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YIELD AND QUALITY CHANGES IN BARLEY GENOTYPES DURING HIGH TEMPERATURE STRESS CAUSED BY LATE SOWING

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ABSTRACT

In achieve yield sustainability, it is important to cultivate barley varieties that are resistant to the heat and drought stress conditions carried on by global climate change. Barley is one of the significant cultivars that is negatively affected by global climate change due to its low tolerance to heat stress. Late sowing was employed to ensure that plants were exposed to heat stress in order to evaluate the agronomic performance of barley genotypes under high temperature stress. The late sowing process was carried out in February 2019 and 2020 years. Heading time, physiological maturity, plant height, chlorophyll content (SPAD), normalized difference vegetation index (NDVI), grain weight, protein content, test weight, ground cover (Canopeo) and leaf area index (LAI) were investigated using three local varieties, three advanced lines, and two standard barley varieties. Precipitation of more than 450 mm throughout the vegetation period in both years, as well as sufficient water storage in the soil before to the vegetation period, allowed the growth phase to be effectively examined under heat stress. There were significant differences among genotypes in all traits except plant height and NDVI. Except for physiological maturation and protein ratio, the genotype x environment interaction had an effect on all characteristics. This demonstrated that, in the absence of water stress, mainly high temperature effects had an impact on yield. Among the advanced lines examined, the DZ21-17 genotype succeeded in terms of staying green, being early, increasing chlorophyll content, and increasing grain weight. Local varieties maintained productivity in heat stress by increasing leaf area, while grain yield potential stayed behind standard varieties and advanced lines. Local cultivars had the advantage of fast ground cover and having a high growth rate. It has been determined that barley genotypes with high plant height and grain weight will have a high yield potential under conditions of heat stress.

Keywords: climate change, drought stress, local varieties.

INTRODUCTION

Barley is not indigenous to a single center of origin. Its distribution to different geographical regions is the major reason why barley has a mosaic of adaptive variants tolerant to biotic and abiotic stresses (Allaby, 2015; Poets et al., 2015). As a result, significant genetic potential exists for the development of new tolerant genotypes (Ellis et al., 2002; Vasilescu et al., 2022). Nowadays, many research are conducted using a variety of techniques, including molecular, biotechnology, and mutation, in order to create new varieties from existing genetic variation. Therefore, there is genetic variation of barley in aspects of drought and heat stress for successful breeding program (Langridge, 2018). As a result, it is necessary to determine the abiotic stress resistance of local and modern barley varieties.

Global climate change is anticipated to increase the impact and intensity of heat stress, which causes significant losses in food production (Talukder et al., 2014). By 2050, a 0.3 percent increase in global temperature every ten years is predicted to lead in a 50% decrease in yield in South Asia (IFPRI, 2009). Global barley production is currently limited by drought and high temperature stress, which are the two most critical factors affecting yield improvement. Furthermore, due to global climate change, barley production regions that today have high yield potential are projected to become stressful in the future (Lopes et al., 2012).

Ozturk et al. (2017), Kılıc et al. (2020) and Ertus (2021), determined that high temperatures were effective in reducing grain

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yield during the grain filling period and that among existing genotypes; there were heat stress tolerant genotypes with high grain yield and protein ratio. The improvement of suitable barley varieties for the different ecologic zones has world-wide importance. There is a need for research interventions to develop improved varieties with higher yield, better resistance to lodging, tolerance to heat and drought stress, a higher nutritional value, and to strengthen the barley pathology research programs. To successfully utilize genetic resources in plant breeding programs, it is required to first assess whether beneficial genetic diversity exists in the material and, second, to find the most cost-effective means of integrating potentially helpful genes into commercially suitable material (Kearsey, 1997). Barley-improvement programs, whether by breeding or direct gene manipulation, aim to match adaptation to the local environment and to enhance quality for processing (Ellis et al., 2002).

In order to maintain grain yield and ensure agricultural production, it is necessary to breed and research local line and tolerant genotypes, taking into account all of the effects of drought and heat stress factors. The purpose of this study was to explore the effects of heat stress on the agronomic and quality features of local and current barley genotypes.

MATERIAL AND METHODS

The research was conducted in the experimental area of Dicle University, Faculty of Agriculture (Diyarbakır/Turkey) under dry conditions over two years 2019 and 2020. Three barley lines from ICARDA, three local barley genotypes, collected from Diyarbakir/Turkey barley production areas, and two standard varieties were used as material (Table 1). The soils were clay loam and salinity was low. Organic matter and phosphorus ($H_2PO_4^-$) contents were very low while potassium (K^+) was very high. Magnesium content was at middle level (616 ppm). The soils contain lime between 10.0-11.0% at depth of 0-60 cm.

Table 1. Details of line and standard barley variety used in the study

Genotypes	Local 32	Local 69	Local 71	DZ21-17	DZ21-9	DZ21-16	Onder	Kendal
Head Types	2 row	2 row	2 row	6 row	6 row	6 row	2 row	6 row
Origin	Diyarbakır-Center-Telli kaya	Diyarbakır-Silvan	Diyarbakır-Silvan	ICARDA	ICARDA	ICARDA	Dicle Univ. Faculty of Agriculture	GAPUTAEM

Climate data showed the average temperature was 14.8℃, and relative humidity was 64.3% for the 2019 growing season. It were the average temperature 14.6℃ and relative humidity 62.2% for the 2020 growing season. In April-May, which covers the pre-heading and grain filling period, there was more rainfall in the first year compared to the second year. In the first and second years following planting, the precipitation is 412 and 372 mm, which is greater than the long-term average (256 mm) (Figure 4). The pre-sowing total precipitation was 422.6 and 335.8 mm at first and second experiment years, respectively. The data on precipitation suggest that there is no drought effect during the barley development phase. The temperature data of from sowing to pre-heading and post-heading growth stages at 2019 and 2020 growing seasons are given in Figure 1, 2 and 3.

