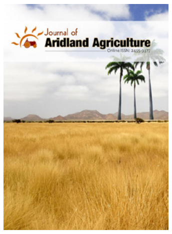
Journal of Aridland Agriculture 2025, 11: 139-147
doi: 10.25081/jaa.2025.v11.9700
https://updatepublishing.com/journal/index.php/jaa

Research Article



ISSN: 2455-9377

Evaluation of some triticale (*x Triticosecale* Wittmack) genotypes under rainfed and supplemental irrigation conditions in Diyarbakir ecology

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Received: December 27, 2024
Revised: August 25, 2025
Accepted: September 02, 2025
Published: September 18, 2025

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ABSTRACT

This study was conducted in the research area of the Dicle University Faculty of Agriculture during the 2017-2018 growing season to evaluate triticale genotypes based on various agricultural traits and identify genotypes suitable for Diyarbakir ecology. The experiment was conducted under two different conditions: rainfed and supplementary irrigation. The plant materials included two commercial triticale varieties (Alperbey and Esin) and three lines (DZ9-01-02, DZ9-06, and TBT16-11) developed by the Faculty of Agriculture of Dicle University. Under rainfed conditions, drought before heading adversely affected the traits, whereas supplemental irrigation improved all examined characteristics. Among the genotypes, TBT16-11 demonstrated high yield stability and superior attributes, including earliness. Alperbey has been identified as a promising parent in breeding programs. Regression analysis revealed an inverse relationship between canopy temperature and LAI under both rainfed and irrigated conditions, with high temperatures reducing the leaf area. Additionally, the heading time had a positive influence on grain yield, while the SPAD value enhanced thousand-kernel weight and grain yield. In conclusion, supplemental irrigation significantly increased triticale yield, highlighting its resilience to adverse conditions and its positive response to favorable environmental factors.

KEYWORDS: Triticale, Drought, Grain yield, Rainfed, Irrigated, Regression analysis

INTRODUCTİON

Triticale (*x Triticosecale* Wittmack), a hybrid of wheat (*Triticum* spp.) and rye (*Secale* cereale), is more tolerant to biotic and abiotic stress conditions than wheat. Therefore, it is a more suitable plant for marginal areas (Villegas *et al*., 2010). Compared to other cereals, Triticale has a high yield, high nutrient content, and wide adaptability (Oettler, 2005). It is also more competitive with weeds than with wheat (Beres *et al*., 2010). Triticale varieties developed in different countries can provide a stable and 20-35% higher yield than wheat under unfavorable conditions (Shchipak *et al*., 2013).

Triticale, which has a cultivation area of 3.6 million ha and a global production of 14 million tons, is cultivated in Poland, Germany, Australia, China, and France (FAOSTAT, 2022). In Turkey, triticale was cultivated in 0.10 million ha in 2022 and approximately 0.32 million tonnes of grain product was obtained from this area. In our country, approximately 90% of triticale production is realized in the Black Sea, Aegean, Central Anatolia and Marmara Regions (Turkstat, 2022).

Triticale has a weaker gluten structure and high alpha amylase activity compared to wheat and can be used as a raw material in cereal products such as biscuits, cereal flakes, pasta where swelling is not desired, and in malt and beer production (Çifçi *et al*., 2010). In addition to human nutrition, it is recommended for use in pig and poultry rations as an alternative to wheat, barley, and oats in animal nutrition (Çiftçi *et al*., 2003). Producers are turning to different alternatives to overcome the deficit of roughage, and the production of triticale, which has found an important place in this search, for grain feed and grass purposes is gradually increasing (Özer *et al*., 2010). Triticale is an important plant that can be used to close the current roughage and concentrate feed deficits in Turkiye (Mut & Köse, 2018). In our country, the cultivation of forage crops is limited by the use of known species. While alfalfa and silage maize constitute 80% of our forage crop production, different types of forage crops are cultivated in the remaining 20% (Özkan & Demirbağ, 2016).

The problems of global warming, decreasing rainfall, frequent droughts, and climate change adversely affect the current cool climate of cereal agriculture, especially wheat production (Peña, 2004). In this situation, in order to meet the increasing human nutritional needs, the search for new species and varieties that are productive, high quality, and adaptable to changing climatic conditions continues to increase in breeding and adaptation studies in order to obtain various alternative food crops (Martinek *et al.*, 2008). In the breeding and adaptation research on triticale, studies are continuing to adapt it to wheat cultivated areas to a wider extent. In fact, studies have shown that this plant performs better than wheat under stressful conditions (Mergoum *et al.*, 2019). Under these conditions, triticale is expected to become more important than today.

