BIOMASS IN BARLEY GENOTYPES (*Hordeum vulgare* L.) AND ASSOCIATION WITH ENVIRONMENTAL EFFECTS UNDER RAINFED CONDITIONS

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Abstract

*Biomass in barley is one physiological parameter associated with grain yield and quality in barley genotypes. In the present study, there were various relations between NDVI and parameters investigated barley genotype. This research was carried out in the Trakia region over four environments during the 2018-2019 cycles. The experiment was set up with 25 barley genotypes in a randomized complete block design (RCBD) with four replications. In the study, normalized difference vegetation index (NDVI), grain yield (GY), plant height (PH), days of heading (DH), 1000-kernel weight (TKW), test weight (TW) and protein ratio (PRT) were investigated. The results of the variance analysis (ANOVA) for NDVI are presented in Table 1. The combined ANOVA revealed a significant difference in E2 and E4 locations between genotypes in the Z34 period. In the Z55 period, there was a significant difference between genotypes in E1, E2 and E3 locations. Pearson's correlation analysis determined correlation coefficients between NDVI and the parameters tested. Over four environments, NDVI was made in barley genotypes in the Z34 and Z55 periods. NDVI in the Z34 period was slightly positively related to grain yield in E1 and E4. NDVI also had a positive effect on thousand-grain weight in three (E1, E3, E4) environments, on test weight in E1 (r=0.583**) and E4 (r=0.679**). NDVI had a positive effect on protein ratio in genotypes over four environments. The positive effect of NDVI on grain yield in the heading period (Z55) showed the importance of the relationship between yield and NDVI value. Normalized difference vegetation index had a positive effect on TKW in three environments (E2, E3 and E4), to TW in 4 environments during the Z55 period. In the study, a slightly different relationship was determined between NDVI and protein value in the Z55 period. The positive effect of NDVI on yield and quality values has shown that it is an important physiological parameter that can be used in selection. It is recommended that the increased biomass genotypes identified could be used as parents in a breeding programme to produce genotypes with a higher yield.*

Keywords: *Barley, normalised vegetative difference ındex, genotypes, yield, quality, correlations*

1. INTRODUCTION

Barley (*Hordeum vulgare* L.) is among the oldest cultivated global crops and, with respect to other cereals, it is adapted to grow in many different environments. Despite such a potentially wide-growing habitat barley is only the fourth most cultivated cereal crops (Newton et al., 2011; Dawson et al., 2015). Future projections of climate trends indicate that most of the harvested barley areas will get warmer and drier, resulting in a global decline in barley yield and production (Xie et al., 2018). Drought and heat stress are two significant abiotic stresses that occur in nature. Recent climate change models predict that the frequency and duration of periods of high temperatures and moisture deficits are on the rise and can be detrimental to crop production and hence a serious threat to global food security (Mahalingam and Bregitzer, 2019). The changes in climatic variables on quality traits of barley may be as equally significant as yield (Wardlaw et al., 2002). High temperature and lack of water availability can considerably change the grain quality through alteration in composition and concentration of starch and protein (Högy et al., 2013). Timely and reliable prediction of grain yield and quality of barley represents a key requirement for effective crop management. Early growth of barley and tiller differentiation is a key parameter for the formation of yield and grain quality (Křen et al., 2014).