The experiment was laid out the randomized complete block design with three replications. Plots size was 4.8 m^2. Seeds were sown on 5 February 2019 and 26 February 2020. Sowing density was 500 seeds per m^2. Fertilizer treatments were applied 60 kg ha^{-1} pure N and P (as 20.20.0 NP compose fertilizer) at sowing time, and 60 kg ha^{-1} pure N (Urea %46 N) at the end of tillering stage. Herbicide was used to control the weeds. Plant harvested 15-20 days after physiological maturity.

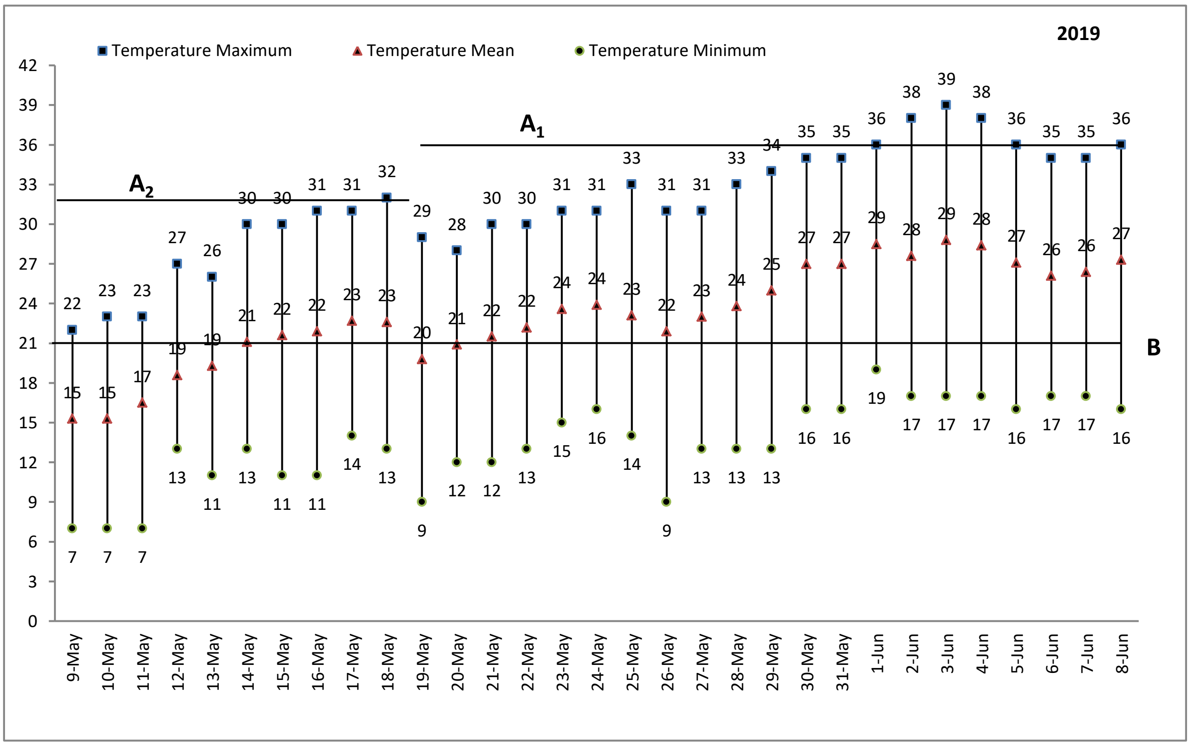

Figure 1. Daily temperatures after heading stages of the barley for 2019.
A1 represents the maximum temperature (Tmax) stress limit for barley between the spike emergence and the end of flowering; A2 represents the maximum temperature (Tmax) stress limit for wheat during grain filling period; B is optimum temperatures (Topt) for post-heading stages in barley.

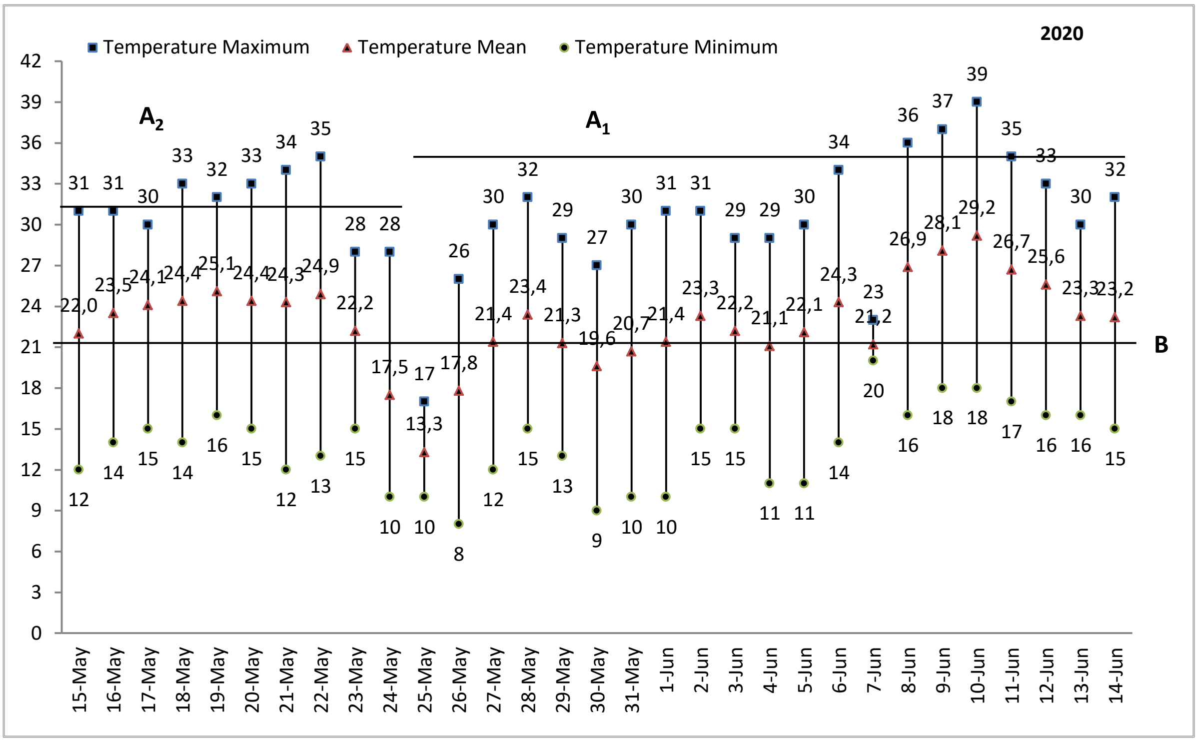

Figure 2. Daily temperatures after heading stages of the barley genotypes for 2020.
A1 represents the maximum temperature (Tmax) stress limit for barley genotypes between the spike emergence and the end of flowering; A2 represents the maximum temperature (Tmax) stress limit for wheat during grain filling period; B is optimum temperatures (Topt) for post-heading stages in barley.