Cold damage, heat stress, and drought are the main factors that limit cereal production in Southeastern Anatolia. The identification of genotypes resistant to these factors is important for achieving a high yield potential in the region. The aim of this study was to evaluate triticale genotypes in terms of agricultural traits and to determine the genotypes suitable for Diyarbakir ecology.

MATERİALS AND METHODS

This study was conducted in the research area of Dicle University Faculty of Agriculture in 2017-2018. Diyarbakir Province is located in the central part of the Southeastern Anatolia Region between 37° 30' and 38° 43' north latitude and 40° 37' and 41° 20' east longitude. The altitude above sea level was 670 m. The region has a harsh continental climate and a semi-arid highland climate. Summers are hot, dry, and long, and winters are cold and less rainy. Climatic data for the year 2107-18 and the long years are given in Table 1.

Triticale can be grown in different agro-ecologies from sea level to 3000 m altitude, and requires an average rainfall of 500-600 mm during the growing season. However, it has been reported to perform well with as little as 350 mm of seasonal rainfall (Loha *et al.*, 2007). In this study, the long-term average rainfall was 455 mm and 439.6 mm during the growing season. The total rainfall in March and April (60.4 mm), which covers the period from plant emergence to stem elongation, was below the long-term average (135.1 mm). In May, the month of heading, total monthly rainfall (157.8 mm) was higher than the long-term average (44.2 mm). Although there was a significant increase in temperature and rainfall drought in the pre-heading period, this effect was not observed in the heading and post-heading periods. In addition, the monthly average temperature value (18.62 °C) during the growing period (March-June) was higher than the long-term average (16.8 °C) (Table 1).

Samples taken from 0-30 cm and 30-60 cm depths were analyzed to determine the soil properties of the study area. According to the results, the pH of the soils in the experimental area was slightly alkaline, with no salt stress, medium lime content, and low organic matter content. In addition, it was observed that the soils in the test area were deficient in nitrogen and phosphorus and were rich in K. The chemical and physical properties of the soil in the experimental area are listed in Table 2.

In this study, two commercial triticale varieties (Alperbey and Esin) and three triticale lines (DZ9-01-02, DZ9-06, and TBT16-11) developed by the Faculty of Agriculture of Dicle University were used as plant materials. The experiment was established under rain-fed and irrigated conditions according to a randomized block design with four replications. Sowing was carried out on March 9, 2018, using a parcel combine harvester with 500 seeds per square meter. Each plot was 5 m long, with 0.2 m row spacing and six rows. In this experiment, 6 kg da^{-1} N and 6 kg da^{-1} P_2O_5 were applied in pure form at sowing, and 6 kg da^{-1} N was applied at emergence. Weed control was performed using mechanical methods. Harvesting was carried out on July 1, 2018, using a parcel combine harvester.

The genotypes were grown under rainfed and irrigated conditions. Irrigation was performed three times during emergence, heading, and grain filling using a drip irrigation system. A sufficient isolation distance (30 m) was maintained between the trials. A total of 232.6 mm of rainfall fell during March-July, whereas the control group received an additional 148.5 mm of irrigation water.

Traits analysed in the research; Heading time (days): This was calculated as the period from the sowing date until the spike emerged in ½ of the flag leaves in 70% of the plants in each plot.

Table 1: Average monthly temperature (°C), total monthly precipitation (mm)

		Temperature (°C)					
Periods	Months	Maximum	Average	Minimum	Long years	Total	Long years
Pre-sowing	November	16.03	10.1	4.63	9.6	21.2	55.2
	December	12.61	5.81	0.22	4	12.8	73.1
	January	10.12	5.23	0.96	1.7	86.6	70.9
	February	13.35	7.63	2.35	3.6	86.4	67.7
Pre-heading	March	18.96	12.45	5.45	8.3	11.6	65.6
	April	23.63	15.91	7.53	13.7	48.8	69.5
Post-heading	May	26.03	19.52	13.09	19.2	157.8	44.2
	June	34.13	26.61	17.46	26	14.4	8.8
	Means/Total	19.35	12.9	6.46	10.76	439.6	455

Maturation time (day): It was calculated as the number of days between the sowing date and the date when 95% of the plants in each plot had matured.

