to the different environmental and ecological conditions of the two years, the use of different genotypes, genetic differences between the genotypes and the different adaptation ability of the genotypes. It can also be said that the genotypes responded differently to ecological circumstances.

Considering this research, it may be recommended to carry out studies with different locations, plants and genotypes in order to move forward in this field in terms of agricultural production activities. Definition of the characteristics of the genotypes is also important for future breeding studies.

Author Contributions

The percentage of the author(s) contributions is presented below. The author reviewed and approved the final version of the manuscript.

	F.Ö.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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