Plant phenology characterises the developmental life cycle events of plants and how these events are influenced by seasonal and inter-annual variations in climate as well as habitat factors (Wilczek et al., 2010). In barley, different development stages, such as spikelet initiation and duration of grain development can seriously influence yield and quality. These stages are regulated by environmental factors such as temperature or growing degree days (Landes and Porter, 1989). Heading date is essential in adapting barley genotypes to various stresses such as heat stress, waterlogging, salinity and drought. Heat stress can fast deplete the available moisture through high rates of evapotranspiration ultimately leading to terminal drought (Hossain et al., 2012). Earliness is a favourable character in barley due to early maturating cultivars less affected by diseases and other environmental factors, followed after harvesting farmers produce second crops in the same growing season. The amount of rainfall during the growing season is enough but the distribution of this rainfall is not regular and variation in weather conditions causes some biotic and abiotic stress factors (Öztürk et al., 2014). The development of varieties, that can be adapted to a wide range of diversified environments, is the ultimate goal of plant breeders in barley improvement programs (Vulchev et al., 2013; Valcheva et al., 2009). Barley heading date is essential in adapting barley genotypes to different environments. Important factors affecting the heading date in barley are temperatures, photoperiod and sowing date. The sowing date is a management option to influence the heading date. It reduces climatic risks such as frosts and water stress at sensitive periods during crop development. Three significant genes control heading date in barley (Ibrahim et al., 2016). Both heat and drought at late sowing may interrupt barley developmental processes usually from the double ridge to maturity. The resulting effects of these stresses are a reduction in plant height, dry matter accumulation and grain yield (Hossain et al., 2012).

Barley (*Hordeum vulgare* L.) is the primary cereal in many areas of the Trakia region and is essential for the livelihoods of many farmers. Barley is an annual cereal crop and is grown in environments ranging from many areas. Grain yield in barley is a complex character depending on a large number of environmental, agronomic and physiological characteristics (Öztürk et al., 2018). In the study, the effect of NDVI, which was measured in different growth periods in the plant, on yield and quality values was investigated. Biological components in plants are directly related to yield. The ratio of 1000-kernel weight, test weight and protein ratio varies depending on the increase or decrease of biomass in the plant. Earliness and plant height are two important factors in adaptation to dry conditions in barley. In plants, NDVI is one of the most important features of both earliness and plant height, especially in adaptation to arid conditions. A convenient and dependable forecast of grain yield and quality of barley represents a fundamental requirement for sufficient crop management. In this study, we evaluated the relationships between biomass production in different growth stages, grain yield, grain quality, plant height and earliness in different growth stages.

2. MATERIALS AND METHODS

This research was carried out in the Trakya region (Turkey) across four environments during the 2018-2019 growing years. The experiment was set up with 25 barley genotypes in a randomized complete blocks design (RCBD) with four replications. The research site is located in four different environments, E1 (Edirne: 41º 38´ 59´´ N and 26º 35´ 49´´ E, altitude 41 m), E2 (Lüleburgaz: 41º 23´ 04´´ N and 27º 16´ 26´´ E, altitude 62 m), E3 (Tekirdağ: 40º 58´ 27´´ N and 27º 27´ 59´´ E, altitude 42 m) and E4 (Keşan: 40º 43´ 39´´ N and 26º 26´ 42´´ E, altitude 24 m). In the experiment, 6-row plots were planted with a 6 m long row spacing of 0.17 cm. Sowings were performed by using a plot drill and a seed rate of 500 seeds m^2 and fertilizer 180 kg ha^{-1} N and 40 kg ha^{-1} P_2O_5 was used. In the experiments,

Studied Parameters

Normalized difference vegetation index (NDVI), grain yield (GY) (kg ha^{-1}), plant height (PH) (cm), days of heading (DH), thousand kernel weight (TKW) (g), test weight (TW) (kg) and protein ratio (PRT) (%) were investigated.

NDVI: The normalized difference vegetation index (NDVI) provides the rapid ground-level measurement of crops at a resolution to characterize the canopy for leaf area index (LAI) and green area index (GAI), biomass and nutrient content. Data can be used to estimate yield prediction, biomass accumulation and growth rate, ground cover and early vigor, senescence pattern estimations, and for biotic and abiotic c stress detection (Araus, 1996; Gutierrez-Rodriguez et al., 2004; Raun et al., 2001).

NDVI measurements were taken from 11:00h to 14:00h, on a clear, sunny day. Measurements were taken for plant growth at the Z34 and Z55 development stages. Measurements were made using a hand-held Ntech 'Greenseeker' NDVI meter (N Tech Industries (2011) Greenseeker. Available at: http://www. ntechindustries.com/greenseeker-home.html

Plant height (cm): The height of ten randomly taken plants was measured at harvest maturity from the ground level to the tip of the tallest spike in centimeters and averaged.