Plant height (cm): The length of 10 randomly selected plants from each plot that reached harvest maturity was measured in centimeters from the soil level to the tip of the top spikelet.

Grain yield (kg ha^{-1}): At the end of harvesting with a parcel harvester, the grain obtained from each parcel was weighed on a 0.01 g sensitive balance and the values obtained were calculated in kg ha^{-1}.

Thousand kernel weight (g): From the samples taken from each plot, 400 grains were counted and weighed using a thousand-kernel counting device, and the average of the data obtained was multiplied by a coefficient of 2.5.

Chlorophyll content (SPAD): A SPAD-502 Plus chlorophyll meter (Minolta SPAD-502, Osaka, Japan) was used to measure the chlorophyll content in the flag leaves of 10 randomly selected plants during the grain filling stage.

The Leaf area index (LAI) was calculated using LAI-2000 (LI-COR, Lincoln, NE) when the plants were in the grain-filling stage. LAI value was determined by one measurement over the plants in the plot, and then by two measurements taken at the soil level.

The normalized vegetation difference index (NDVI) was measured using a Trimble Greenseeker (Trimble Navigation Limited, Sunnyvale, CA, USA) with a range of 0.00-0.99 when the plants were in the grain filling period.

Canopy temperature was measured in degrees centigrade (°C) using a portable Rothenberger-sensitive infrared thermometer (thermal camera) when the plants were in the grain-filling stage.

The JMP Pro 13 statistical package was used to analyze the data. Differences between means were determined using LSD tests. Regression analyses were also performed to determine the relationships between traits.

RESULTS AND DISCUSSION

Tables 3, 4, and 5 present the variance analysis results and average values from the study on the agronomic traits of triticale genotypes in the Diyarbakir region.

The genotypes and treatments had a statistically significant effect on heading time, but the genotype × treatment interaction was found to be insignificant (Table 3). The heading time varied between 60.25-63.50 days. The Esin variety and the TBT16-11 line were found to be stable in terms of earliness in both environments. Under rainfed conditions, drought stress did not occur because of the above-average rainfall and low temperature in May. Therefore, the irrigation treatments did not effect spike emergence. However, because of late sowing, the plant emerged early due to the stress effect. Naneli (2024) reported that under high temperature and drought conditions, plants reached the heading and maturity stages earlier. It has also been stated that heading time is affected by sowing time, rainfall, fertilization, and genetic structure (Genç *et al.*, 1989). Bezabih *et al.* (2019) stated that heading time is significantly affected by variety and environmental differences and their interaction. Albayrak *et al.* (2021) reported that ideal genotypes had average heading times under variable rainfall conditions.

Genotype and treatment had a significant effect on maturity time, but the genotype × treatment interaction was found to be insignificant (Table 3). The maturation period varied

Table 2: Physical and chemical soil properties at the experimental site

Saturation (%)	% Salt TS 8334	pH (0-14)	Lime (%)	Organic Matter (%)	Nitrogen (%)	Phosphorus (ppm)	Potassium (ppm)
63.20	0.042	8.15	10.59	0.77	0.04	6.00	493.26
Clay loam	No salt	Slightly alkaline	Medium	Low	Low	Low	High

Table 3: Values of the HT (day), MT (day) and SPAD under different cultivation conditions

	HT (day)			MT (day)			SPAD		
Genotype	RC	IC	Mean	RC	IC	Mean	RC	IC	Mean
Alperbey	62.75	63.50	63.13^{a}	102.50	107.00	104.75^{ab}	54.53^{cd}	58.43^{a}	56.48^{a}
Esin	60.75	60.75	60.75^{c}	102.25	106.75	104.50^{bc}	54.05^{d}	52.68^{e}	53.36^{c}
DZ9-01-02	61.50	62.00	61.75^{b}	103.50	107.50	105.50^{a}	54.98^{bc}	51.38^{f}	53.18^{c}
DZ9-06	61.00	62.25	61.63^{bc}	101.75	105.75	103.75^{cd}	51.93^{f}	55.08^{bc}	53.50^{c}
TBT16-11	60.25	61.50	60.88^{bc}	101.50	105.50	103.50^{d}	55.50^{b}	54.60^{cd}	55.05^{b}
Means	61.25^{b}	62.00^{a}	61.62	102.30^{b}	106.50^{a}	104.40	54.20	54.43	54.31
CV (%)		1.41			0.71			0.84	
LSD (G)		0.89**			0.76**			0.47**	
LSD (C)		3.31*			0.48**			ns	
LSD (G x C)		ns			ns			0.66**	