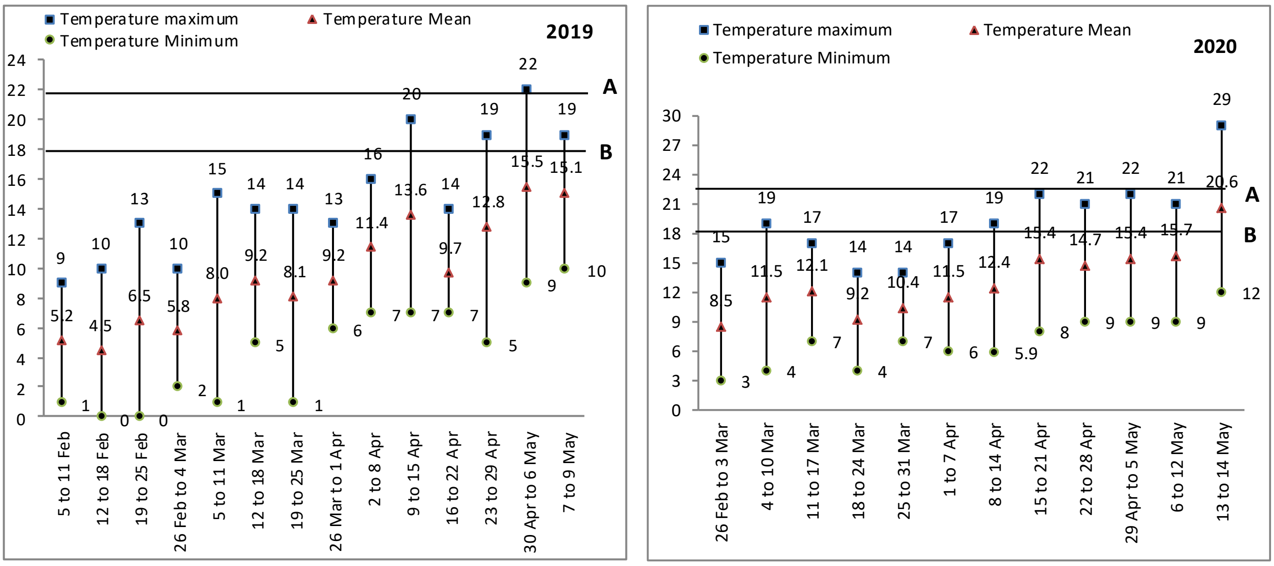

Figure 3. Temperature (°C) from sowing to pre-heading period of barley genotypes for 2019 and 2020 growing seasons. B is optimum (Topt) temperatures and A maximum temperatures (Tmax) for the barley genotypes growing period.

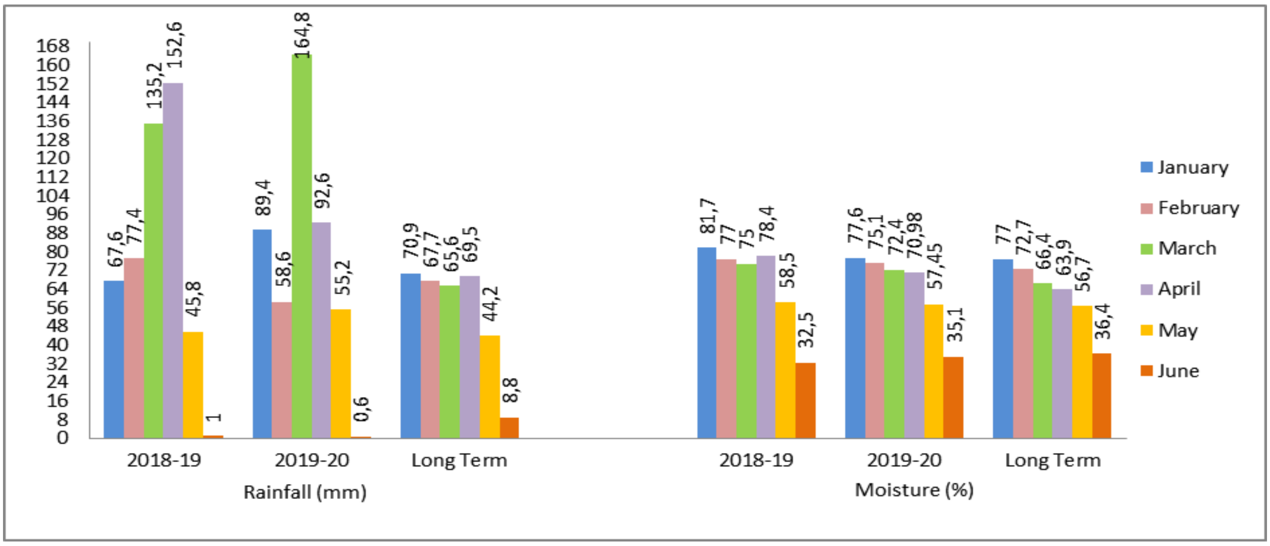

Figure 4. Distributions of precipitation and humidity according to the months following planting at the experiment site