Days of heading: It has been determined as the date that 50% of the spikes in each parcel emerged from the beginning of January 1.

Thousand kernel weight (g): Thousand kernel weight (TKW) was recorded as grams/1000 kernels of cleaned wheat

Test weight (kg): Test weight (TW) was recorded as kilograms/hectoliter (kg/hL) based on (American Association of Cereal Chemists International, 2000).

Protein ratio (%): Protein ratio determination by NIR method (ICC Standard No: 105 methods).

Statistical analysis

Data were analyzed statistically for analysis of variance in the method described by Gomez and Gomez (1984). The differences between genotype means of parameters were tested by the L.S.D test (0.05). Letter groupings were generated by using a 5% level of significance. The regression equations were calculated according to Finlay and Wilkinson (1963), and Eberhart and Russell (1969). Regression graphs were used to predict the adaptability of genotypes and the correlations between the quality parameters were determined by Pearson's correlation analysis.

3. RESULTS AND DISCUSSION

Biomass in barley is one physiological parameter associated with grain yield and quality in barley genotypes. Four experiments were carried out to measure grain yield, quality and normalised difference vegetative index of barley breeding genotypes. In the present study, there were various relations between NDVI and parameters investigated barley genotype. The results of the variance analysis (ANOVA) for NDVI are presented in Table 1. The combined ANOVA revealed, there was a significant difference in E2 and E4 locations between genotypes in the Z34 period. In the Z55 period, there was a significant difference between genotypes in E1, E2 and E3 locations (Table 1).

Table 1. Sum of square, mean square and F ratio for parameters investigated over four environments

Environment	NDVI (Z34)		NDVI (Z55)	
	MS	F Ratio	MS	F Ratio
Environment E1	0.016	1.584ns	0.0004	4.514**
Environment E2	0.017	5.296**	0.00092	4.327**
Environment E3	0.004	1.118ns	0.00079	1.180ns
Environment E4	0.004	3.315**	0.001	7.785**

*, ** Significant at p<0.05 and p<0.01 respectively, ns: non-significant. MS: mean of square

In the study, measurements made of the NDVI in Z34 and Z55 periods in 4 different environments were given in Table 3. The highest NDVI was determined in E4 (0.69) and E3 (0.63) in the Z34 growth stage and in E1 (0.80) and E4 (0.79) in the Z55 period. In the Z34 period, the highest NDVI in genotypes was found in G7 and G11 in E1, G19 in E2, G14 in E3 and G15 in E4. In the Z55 period, genotypes G22 in E1, G14 in E2, G5 in E3 and G15 in E4 produced significantly greater biomass yields than the mean of the varieties (Table 2). It is recommended that the increased biomass genotypes identified could be used as parents in a breeding programme to produce genotypes with a higher yield. NDVI differed between measured environments and genotypes. The fact that the genotypes had different development types was the main factor. In addition, soil structure, temperature and precipitation variability between locations were among other factors.

Table 2. Normalised difference vegetative index over four environment at Z34 and Z55 in barley genotypes