*=Significant at P≤0.05; **=Significant at P≤0.01; ns=not significant; CV=Coefficient of variation; LSD=Least Significant Difference; G=Genotype; C=Condition; RC=Rainfed Conditions; IC=Irrigated Conditions; HT=Heading Time; MT=Maturation Time; SPAD=Chlorophyll Content

Table 4: Values of the NDVI, LAI and CT under different cultivation conditions

	NDVI			LAI			CT		
Genotip	RC	IC	Mean	RC	IC	Mean	RC	IC	Mean
Alperbey	0.49^{cd}	0.62^{ab}	0.56^{b}	1.95^{cd}	4.58^{a}	3.26	34.88	25.18	30.03^{bc}
Esin	0.48^{d}	0.61^{b}	0.55^{b}	2.15^{c}	4.03^{b}	3.09	34.38	25.28	29.83^{c}
DZ9-01-02	0.48^{d}	0.63^{ab}	0.55^{b}	1.78^{cd}	4.60^{a}	3.19	35.30	25.35	30.33^{ab}
DZ9-06	0.51^{c}	0.65^{a}	0.58^{a}	1.75^{cd}	4.33^{ab}	3.04	35.20	25.25	30.23^{ab}
TBT16-11	0.44^{e}	0.64^{a}	0.54^{b}	1.68^{d}	4.68^{a}	3.18	35.28	25.60	30.44^{a}
Means	0.48^{b}	0.63^{a}	0.56	1.86^{b}	4.44^{a}	3.15	35.01^{a}	25.33^{b}	30.16
CV (%)		2.90			9.14			1.00	
LSD (G)		0.016**			ns			0.30**	
LSD (C)		0.010**			0.18**			0.19**	
LSD (G x C)		0.022**			0.41**			ns	

**=Significant at P≤0.01; ns=not significant; CV=Coefficient of variation; LSD=Least Significant Difference; G=Genotype; C=Condition; RC=Rainfed Conditions; IC=Irrigated Conditions; NDVI=Normalized difference vegetation index; LAI=Leaf Area Index; CT=Canopy Temperature

Table 5: Values of the PH (cm), GY (kg ha^{-1}) and TKW (g) under different cultivation conditions

	PH (cm)			GY (kg ha^{-1})			TKW (g)		
Genotip	RC	IC	Mean	RC	IC	Mean	RC	IC	Mean
Alperbey	80.81^{b}	96.13^{a}	88.47^{a}	25.838^{d}	61.810^{a}	43.824^{a}	30.09^{d}	35.44^{b}	32.76^{c}
Esin	82.44^{b}	94.81^{a}	88.63^{a}	22.008^{ef}	48.590^{c}	35.299^{c}	32.70^{c}	43.51^{a}	38.10^{a}
DZ9-01-02	78.31^{c}	96.44^{a}	87.38^{ab}	20.010^{f}	54.628^{b}	37.319^{c}	28.86^{d}	41.94^{a}	35.40^{b}
DZ9-06	77.56^{c}	95.63^{a}	86.59^{b}	23.880^{de}	46.035^{c}	34.958^{c}	33.42^{bc}	41.77^{a}	37.59^{a}
TBT16-11	82.19^{b}	95.63^{a}	88.91^{a}	25.048^{de}	55.858^{b}	40.453^{b}	33.48^{bc}	43.71^{a}	38.59^{a}
Mean	80.26^{b}	95.73^{a}	87.99	23.357^{b}	53.384^{a}	38.370	31.71^{b}	41.27^{a}	36.49
CV (%)		1.69			6.5			3.97	
LSD (G)		1.53**			25.57**			1.49**	
LSD (C)		0.96**			16.18**			0.94**	
LSD (G x C)		2.16**			36.17**			2.11**	

**=Significant at P≤0.01; ns=not significant; CV=Coefficient of variation; LSD=Least Significant Difference; G=Genotype; C=Condition; RC=Rainfed Conditions; IC=Irrigated Conditions; PH=Plant Height; GY=Grain Yield; TKW=Thousand Kernel Weight

between 101.50-107.50 days and it was determined that the DZ9-06 and TBT16-11 lines were stable in terms of earliness. Owing to the stress caused by late sowing, the plants shortened the vegetation period and matured in 104.40 days on average. Additional irrigation had no effect on the maturity time.