Measurements

In the study, physiological maturity time (days), heading time (days), plant height (cm), grain yield (kg/da), thousand grain weight (g), protein content (%), test weight (kg/hl), SPAD value (chlorophyll content), leaf area index (LAI), normalized vegetation difference index (NDVI) and ground cover ratio traits (Canopy) were investigated. The physiological maturity time (PM) was calculated using the GS87 scale, based on the developmental periods described by Zadoks in 1974 (Zadoks et al., 1974). Heading time was calculated as the total number of days between the sowing date and the period when ½ of spike (GS55) is visible at the half of the plot. The leaf chlorophyll content was recorded by SPAD 502 chlorophyll meter, ranging from 0-100 in flag leaves of ten randomly selected plants during the heading period (Minolta SPAD-502, Osaka, Japan). Leaf area index (LAI) was determined on the area covered by the plants in the plot in the 2nd year of the experiment using the LAI-2000 (LI-COR, Lincoln, NE). Normalized vegetation different index (NDVI) was measured with Trimple GreenSeeker Handheld Crop Sensor during the heading period in the range of 0.00-0.99 values. SPAD, LAI and NDVI measurements were recorded between 11:00 and 14:00 when there was no wind and cloud. The amount of protein content (%) and test weight was measured by a NIT analyzer.

The plant ground cover (Canopeo) was determined in the second year of the experiment by photographing the plot four times with the Canopeo application on April 7th, 15th, 23th, and 30th, and calculating the percentage of soil covering. The Canopeo application estimates the ground cover rate with 100% accuracy (Patrignani and Ochsner, 2015). The daily growth rate and the number of day's full ground cover were computed using regression analysis of Canopeo values obtained at regular intervals after plant emergence. The formula for calculating the daily growth rate is given below.

The cubic polynomial curve defined the association between fully ground cover and days after sowing using the formula C: $a + bt + ct^2 + dt^3$. Where C is the growth rate index (coverage rate/day), t is time (days after planting), a, b, c and d are the regression coefficients. Since the coefficient of determination (R^2) exceeds 90% in many genotypes, the model correctly defined the highest growth rate.

Average growth rate can be determined according to the formula (C2 – C1) / (t2 – t1). Here W2 and W1 are the closing amounts at times t2 and t1. Since the amount of leaves on the soil surface will be zero at the time of sowing (t1), the average growth rate was determined as C2 / t2. In order to find the moment when the genotypes have the highest growth rate, the formula C: ct2 + dt3 was used instead of the full cubic curve, since the leaf area and growth rate was zero at the time of sowing (C: $a + bt + ct^2 + dt^3$). As a result, the speed estimate was done at the curve's sharpest point. The highest growth rate was calculated from the formula C: $ct^2 + dt^3$ by converting it to the formula Cmax: -3c2/9d (Gebeyehou et al., 1982). With the help of the JUMP Pro 13 statistical package program, the obtained data were subjected to variance and correlation analyses, and the statistical differences between the means were established using the LSD test.

RESULTS AND DISCUSSION

A cool season cereal requires cool temperatures during its growing season in the range of about 14ºC to 18ºC. Given that the spike emergence occurred around May 10 as a result of late sowing, it is clear that they were subjected to severe heat stress during the post-heading phase (Figure 1 and 2). When the distribution of heat stress is compared between the two years, the first year is extremely hot after the heading, whereas the second year is highly hot both pre- and post-heading period (Figure 3). Acevedo et al. (1991) reported a mean reduction of 4 percent in grain weight per degree increase in mean temperature during grain filling. Temperature threshold (Topt) that adversely affect the development process of wheat from this level; 22.0 (± 1.6)ºC during germination and emergence, 10.6 (± 1.3)ºC during spike formation, 21.0 (± 1.7)ºC during flowering and 20.7 (± 1.6)ºC during grain growth, and the temperatures (Tmax) at which the growth started to stop were 32.7 (±0.9)ºC, 20.0ºC, 31.0ºC and 35.4.0 (±2.0)ºC, respectively (Yildirim and Barutcular, 2021). According to this information, barley is subjected to heat stress during all stages except germination/emergence.

A combined analysis during two consecutive experiments was performed. Differences among genotypes under high temperature stress caused by late sowing were significant for physiological maturity time, heading time, SPAD, a thousand seed weight, grain yield, protein content and test weight but plant height and NDVI were no significant (Tables 2 and 3). Differences among years were significant for all other parameters except for thousand grain weight and grain yield. G x Y interaction was significant for all traits, except heading time and protein content. This suggests that the genotypes respond similarly to a heat-stressed environment for heading time and protein content.

Differences among years for heading time were significant, and the second year was earlier than the first year. This result could be caused by rainfall before the heading period. Before at the heading time in the first year was 40 mm more precipitation and it colder than in the second year (Table 2). Also barley genotypes were planted earlier than the second year in the first year, they were heading time later than the second year. The local genotypes in the study generally were later than the standard cultivars and advanced lines. However, Akinci and Yildirim (2009) reported that local genotypes were earlier than standard varieties in their study. In the first year, Onder standard variety had the lowest physiological maturity time with a value of 115.7 days. In the second year, the difference between genotypes was found to be closer to each other and they showed maturation at similar dates. Based on the two-year average data, the DZ21-17 genotype remained longest stay green (109.0 days), while the Onder genotype had short stay green (111.3 days). With a long physiological maturity time and a long grain filling time by early heading, the DZ21-17 genotype has the potential to stay green for a long time.

Looking at the two-year average data, Local 69 had the highest plant height (92.2 cm). According to different researchers that have come to similar conclusions as ours, the 80-100 cm range belongs to the group of short or medium plants, which are resistant to lodging and have a larger production potential than tall plants (Ozturk et al., 2017; Sonmez and Yuksel, 2019).

The lowest chlorophyll content estimated by SPAD meter was found in the Local 32 genotype (37.1) during the 2019 growing season, and the highest content was found in the DZ21-17 genotype, with a value of 46.6 during the same period. In the same year, genotypes DZ21-9, Kendal, Onder and Local 32 had low values. In the 2020 growing season, the lowest value was found in Kendal and Local 69 genotypes, and the highest value was found in DZ21-9 genotype. While Elis and Yildirim (2021) reported SPAD values under heat stress conditions that were quite similar to the SPAD average obtained in the first year (41.1), they were far below SPAD average obtained in the second year (48.3).