G. No	Environment E1		Environment E2		Environment E3		Environment E4	
	NDVI (Z34)	NDVI (Z55)	NDVI (Z34)	NDVI (Z55)	NDVI (Z34)	NDVI (Z55)	NDVI (Z34)	NDVI (Z55)
G1	0.40d	0.81d-g	0.50l	0.70d-ı	0.74ab	0.79abc	0.71a-e	0.79d-g
G2	0.63ab	0.82a-d	0.61g-k	0.72ab	0.65d	0.80abc	0.70b-f	0.80a-d
G3	0.60abc	0.81b-e	0.62g-k	0.71b-f	0.67a-d	0.80abc	0.69b-h	0.80b-f
G4	0.63ab	0.80d-g	0.62g-k	0.71a-e	0.64d	0.79a-d	0.73ab	0.81ab
G5	0.63ab	0.82a-d	0.63e-j	0.72a-d	0.68a-d	0.81a	0.71a-f	0.80b-f
G6	0.49bcd	0.81d-g	0.56ı-l	0.69e-ı	0.66bcd	0.79abc	0.72a-d	0.79c-f
G7	0.65a	0.80gh	0.71a-e	0.69f-ı	0.66a-d	0.79abc	0.66f-ı	0.78efg
G8	0.56abc	0.80efg	0.72a-d	0.71a-e	0.67a-d	0.75d	0.68c-h	0.80a-d
G9	0.46cd	0.80fgh	0.62g-k	0.71a-f	0.68a-d	0.78a-d	0.71a-e	0.80a-d
G10	0.50bcd	0.80d-g	0.54kl	0.71a-f	0.65cd	0.78a-d	0.69b-h	0.81ab
G11	0.65a	0.81c-f	0.60g-k	0.70d-ı	0.67a-d	0.80abc	0.73ab	0.79d-g
G12	0.51a-d	0.83ab	0.59h-k	0.72abc	0.69a-d	0.78a-d	0.70b-g	0.81abc
G13	0.61ab	0.82abc	0.66c-h	0.70b-g	0.70a-d	0.79a-d	0.76a	0.80a-d
G14	0.59abc	0.80efg	0.65c-h	0.73a	0.75a	0.80abc	0.73abc	0.80a-d
G15	0.58abc	0.82abc	0.64d-ı	0.72a-d	0.74a	0.81ab	0.73ab	0.82a
G16	0.51a-d	0.81c-g	0.73abc	0.70d-ı	0.65d	0.77cd	0.64hı	0.77hı
G17	0.52a-d	0.83ab	0.68b-g	0.70b-h	0.70a-d	0.77cd	0.67d-ı	0.77hı
G18	0.61ab	0.80d-g	0.63f-j	0.69f-ı	0.69a-d	0.79a-d	0.62ı	0.76ı
G19	0.54abc	0.79h	0.77a	0.67j	0.68a-d	0.77bcd	0.70b-g	0.77hı
G20	0.59abc	0.81b-e	0.65c-h	0.68hıj	0.69a-d	0.79a-d	0.72a-e	0.78fgh
G21	0.54a-d	0.80efg	0.76ab	0.68g-j	0.72a-d	0.79a-d	0.67e-ı	0.77hı
G22	0.53a-d	0.83a	0.70a-f	0.68ıj	0.69a-d	0.78a-d	0.65ghı	0.77ghı
G23	0.54a-d	0.80d-g	0.55jkl	0.70c-h	0.72a-d	0.80abc	0.68d-h	0.78fgh
G24	0.61ab	0.80d-g	0.64d-ı	0.70b-g	0.74abc	0.77cd	0.67d-ı	0.80b-e
G25	0.61ab	0.82abc	0.67c-h	0.70d-ı	0.71a-d	0.81a	0.71a-e	0.78efg
Mean	**0.56**	**0.80**	**0.64**	**0.70**	**0.68**	**0.78**	**0.69**	**0.79**
$LSD_{(0.05)}$	0.14	0.01	0.08	0.02	0.08	0.04	0.05	0.02

NDVI: Normalised difference vegetative index, Z: Zadoks

The results of the variance analysis (ANOVA) for grain yield, plant height, days of heading, 1000-kernel weight, test weight and protein ratio are presented in Table 3. The combined ANOVA revealed significant differences among genotypes for all parameters (P<0.01).

Table 3. Sum of square, mean square and F ratio for parameters investigated over four environments

Parameters	SS	MS	F Ratio
Grain yield (GY)	735541.00	30647.50	6.059**
Plant height (PH)	4997.500	208.229	4.977**
Days of heading (DH)	1049.760	43.740	8.323**
Thousand kernel weight (TKW)	3461.157	144.215	26.910**
Test weight (TW)	629.327	26.222	9.521**
Protein ratio (%)	39.900	1.662	3.293**

*, ** Significant at p<0.05 and p<0.01 respectively, ns: non-significant. SS: Sum of square, MS: mean of square