The Genotype and genotype × treatment interaction on SPAD values was found to be significant, while the effect of treatment was insignificant (Table 3). SPAD values varied between 51.38-58.43. TBT16-11 line had the highest SPAD value under rainfed conditions, whereas the Alperbey variety had the highest SPAD value under irrigation conditions. Genotypes with a high flag leaf chlorophyll content are preferred because of their higher photosynthetic capacity and high grain yield. Fischer (2001) stated that the chlorophyll content of the leaves represents their photosynthetic capacity. Giunta *et al.* (2002) reported that SPAD values are affected by variety and environmental conditions and are positively correlated with leaf nitrogen. Yildirim *et al.* (2009) stated that there is wide variation among genotypes in terms of chlorophyll content. Kızılgeçi & Yıldırım (2017) reported that the SPAD value of triticale genotypes grown in Diyarbakir varied between 47.9-54.4.

The NDVI value was significantly affected by the genotype, treatment, and genotype × treatment interaction (Table 4). The values ranged between 0.44-0.65 and line DZ9-06 gave the highest value in both conditions. Irrigation increased NDVI, whereas drought decreased the values by weakening plant growth. NDVI reflects healthy plant growth and vegetation density. Kizilgeci *et al.* (2018) stated that NDVI is related to grain yield, while Crusiol *et al.* (2017) reported that measurement conditions affect NDVI.

Although the LAI value was significantly affected by treatment and genotype × treatment interaction, no difference was observed between genotypes (Table 4). Values varied between 1.68-4.68, and Esin under drought conditions and the TBT16-11 line under irrigated conditions gave the highest LAI. Additional irrigation under drought conditions increased the LAI. Austin *et al.* (1980) reported that there were differences in LAI among varieties and the tillering capacity of triticale was lower than wheat. Koç and Barutçular (2000) stated that LAI reached its highest level before flowering and then decreased due to maturity.

Although canopy temperature was significantly affected by genotype and treatment, the genotype × treatment interaction was found to be insignificant (Table 4). CT value varied between 25.18-35.30 in the Esin cultivar under drought conditions and the Alperbey cultivar under irrigated conditions had low CT values. High CT under drought conditions is caused by temperature and drought stress (Araghi & Assad, 1998). Fischer (2001) stressed that low canopy temperature indicates heat and drought tolerance and Munjal and Rana (2003) stated that the canopy temperature of genotypes varies according to climatic conditions. The selection of genotypes with low canopy temperatures may enable the development of varieties that efficiently utilize soil moisture (Bahar *et al.*, 2008; Hui *et al.*, 2008).

Plant height was significantly affected by the genotype, treatment, and genotype × treatment interactions (Table 5). Plant height varied between 77.56 and 96.44 cm; the Esin variety reached its highest plant height under drought conditions, and the Alperbey variety reached its highest plant height under irrigated conditions. It was found that supplementary irrigation increased plant height compared to rain-fed conditions. This difference may be due to a decrease in rainfall and temperature differences. Because triticale is important for both grain production and livestock products such as hay, silage, and roughage, plant height is a critical parameter (Kutlu & Kınacı, 2011). In addition, genotype × treatment interactions indicated that genotypes respond differently to different environmental and climatic conditions. Studies have reported that plant height decreases under low rainfall and high-temperature conditions (Özer *et al.*, 2005; Atak & Çiftçi, 2006; Mut *et al.*, 2006).

Grain yield was affected by genotype, treatment, and the genotype × treatment interaction (Table 5). The yield varied between 20.010-61.810 kg ha^{-1}, with the Alperbey variety and TBT16-11 line having the highest yield under both conditions. Supplemental irrigation increased the yield by approximately 43.75% compared with under rain-fed conditions. During the dry season, the lack of temperature and rainfall during the pre-spike period reduced yields under rain-fed conditions, resulting in poor growth, short height, narrow leaf area, and spindly grain formation. The results indicate that irrigation supported yield increase even in resistant crops such as triticale, and genotypes responded favorably to good environmental conditions.

Water deficit is one of the main factors limiting crop production in arid and semiarid regions (Hellal *et al.*, 2018). The irregularity and variability of rainfall creates significant constraints on growth and yield. Under rainfed conditions, drought causes severe yield losses in cereal production (Hossain & da Silva, 2012). Grain yield is affected by climate, soil conditions, agronomic practices, and genetic traits (Atak & Çiftçi, 2006). It has been reported that the grain yield of genotypes varies significantly depending on environmental conditions, which determine adaptation and stability (Karaman *et al.*, 2023).