The Local 69 genotype (60.0) had the highest the normalized vegetation difference index (NDVI) in the first year, followed by the Local 32 genotype (78.33) in the second year. The averages for the first and second years were 51.3 and 73.3, respectively. There was a 30% difference between years. The NDVI difference between years can be attributed to the difference in total precipitation prior to heading time. Despite the fact that this condition is unexpected, Kızılgeci and Yildirim (2019) similarly reported that the NDVI value declined by 39.5 percent during the year when precipitation was high. NDVI is a parameter according to quite a researchers that can be indicates the photosynthetic area over the vegetation, gives predictive information for growth biomass, and is a parameter that can be used to estimate leaf angle and erectness (Gong and McDonald, 2017).

Table 2. Variance analysis and mean of the physiological maturity (PM), heading time (HT), plant height (PH), SPAD and NDVI in barley that were exposed to heat stress during to growing season

Genotypes	PM (day)			HT (day)			PH (cm)			SPAD (unit)			NDVI		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
Local 32	121.0 ab	106.0 d	113.5 bc	95.0	80.0	87.5 a	70.8 d	95.3 a	83.1	37.0 f	48.5 ab	43.3 c	46.0 d	78.33 a	62.2
Local 69	119.3 bc	109.0 d	114.2 abc	93.5	75. 7	84.6 bc	96.9 a	87.5 abc	92.2	43.6 de	46.8 a-d	45.2 bc	60.0 c	70.5 ab	65.3
Local 71	121.3 ab	108.0 d	114.7 ab	91.0	81.0	86.0 ab	88.4 ab	87.9 ab	88.2	44.1 cde	48.3 ab	46.2 ab	53.7 cd	73.5 ab	63.6
DZ21-17	125.3 a	109.0 d	117.2 a	91.5	74.3	82.9 cd	85.3 abc	86.3 abc	85.8	46.7 bcd	49.9 ab	48.1 a	46.5 d	75.0 ab	60.7
DZ21-9	125.3 a	106.7 d	116.0 ab	93.0	75.3	84.1 bcd	75.4 bcd	86.9 abc	81.1	38.7 f	50.3 a	44.5 bc	51.5 cd	69.3 b	60.4
DZ21-16	124.7 a	108.3 d	116.5 ab	89. 7	73.0	81.3 d	80.8 de	92.6 ab	86.7	40.5 ef	48.6 ab	44.6 bc	49.3 d	74.5 ab	61.9
Kendal	123.3 ab	109.0 d	116.2 ab	94.3	77.7	86.0 ab	81.6 bcd	88.0 ab	84.8	39.0 f	46.4 a-d	42.7 c	53.0 cd	73.0 ab	63.0
Onder	115.7 c	107.0 d	111.3 c	92.7	74.0	83.3 bcd	90.9 ab	82.0 bcd	86.4	38.6 f	47.6 abc	43.1 c	50.0 d	72.3 ab	61.2
Mean	122.0 a	107.9 b	114.9	92.6 a	76.4 b	84.5	83.8 b	88.3 a	86.0	41.1 b	48.3 a	44.9	51.3 b	73.3 a	62.3
LSD (GxY)		2.13 *			ns			6.08 **			1.94 *			4.18 *	
LSD (G)		1.51 *			1.42 **			ns			1.37 **			ns	
LSD (Y)		0.43 **			0.78 **			1.22 *			0.88 **			2.38 **	
CV (%)		2.27			2.90			8.66			5.32			8.21	

*, **: Significant at $P < 0.05$, $P < 0.01$; ns: non significant; G: genotype; Y: year.

Table 3. Variance analysis and mean of the grain yield (GY), thousand grain weight (TGW), protein content (PC), test weight (TW) in barley that were exposed to heat stress during to growing season

Genotypes	GY (kg/ha^{-1})			TGW (g)			PC (%)			TW (kg hl^{-1})		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
Local 32	114.7 g	207.7 bc	161.2 d	37.5 d-g	44.9 bc	41.2 b	13.07	14.83	13.95 b	61,5 e	65,8 d	63,7 c
Local 69	127.5 g	168.0 e	147.8 d	32.2 gh	41.3 b-e	36.8 cd	13.21	13.80	13.50 b	65,7 d	68,1 bcd	66,9 b
Local 71	159.9 ef	171.8 de	165.8 cd	39.8 b-f	45.6 ab	42.7 ab	13.32	13.20	13.26 bc	61,3 e	67,8 bcd	64,5 c
DZ21-17	227.3 ab	112.0 g	169.6 cd	35.0 fg	28.2 h	31.6 e	12.42	12.93	12.68 cd	66,1 cd	68,2 bcd	67,1 b
DZ21-9	184.6 cde	188.4 cde	186.5 bc	35.8 efg	37.0 d-g	36.4 d	11.40	12.80	12.10 d	71,4 a	65,8 d	68,6 ab
DZ21-16	183.3 cde	211.4 bc	197.3 ab	40.3 b-f	51.5 a	45.9 a	13.08	14.40	13.74 b	66,8 cd	67,8 bcd	67,3 b
Kendal	189.6 cde	247.2 a	218.4 a	35.3 efg	37.8 d-g	36.6 d	12.75	13.97	13.30 bc	70,2 ab	69,0 abc	69,6 a
Onder	203.4 bcd	120.5 g	162.0 d	39.5 c-f	42.3 bcd	40.9 bc	14.99	15.53	15.26 a	67,9 bcd	68,6 a-d	68,3 ab
Mean	173.8	178.4	176.1	36.9 b	41.1 a	42.2	13.03 b	13.93 a	13.50	66,4	67,6	67
LSD (GxY)		16.25 **			2.93 **			ns			1,47 **	
LSD (G)		11.49 **			2.07 **			0.37 **			1,04 **	
LSD (Y)		ns			1.20 *			0.052 **			ns	
CV (%)		11.30			9.2			4.74			2,68	

*, **: Significant at $P < 0.05$, $P < 0.01$; ns: non significant; G: genotype; Y: year.