Table 4. The mean value of the investigated parameters in barley genotypes

Genotype	GY	PH	DH	TKW	TW	PRT
G1	7605d-g	105.0e-j	109.0c-g	46.5b-e	72.5bcd	11.6a-d
G2	8128abc	96.5jk	106.5f-ı	48.3bc	72.8abc	10.3fgh
G3	8208abc	95.0k	106.0g-j	48.7b	73.3abc	10.0h
G4	8514a	98.8g-k	106.8f-ı	45.0def	71.5cde	10.7c-h
G5	7817cde	110.0c-f	105.5hıj	44.1ef	75.1a	11.3b-f
G6	8118abc	103.3f-k	108.5c-h	46.7b-e	72.9abc	10.6e-h
G7	8203abc	104.5e-j	108.5c-h	36.5gh	69.6efg	10.6d-h
G8	7764c-f	107.0d-h	103.3j	42.3f	72.2bcd	10.6d-h
G9	8369ab	103.3f-k	107.0e-ı	45.1c-f	71.8b-e	10.2gh
G10	8043a-d	98.0h-k	105.5hıj	29.0ı	70.2def	10.3fgh
G11	7148gh	102.8f-k	119.0a	47.8bcd	74.0ab	10.9c-h
G12	8015bcd	97.3ıjk	110.8cd	38.1g	70.4def	11.1c-g
G13	7417e-h	109.8c-f	106.3g-j	45.9b-e	73.8abc	11.5a-e
G14	7379e-h	109.0def	105.3ıj	52.0a	72.7bc	11.7abc
G15	8169abc	111.3c-f	105.5hıj	44.1ef	72.1bcd	11.1c-g
G16	8089a-d	112.8b-e	106.8f-ı	38.5g	67.3gh	11.5a-e
G17	8041a-d	106.3d-ı	110.0cde	30.7ı	64.7ı	11.4a-e
G18	7025h	118.3abc	109.5c-f	43.9ef	67.7gh	10.7c-h
G19	7287fgh	105.5d-j	109.5c-f	37.2gh	69.1fgh	10.8c-h
G20	7771c-f	114.5a-d	108.3d-ı	44.9def	72.0bcd	11.4b-e
G21	7188gh	104.8e-j	110.3cd	34.4h	68.3fgh	11.4b-e

G22	7481e-h	110.3c-f	114.0b	34.0h	68.9fgh	12.4a
G23	7380e-h	120.8ab	111.3bcd	38.3g	67.2h	12.2ab
G24	7040h	122.3a	111.5bc	48.1bcd	70.3def	12.2ab
G25	7774c-f	107.3d-g	106.5f-ı	42.1f	73.0abc	11.4b-e
Mean	**7759**	**106.9**	**108.4**	**42.1**	**70.9**	**11.1**
$LSD_{(0.05)}$	493	9.10	3.22	3.25	2.33	0.99

GY: Grain yield (kg ha^{-1}), PH: Plant height (cm), DH: Days of heading, TKW: Thousand kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%).

Based on the results, there were highly significant differences in yield among genotypes in yield. Averaged over four environments the mean grain yield was 77759 kg ha^{-1}. In the study, genotypes G4 (8514 kg ha^{-1}) and G9 (8369 kg ha^{-1}) produced the highest grain yield. Changes in yield varied depending on the environmental effects, and genotypic factors (Table 4). Stem length is one of the most important initial selection criteria in barley breeding works, being a direct component of lodging resistance and an indirect component of both yield and quality (Madic et al., 2012). While tall genotypes are preferred in arid environments, short genotypes are preferred for under fertile and rainfed conditions. Significant differences were observed in peduncle length and spike length in barley genotypes. The mean plant height was 108.4 cm. The longest plant height (122.3 cm) was measured in G24 followed by G23, while the short plant height was measured in G3, G2 and G12. Heading date is a complex trait in barley that has a direct impact on grain yield and quality and also forms the basis of evolutionary adaptation to the changing climate (Ibrahim et al., 2016). Earliness in genotypes is an important feature especially, for drought avoidance. The earliest genotypes were G8, followed by G14, G5 and G13. The quality of barley is important for animal feed and high TKW, TW and protein ratios are preferred. In the study 1000-kernel weight (TKW) was significantly affected by genotypes and environment. Maximum 1000-kernel weight (52.0 g) was recorded in G14 and the lowest was recorded in genotypes G10 (29.0 g) and G17 (30.7 g). The highest test weight was established in G5 (75.1 kg) and G11 (74.0 kg) the lowest was recorded in genotypes G17 (64.7 kg). Protein content in barley is highly correlated with nitrogen fertilization time and amount. The highest protein content was determined in G22 (12.4%), G23 (12.2%) and G24 (12.2%) genotypes (Table 4).