Various studies have demonstrated that triticale grain yield is affected by environmental factors, as well as genetic potential (Aktaş *et al.*, 2009). Alp (2009), Kızılgeçi and Yıldırım (2017) and Albayrak *et al.* (2022) reported that grain yield values

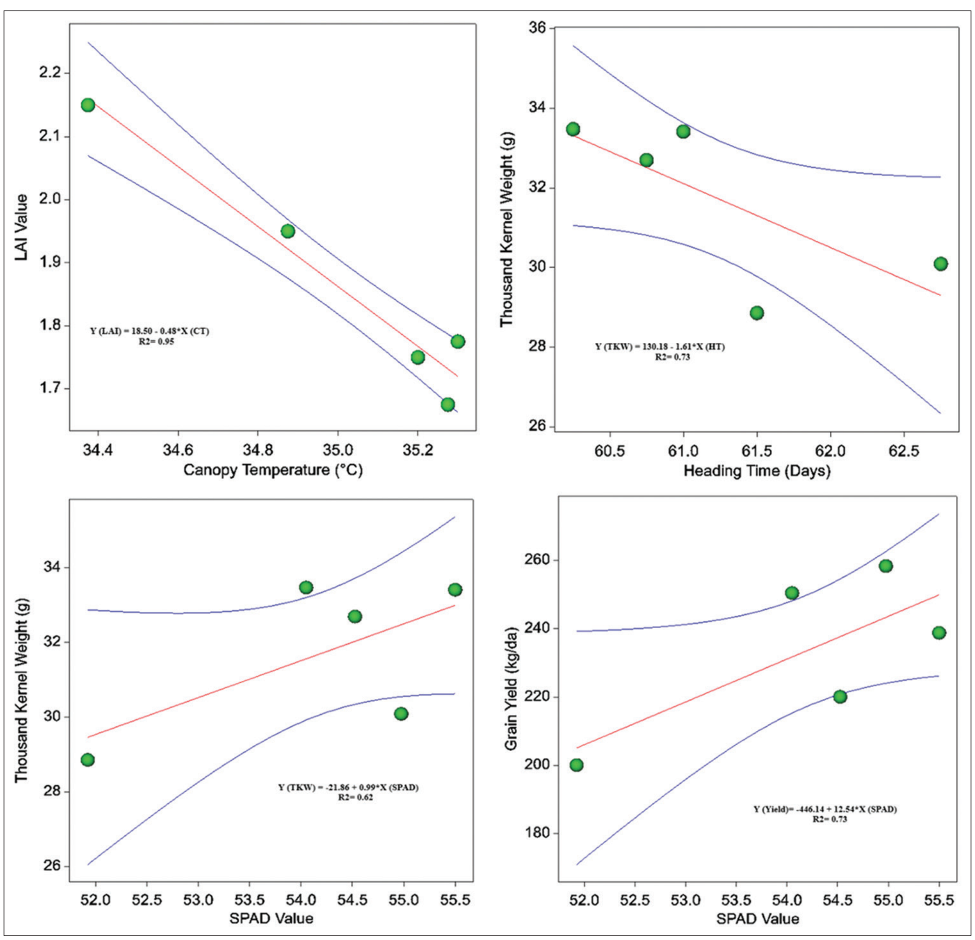

Figure 1: Linear regression responses fitted for canopy temperature vs. LAI, heading time vs. thousand kernel weight, SPAD vs. thousand kernel weight, and SPAD vs. grain yield under rainfed conditions. The regression line represents the values of the predicted trait, and the blue curves represent 95% confidence intervals.

varied between 378.18-678.5 kg ha^{-1}. Karaman (2023), similar to our study, reported that the TBT16-11 line and the Alperbey variety had high grain yield. Studies conducted under different ecological conditions have shown that grain yields can vary over a wide range. Kutlu and Kınacı (2011) reported yield values ranging from 383.79-668.52 kg ha^{-1} under dry conditions and 699.53-1081.94 kg ha^{-1} under irrigated conditions in Eskişehir. Similarly, Subhan *et al.* (2017) reported yield results ranging from 444.0-641.7 kg ha^{-1} under irrigated conditions. The data obtained in our study are largely in line with the literature, which emphasizes the significant effect of environmental conditions on triticale grain yield (Akıncı *et al.*, 2001; Kozak *et al.*, 2007; Dumbravă *et al.*, 2016; Lermi & Palta, 2018). These results demonstrate that environmental effects should be considered when evaluating the adaptability and stability of triticale genotypes.