Grain yield ranged between 114.7-227.3 kg/ha^{-1} in the 2019 growing season and 112.0-247.2 kg/ha^{-1} in the 2020 growing season. In the first year, DZ21-17 genotype had the highest grain yield, while Local 32 genotype had the lowest yield. It was found that in the second year, Kendal standard variety had the highest yield and DZ21-17 genotype had the lowest yield. The obtained grain yield are higher than Kuzu (2020) findings, but lower than Jedel et al. (1998) and Sonmez and Yuksel's (2019) findings. Although there was no difference in grain yield between years, the fact that the genotype-environment interaction was important caused the genotype ranking to show very different changes according to the years. The high yield potential of the Kendal variety in both years demonstrates that this variety is stable in terms of resilience to high temperatures. On the other hand, Onder and DZ21-17, which had a high yield in the first year, remained at the lowest level in the second year, indicating that they were affected by the changing environmental conditions. It is observed that the average grain yield of local varieties is approximately 32 kg lower than that of standard varieties and 5 kg lower than that of advanced lines. This shows that under conventional conditions, local varieties cannot compete with standard varieties. Therefore, identifying the specific traits of local varieties that are resistant to biotic and abiotic stress factors would assist in grain yield improvement. The fact that the yield potential of the advanced lines do not exceed the standard varieties shows that there is a genetic bottleneck in raising grain yield and that genetic diversity should be increased. However, in a study conducted by Akinci and Yildirim (2009) in drought conditions, local varieties had a 13.8 percent higher yield than standard varieties, indicating that local genotypes have a high yield potential.

The average thousand grain weights in the first and second years were 32.2-40.3 and 28.2-51.5 g, respectively. In both growing seasons, the DZ21-16 genotype had the highest thousand grain weights. Protein content, an important quality parameter, was found to be highest in the Onder standard variety in both years, and lowest in the DZ21-9 genotype. According to the two-year results, the protein content ranged between 12.0 to 15.26%, which was similar to the 13.2-15% protein values reported by Akinci and Yildirim (2009). DZ21-9 genotype had the highest test weight value (71.4 kg hl^{-1}), compared to the other first year genotypes. The genotype Local 32 had the lowest value (61.5 kg hl^{-1}) followed by the genotype Local 71. In the second year, the averages between genotypes were found to be in the range of 65.8-69.0 kg hl^{-1}, with the lowest value occurring from Local 32 genotypes and the highest value obtained from the Kendal standard variety.

When comparing the genotypes in terms of Canopeo (%) values, which indicate plant growth rates and gives ground cover rates, there was a difference between them during the first three measurement periods; however, the difference disappeared during the last measurement period, when the average cover rate was 80.17% (Table 4). This condition indicates that after a certain period of time, the difference between fast and slow growing genotypes stabilizes. While the plants covered an average of 30.45% of the soil surface 26 days after emergence, the growth attained after 8 days covered another 10%. The growth rate increased over the next 8 days, achieving a 20% increase. The 15% rise was achieved in the 7-day period before the latest measurement. Plant growth rates are affected by temperature changes over time; nonetheless, an increase in leaf area that closes the soil leads to an increase in total photosynthetic area, which raises the growth rate. It was determined that the average growth rates of genotypes between 1.53 and 1.76% per day (Table 4). According to estimate from the regression curves, the daily highest closing speed differed between 1.76 and 4.82% per day (Figure 1 and 2). For barley genotypes, having the highest covering rate can be advantageous, especially during stressful periods or conditions. The total soil coverage duration estimated from the regression curve differed from 52.3 to 60 days. In general, local varieties provide faster full closure, whereas standard varieties provide later closure (Figure 5). Between the 34th and 42nd days following emergence, the growth rates of the genotypes were very high. Fast ground covers is important for increasing photosynthetic surface area per unit area while also minimizing water loss through evaporation. It should be emphasized here that, while genotypes with a vertical growth habit provide more leaf area, they may later fully ground cover. In the correlation analysis, it was observed that Canopeo values were not related to yield and LAI (data not shown). McGlinch et al. (2020) reported that the ground cover rate determined by Canopeo showed a high correlation with the stem number and could be used to estimate grain yield in barley. Canopeo data can be utilized to determine the biomass weight of genotypes in sorghum, according to Chung et al. (2017). Local barley varieties have a high leaf area index (LAI) value, according to research (Table 4).

Table 4. Ground cover rate (Canopeo), growth rate estimates and LAI values of barley genotypes

Genotypes	Canopeo (%)				Estimated fully cover	Growth rate (%/day)		
	26th day	34th	42nd	49th	Day	Mean	Max	LAI
Local 32	29.07	41.83	74.62	86.39	52.3	1.76	4.09	3.10
Local 69	28.94	39.83	61.30	75.06	56.5	1.53	4.82	4.73
Local 71	37.43	47.93	67.91	83.64	55.3	1.71	2.88	5.37
DZ21-17	37.20	58.60	70.33	80.79	57.2	1.65	2.66	2.83
DZ21-9	32.65	45.13	59.73	79.72	55.4	1.63	1.73	3.33
DZ21-16	29.15	50.51	69.81	80.96	54.9	1.65	4.25	3.23
Kendal	27.43	44.20	62.75	78.80	60.0	1.61	2.56	3.03
Onder	21.77	37.96	52.06	76.00	57.5	1.55	1.76	2.43
Mean	30.45	45.75	64.81	80.17	56.1	1.64	3.09	3.51
LSD	5.34*	6.53*	5.45*	ns				0.33**
CV(%)	21.49	17.51	10.31	8.39				11.36