Correlation coefficients among investigated parameters were determined by Pearson's correlation analysis (Table 5, 6, 7, 8). NDVI measurements were made in 25 barley genotypes in the Z34 and Z55 periods in 4 different environments. Due to the environmental effect, it was determined that there was a significant difference between the NDVI and the parameters investigated in the locations. It was observed that the NDVI value measured in the Z34 period was slightly negatively related to grain yield in E2 and E3 and positively in E1 and E4. Plant height was positively correlated with NDVI in all environments. No correlation was found between NDVI and DH measured in the Z34 period. While NDVI had a positive effect on thousand grain weight in three environments, a negative effect was detected on E2. While NDVI had a significant positive effect on test weight in locations E1 (r=0.583**) and E4 (r=0.679**), a negative effect was detected in locations E2 and E3. NDVI correlated better with protein ratio in genotypes over four environments. In addition, a significant positive relationship was established in the E3 (r=0.614**) environment.

Table 5. Correlation coefficient among investigated parameters in environment E1

Parameters (E1)	**NDVI (Z34)**	**NDVI (Z55)**	**GY**	**PH**	**DH**	**TKW**	**TW**
NDVI (Z55)	-0.015						
GY	0.137	0.332					
PH	0.117	-0.153	-0.222				
DH	0.178	-0.128	-0.070	0.357			
TKW	0.369	-0.144	-0.419*	0.089	0.056		
TW	0.583**	0.203	0.146	0.039	0.103	0.382*	
PRT	0.121	0.114	-0.186	0.661**	0.256	0.137	0.037

*, ** Significant at *P*<0.05 and *P*<0.01 respectively, ns: non-significant. NDVI: Normalised difference vegetative index, GY: Yield (kg ha^{-1}), PH: Plant height (cm), DH: Days of heading, TKW: Thousand kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%)

The positive effect of NDVI on grain yield in the heading period (Z55) in genotypes showed the importance of the relationship between yield and NDVI value. So, NDVI was significantly positively correlated with grain yield in E2 (r=0.538**) and positively correlated in E4 (r=0.407*). It was observed that the NDVI value measured in the Z55 period was negatively associated with plant height at three environments (E1, E2 and E3) and positive in E4. The day of heading and NDVI were found to be negatively correlated at all locations. While NDVI had a positive effect on TKW in three environments (E2, E3 and E4), a negative effect was determined in E1. In the study, the positive effect of NDVI on TW in 4 locations during the Z55 period showed that NDVI is important in terms of this parameter. In the study, a slightly different relationship was determined between NDVI and protein value in the Z55 period.

Table 6. Correlation coefficient among parameters in environment E2

Parameters (E2)	**NDVI (Z34)**	**NDVI (Z55)**	**GY**	**PH**	**DH**	**TKW**	**TW**
NDVI Z55	-0.412*						
GY	-0.244	0.538**					
PH	0.453*	-0.387*	-0.394*				
DH	0.050	-0.496*	-0.483*	0.032			
TKW	-0.337	0.415*	0.356	-0.063	-0.438*		
TW	-0.329	0.334	0.376	-0.205	-0.571**	0.838**	
PRT	0.104	-0.178	-0.593**	0.242	0.450*	-0.361	-0.440*

*, ** Significant at *P*<0.05 and *P*<0.01 respectively, ns: non-significant. NDVI: Normalised difference vegetative index, GY: Yield (kg ha^{-1}), PH: Plant height (cm), DH: Days of heading, TKW: Thousand kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%)