The thousand kernel weights exhibited significant differences based on genotype, treatment, and genotype × treatment interaction (Table 5). Values ranged from 28.86 to 43.71 g, with the TBT16-11 line consistently maintaining a high thousand-kernel weight across conditions. While the Alperbey variety achieved the highest yield, it had the lowest thousand kernel weight. Supplemental irrigation was found to increase thousand-kernel weight compared to the rain-fed conditions. This trait is strongly influenced by environmental factors and cultivation practices. Drought, in particular, affects the grain-filling process, leading to a reduced thousand-kernel weight. Factors, such as rainfall distribution and location, play important roles in cultivation (Özdemir *et al.*, 2019). Studies have reported significant variation in thousand-kernel weight among triticale genotypes (Yanbeyi & Sezer, 2006; Albayrak *et al.*, 2006; Kızılgeçi & Yıldırım, 2017; Albayrak *et al.*, 2021). These findings demonstrate the effect of the adaptability of genotypes to environmental conditions on thousand-kernel weights.

The regression line represents the values of the predicted trait, and the blue curves represent 95% confidence intervals (Figure 1). Among the traits examined under rainfed conditions, the regression relationship between canopy temperature vs LAI was R^2=0.95, the relationship between heading time vs thousand kernel weight was R^2=0.73, the relationship between SPAD value vs thousand kernel weight was R^2=0.62, and the relationship between SPAD vs grain yield was R^2=0.73. While an inverse relationship was observed between canopy temperature vs LAI and heading time vs thousand kernel weight, a positive relationship was found between SPAD value vs thousand kernel