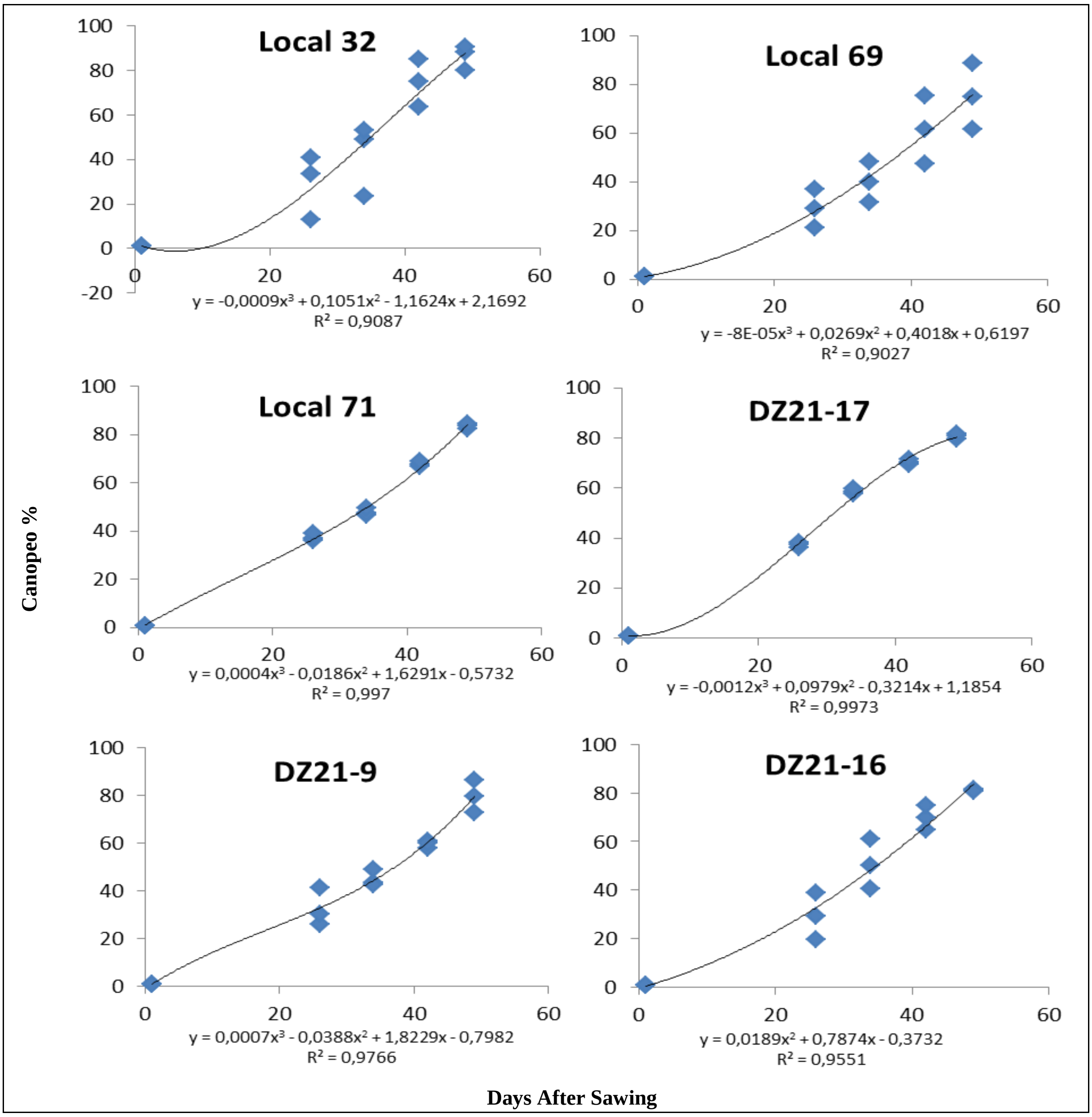

Figure 5. Regression curves of ground cover rates (Canopeo) of different barley genotypes measured on different days after emergence

The correlation analysis (Table 5) showed that grain yield was positively correlated with plant height, test weight and thousand grain weight parameters. SPAD and NDVI, which are physiological characteristics, were positively related to plant height, while a negative correlation was found with physiological maturity and heading time. While both SPAD and NDVI are based on spectral reflectance, SPAD measures the plant community in a single plant, and NDVI measures the plant community as a whole. This situation demonstrates that when measuring foliage, both plant traits produce similar results. Nonetheless, the positive connection of NDVI with protein content indicates that it may be useful in quality selection. Plant height was positively correlated with protein content, but physiological maturity and heading time were negatively correlated. This shows that early growing and early maturing genotypes have higher protein content, and tall genotypes should be selected for good quality.

Table 5. Pearson's correlation of investigated traits of barley genotypes during 2019 and 2020 growing seasons

Parameters	PH	PM	HT	SPAD	NDVI	GY	PC	TW
PM	-0.3409*							
HT	-0.2888*	0.8719***						
SPAD	0.5032***	-0.6462***	-0.7259***					
NDVI	0.4444**	-0.8195***	-0.8057***	0.7208***				
GY	0.3093*	-0.0050	-0.0493	0.0648	-0.0528			
PC	0.2944*	-0.4999***	-0.3766**	0.2703	0.4228**	-0.0144		
TW	0.1176	-0.1217	-0.2240	0.0280	0.1819	0.3198*	-0.1023	
TGW	0.1038	0.1769	0.0474	0.1581	-0.1873	0.4476**	-0.0557	-0.0194

*, **: Significant at $P < 0.05$, $P < 0.01$; ns: non significant; Plant height (PH), Physiological maturity time (PM), Heading time (HT), Normalized differences vegetative index (NDVI), Grain yield (GY), Protein content (PC), Thousand grain weight (TGW), Test weight (TW).

CONCLUSIONS

Although early heading and physiological maturity were not connected with grain yield in barley genotypes, genotypes with high grain weight provided advantages under general temperature stress conditions. In this context, having a high grain filling speed for a high grain weight, as well as a large number of spikes and grains per spike, will be advantageous. It is predicted that barley genotypes, which have an architecture that does not increase the leaf area but extend the plant height, may be suitable plant models for heat stressed conditions. The fact that the local cultivars used in the study have similar phenological, physiological, grain yield, and quality characteristics to standard genotypes and advanced lines indicates that local cultivars can be used directly as cultivars or as donors to improve some of the negative characteristics of developed cultivars.