Table 7. Correlation coefficient among investigated parameters in environment E3

Parameter (E3)	NDVI (Z34)	NDVI (Z55)	GY	PH	DH	TKW	TW
NDVI Z55	0.213						
GY	-0.358	0.109					
PH	0.488*	-0.053	-0.291				
DH	0.003	-0.081	-0.308	0.317			
TKW	0.119	0.339	0.003	-0.174	-0.205		
TW	-0.101	0.368	0.099	-0.529**	-0.298	0.773**	
PRT	0.614**	0.085	-0.353	0.670**	0.373	-0.191	-0.416*

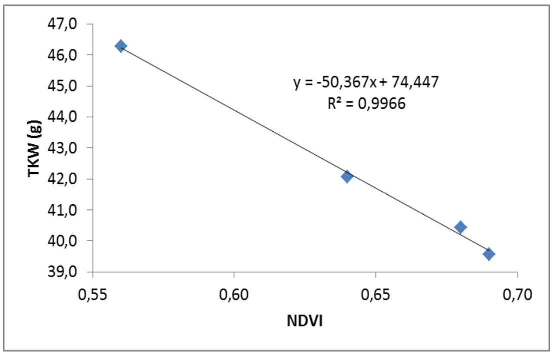
*, ** Significant at *P*<0.05 and *P*<0.01 respectively, ns: non-significant. NDVI: Normalised difference vegetative index, GY: Yield (kg ha^{-1}), PH: Plant height (cm), DH: Days of heading, TKW: Thousand kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%)

Table 8. Correlation coefficient among investigated parameters in environment E4

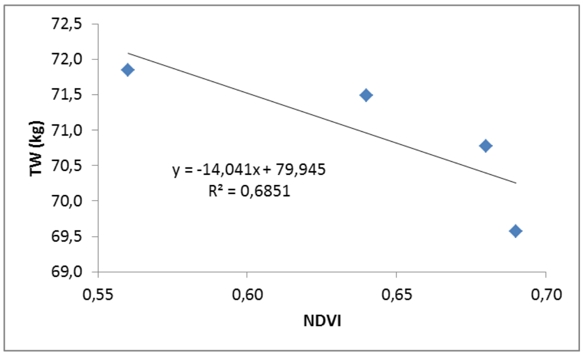
Parameter (E4)	NDVI (Z34)	NDVI (Z55)	GY	PH	DH	TKW	TW
NDVI Z55	0.627**						
GY	0.197	0.407*					
PH	0.160	0.268	-0.043				
DH	-0.025	-0.187	-0.347	-0.165			
TKW	0.371	0.274	-0.256	0.300	0.121		
TW	0.679**	0.504*	-0.171	-0.046	-0.020	0.610**	
PRT	0.174	-0.084	-0.282	0.462*	-0.074	0.021	-0.059

*, ** Significant at *P*<0.05 and *P*<0.01 respectively, ns: non-significant. NDVI: Normalised difference vegetative index, GY: Yield (kg ha^{-1}), PH: Plant height (cm), DH: Days of heading, TKW: Thousand kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%)

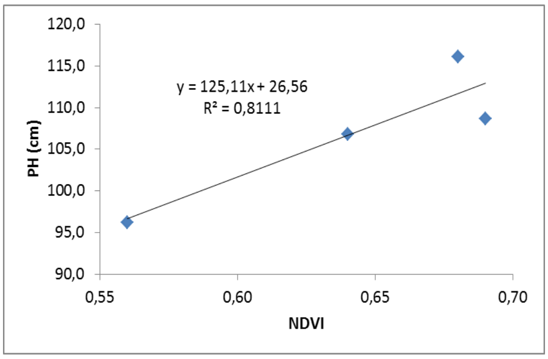
The regression coefficients and relationships between the parameters investigated in the study at the Z34 growth stage are given in Figure 1. Increasing NDVI in genotypes had a negative effect on TKW (R^2=0.996) and TW (R^2=0.685). A positive relationship was determined between NDVI and plant height (R^2=0.811), since the plant height was high, causing an increase in the biomass. The increase in biomass in the plant causes the prolongation of the vegetative period and the delay of the days of heading. So, there was a negative relation between NDVI and days of heading (R^2=0.301) (Figure 1).