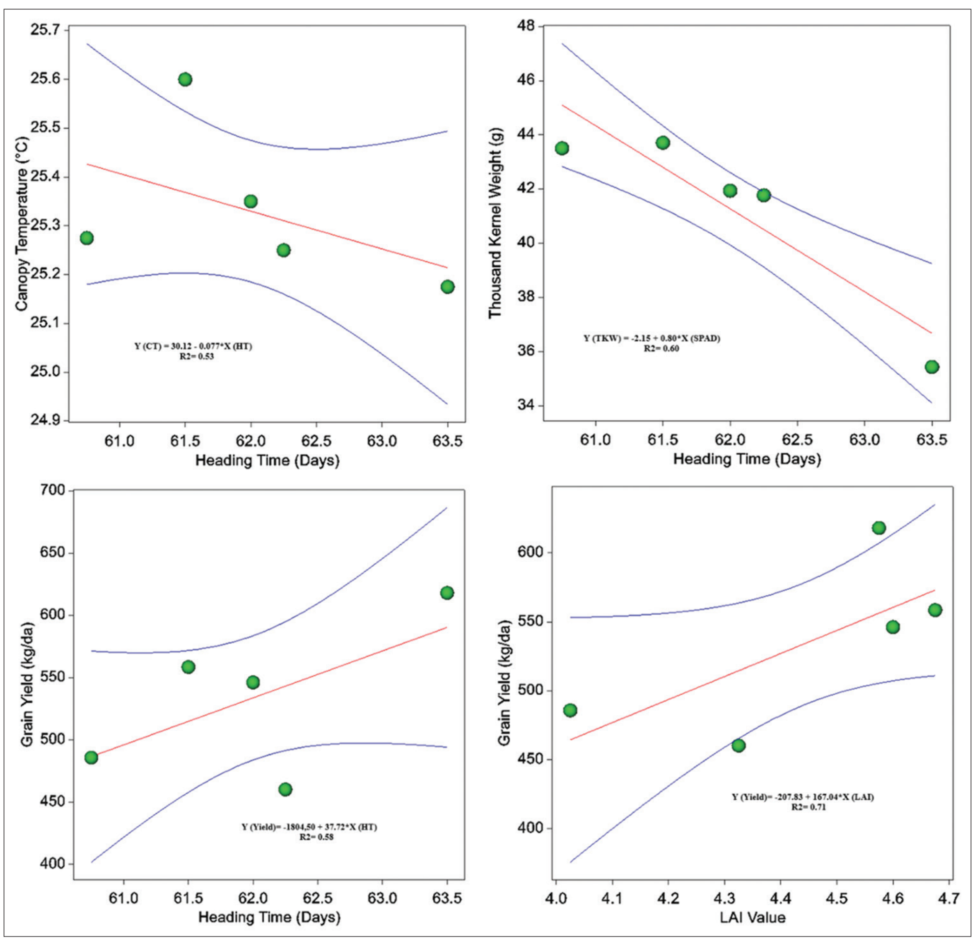

Figure 2: Linear regression responses fitted for canopy temperature vs. heading time, heading time vs. thousand kernel weight, heading time vs. grain yield, and LAI vs. grain yield under supplemental irrigation conditions. The regression line represents the values of the predicted trait, and the blue curves represent 95% confidence intervals.

weight and SPAD value vs grain yield. High temperatures negatively affected the leaf area index of the plants, and grain weight decreased as spike duration increased. In addition, high chlorophyll content positively affected grain weight and SPAD had a significant effect on grain yield (Figure 1).

Among the traits examined under supplemental irrigation conditions, the R^2=0.53 value between canopy temperature - heading time showed a moderate relationship, while the relationships between heading time vs thousand kernel weight (R^2=0.60), and heading time vs grain yield (R^2=0.58) were stronger. The strongest relationship was observed between LAI vs grain yield with R^2=0.71. In general, the relationships between heading time vs yield were moderately strong, whereas the relationship between LAI vs yield was stronger (Figure 2). It was observed that high temperatures negatively affected heading time. It is clear that as the canopy temperature increases, the heading time decreases, which may negatively affect plant development. In addition, it was determined that there was an inverse relationship between the heading time vs thousand-kernel weight. It was observed that the thousand kernel weight decreased as the heading time increased, which indicates that long heading time has a negative effect on grain weight. On the other hand, a linear relationship was found between heading time-grain yield, and an increase in grain yield was observed as heading time increased. This indicates that heading time has a significant effect on yield and a long heading time has a positive effect on yield. In addition, a strong relationship was found between LAI - grain yield, and it was observed that grain yield increased as the LAI value increased. This indicates that a high leaf area index increases the photosynthetic capacity of plants and positively affects the grain yield (Figure 2).

Previous studies have shown that meteorological factors determine winter triticale yield by 88% under starter nitrogen and 98% with additional fertilization (Janušauskaitė, 2008). Weather conditions also significantly affect triticale yields (Obuchowski *et al.*, 2010). Kutlu and Kınacı (2011) found a significant and positive relationship between hectolitre weight and grain width (r=0.54*) and grain thickness (r=0.41*), and a significant and negative relationship with grain length (r= -0.69*) under dry conditions. These results showed that grain width and grain thickness increased hectolitre weight, while grain length decreased it. Under irrigated conditions, they found a negative and statistically significant relationship between hectoliter weight and grain length (r=-0.65*), but they reported that they could not detect a significant relationship between grain width (r=0.24) and thickness (r=0.10) and hectoliter weight.

CONCLUSIONS

Grain yield varies depending on the amount and distribution of rainfall. In the 2018 production season, rainfall differences in the pre and post-spike periods allowed the examination of the responses of triticale genotypes to different environmental conditions. In rain-fed conditions, drought was effective especially before heading, but the genotypes responded positively to supplemental irrigation and showed improvement in all traits examined. The TBT16-11 line stood out with its high and stable yield value and superior traits such as earliness, SPAD, NDVI, LAI, canopy temperature, plant height and high thousand kernel weight. In addition, it was determined that the Alperbey variety can be successfully used as a parent in breeding studies. In the regression analysis, an inverse relationship was found between canopy temperature and LAI under rainfed conditions and high temperatures negatively affected leaf area. While heading time increased yield, SPAD value positively affected thousand kernel weight and grain yield. Similar relationships were observed under supplemental irrigation conditions; canopy temperature negatively affected LAI, while heading time increased yield and SPAD value positively affected yield. In conclusion, it was determined that irrigation application had a significant effect on yield increase for triticale, which is a plant resistant to adverse conditions, and triticale genotypes responded positively under good environmental conditions.

AUTHORS' CONTRIBUTION

MB: Planning and conducting the research, writing the article. RÖ: Conducting the research, performing the analyses, writing the article. LY: Conducting the research and measuring the observations. CA: Planning and conducting the research.

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