REFERENCES

Acevedo, E., 1991. *Improvement of winter cereal crops in Mediterranean environments. Use of yield, morphological and physiological traits*. Colloques de l'INRA (France): 273-305.

Akinci, C., and Yildirim, M., 2009. *Screening of barley landraces by direct selection for crop improvement.* Soil and Plant Science, 59: 33-41. doi: 10.1080/09064710701827782

Allaby, R.G., 2015. *Barley domestication: the end of a central dogma?* Genome Biology, 16(1): 1-3. doi: 10.1186/s13059-015-0743-9

Chung, Y.S., Choi, S.C., Silva, R.R., Kang, J.W., Eom, J.H., Kim, C., 2017. *Case study: Estimation of sorghum biomass using digital image analysis with Canopeo.* Biomass and Bioenergy, 105: 207-210.

Ellis, R.P., Forster, B.P., Gordon, D.C., Handley, L.L., Keith, R.P., Lawrence, P., Thomas, W.T.B., 2002. *Phenotype/genotype associations for yield and salt tolerance in a barley mapping population segregating for two dwarfing genes.* Journal of Experimental Botany, 53(371): 1163-1176. https://doi.org/10.1093/jexbot/53.371.1163

Elis, S., and Yildirim, M., 2021. *Dual-purpose ability of barley and wheat at drought and heat stress conditions.* Journal of Aridland Agriculture, 7: 103-108.

Ertus, M.M., 2021. *A research on the determination of grain yield of some barley (Hordeum vulgare L.) varieties in late autumn sowing in the high altitude agricultural area of Anatolia.* ISPEC Journal of Agricultural Sciences, 5(1): 210-215.

Gebeyehou, G., Knott, D.R., Baker, R.J., 1982. *Rate and duration of gram filling in durum wheat cultivars.* Crop Sci., 22: 337-340.

Gong, X., and McDonald, G., 2017. *QTL mapping of root traits in phosphorus-deficient soils reveals important genomic regions for improving NDVI and grain yield in barley.* Theor. Appl. Genet., 130: 1885-1902. doi:10.1007/s00122-017-2931-3

International Food Policy and Research Institute (IFPRI), 2009. *Annual Reports*. ISBN 0896297853.

Jedel, P.E., Helm, J.H., Burnett, P.A., 1998. *Yield, quality and stress tolerance of barley mixtures in central Alberta.* Canadian Journal of Plant Science, 78(3): 429-436.

Kearsey, M.J., 1997. *Genetic resources and plant breeding.* Biotechnology and Plant Genetic Resources, 175.

Kılıc, H., Aktas, H., Kendal, E., 2020. *Evaluation of bread wheat (Triticum aestivum L.) genotypes based on yield and some quality traits in high temperature conditions.* Kafkas University Institute of Natural and Applied Science Journal, 13(1): 1-18.

Kızılgeci, F., and Yildirim, M., 2019. *The relationship of some physiological traits measured at heading stage with yield and quality properties of durum wheat.* Turkish Journal of Agricultural and Natural Sciences, 6(4): 777-785. doi:10.30910/turkjans.633593

Kuzu, S., 2020. *Determination of yield and yield components of some barley (Hordeum Vulgare L.) cultivars at different sowing rates under bingol conditions.* Bingol University, Master's Thesis, Department of Field Crops: 47.

Langridge, P., 2018. *Economic and academic importance of barley.* In the Barley Genome, Springer, Cham: 1-10. doi: 10.1007/978-3-319-92528-8_1

Lopes, M.S., Reynolds, M.P., Manes, Y., Singh, R.P., Crossa, J., Braun, H.J., 2012. *Genetic yield gains and changes in associated traits of CIMMYT spring bread wheat in a "historic" set representing 30 years of breeding.* Crop Science, 52(3): 1123-1131.

McGlinch, G.J., Jacquemin, S.J., Lindsey, L.E., 2020. *Evaluating winter malting barley grain yield with fractional green canopy cover.* Crop, Forage & Turfgrass Mgmt., 7: e20079. https://doi.org/10.1002/cft2.20079

Ozturk, İ., Girgin, V.C., Avcı, R., Kahraman, T., Ciftcigil, T.H., Tulek A., Tuna, B., 2017. *The effect of physiological parameters on grain yield and agronomic characters of barley (Hordeum vulgare L.) genotypes.* Journal of Field Crops Central Research Institute, 26 (special issue): 1-6. doi:10.21566/tarbitderg.358720

Patrignani, A., and Ochsner, T.E., 2015. *Canopeo: A powerful new tool for measuring fractional green canopy cover.* Agronomy Journal, 107(6): 2312-2320.

Poets, A.M., Fang, Z., Clegg, M.T., Morrell, P.L., 2015. *Barley landraces are characterized by geographically heterogeneous genomic origins.* Genome Biology, 16(1): 1-11. doi:10.1186/s13059-015-0712-3

Sonmez, A.C., and Yuksel, S., 2019. *Determining of grain yield and some physiological traits of advanced barley (Hordeum vulgare L.) genotypes in Eskisehir conditions.* KSU J. Agric. Nat. 22(1): 60-68. doi: 10.18016/ksutarimdoga.vi.530281

Talukder, A.S.M.H.M., McDonald, G.K., Gill, G.S., 2014. *Effect of short-term heat stress prior to flowering and early grain set on the grain yield of wheat.* Field Crops Research, 160: 54-63. https://doi.org/10.1016/j.fcr.2014.01.013

Vasilescu, L., Petcu, E., Sîrbu, A., Petcu, E., Lazăr, C., 2022. *Grain morphometry analysis of Romanian winter barley cultivars registered during 1959-2019 period.* Romanian Agricultural Research, 39: 165-173.

Yildirim, M., and Barutcular, C., 2021. *Heat stress adaptation in wheat through phenotyping.* Theoretical and Practical New Approaches in Cereal Science and Technology, 25.

Zadoks, J.C., Chang, T.T., Konzak, C.F., 1974. *A decimal code for the growth stages of cereals.* Weed Research, 14(6): 415-421.