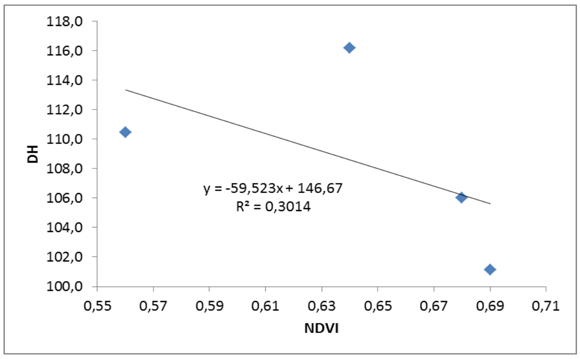
NDVI (Z34) and TKW



NDVI (Z34) and TW



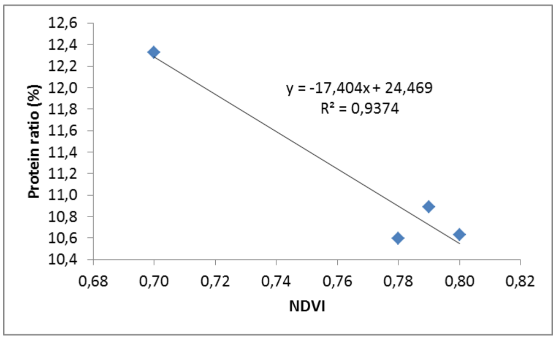
NDVI (Z34)and plant height (PH)



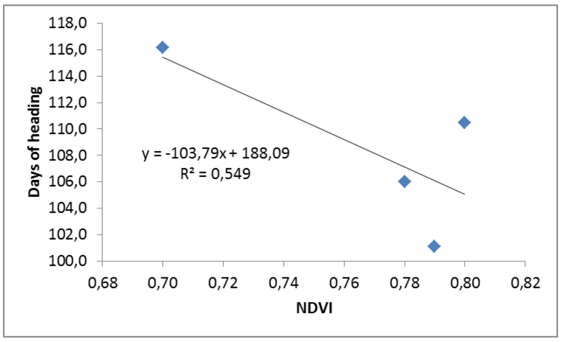
NDVI (Z34) and days of heading (DH)

Figure 1. Relation between NDVI scaled at Z34 with TKW, TW plant height and days of heading

The relationship between NDVI with protein ratio and days of heading is given in Figure 2. The higher normalized difference vegetative index negatively affected protein ratio and days of heading. There was a negative relation between NDVI and protein ratio (R^2=0.937) and also days of heading (R^2=0.549).



NDVI (Z55) and protein ratio



NDVI (Z55) and days of heading (DH)

Figure 2. Relation between NDVI scaled at Z55 with protein ratio and days of heading

4. CONCLUSION

In the study, there was a significant difference in E2 and E4 locations between genotypes in the Z34 period. In the Z55 period, there was a significant difference between genotypes in E1, E2 and E3 locations. NDVI was made in barley genotypes in the Z34 and Z55 periods over four environments. NDVI in the Z34 period was slightly positively related to grain yield in environments E1 and E4.

NDVI had also a positive effect on thousand-grain weight in three (E1, E3, E4) environments, on test weight in E1 and E4. NDVI had a positive effect on protein ratio in genotypes over four environments. The positive effect of NDVI on grain yield in the heading period (Z55) showed the importance of the relationship between yield and NDVI value. Normalised difference vegetative index had a positive effect on TKW in three environments (E2, E3 and E4), to TW in 4 environments during the Z55 period. In the study, a slightly different relationship was determined between NDVI and protein value in the Z55 period. The positive effect of NDVI on yield and quality values has shown that it is an important physiological parameter that can be used in selection. It is recommended that the increased biomass genotypes identified could be used as parents in a breeding programme to produce genotypes with a higher yield. Correlation studies revealed that NDVI at Z34 had a significant and positive association with test weight, protein ratio and plant height. Correlation analyses indicated that NDVI at Z55 had a significant and positive association with grain yield, test weight, and thousand kernel weights.

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