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Araştırma Makalesi / Research Article

Evaluation of Yield, Quality and Physiological Traits of Triticale Genotypes in Irrigated Conditions

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Abstract

This study aimed to evaluate the yield, quality and physiological traits of triticale genotypes (ADAY-8, DZ9-01-02, TBT6-11 and ESIN) in 2022-2023 production season in Diyarbakır, Türkiye. The field experiment was established according to the randomized complete blocks design with three replications. Heading time, plant height, thousand-kernel weight, grain yield, protein content, starch content, NDVI (Normalized Difference Vegetation Index), and SPAD (Flag leaf chlorophyll content) values are investigated traits on the study. The findings of the study demonstrated that there were statistically significant variations among the genotypes, with the exception of protein and starch content in relation to the examined traits. The DZ9-01-02 (1059.0 kg ha^{-1}) and TBT6-11 (1049.7 kg ha^{-1}) advanced lines exhibited the highest grain yield values. Conversely, the ADAY-8 and DZ9-01-02 advance lines were found to have earlier heading time, suggesting that these lines may offer a potential advantage in varying environmental conditions. SPAD values were generally found to be high, which indicated that triticale lines had high chlorophyll content during the heading stage. As a result, DZ9-01-02 and TBT6-11 genotypes can be evaluated as variety candidates for further breeding programs. Further research and testing should be conducted to determine the overall performance and adaptability of these varieties in various environmental conditions.

Keywords: SPAD, NDVI, grain yield, protein content

1. Introduction

The increasing population in the world and changing global climate conditions bring along food deficit and malnutrition. Achieve high yields in production areas and develop varieties and species that will adapt to different climatic and soil conditions may be the main solutions to this situation. Triticale, the first interspecific hybrid created by crossing wheat (*Triticum* spp.) and rye (*Secale cereale*), is promising with its ability to be grown in marginal areas and its different gene potential. The initial aim of triticale, which is not a natural species, was to develop a new cereal crop that would combine the superior agro-morphological, quality and yield traitss of wheat and the adaptability, vigor and resistance of rye to abiotic (saline, nutrient deficient, diseased fields and arid and cold areas with insufficient rainfall) and biotic stresses (Tababtabaei et al., 2012; Kızılgeçi et al., 2017). In 2022, 14 million tonnes of triticale were produced on 3.6 million hectares worldwide. In Turkey, 0.32 million tonnes were produced on 0.10 million hectares (FAOSTAT, 2022). Triticale is grown worldwide mainly for food (making biscuits, cakes, pasta and other baked goods), feed, and bioenergy production. Although triticale has a lower grain quality than cereals such as wheat, it has high resistance to diseases and pests and many beneficial genes have been effectively transferred from wheat to triticale. The majority of triticale breeding programs focus on improving economically important traits such as grain and biomass yield, disease and pest resistance, quality and agronomic traits. This study was carried out to determine grain yield, quality and physiological characteristics of some triticale genotypes under irrigated conditions.

2. Materials and Methods

2.1. Plant material and growing conditions

The experiment was conducted at Diyarbakir during the growing seasons of 2022-2023. The research farm of Teknobiltar company was located at 37˚55'34.24" N; 40˚15' 27.34" E at an altitude of 680 m above mean sea level in Diyarbakir, Türkiye. Three advanced triticale lines (ADAY-8, DZ9-01-02, TBT6-11) and Esin triticale variety were used as material in the study. The study was established on December 11, 2022 according to the randomized completely block design with 3 replications. Sowing was carried out with a trial seeder on plots of 4 m x 1.2 m = 4.8 m^2, with 550 seeds per m^2. Fertiliser was applied in two periods. Half of the fertiliser was applied as 20-20-0 compound fertiliser with 60 kg of pure nitrogen and 60 kg of pure phosphorus per hectare with sowing and the remaining 60 kg of pure nitrogen was applied in the form of urea (46 %) during the steam elongation period. The meteorological data of Diyarbakır province for the plant growing period are given in Table 1. The rainfall in December (4.7 mm) was much lower than the long-term rainfall (71.2 mm). The average temperature and total rainfall for the growing season of 2022-2023 were 15.2 ºC and 308.5 mm, respectively. The research was conducted under irrigated conditions with sprinkler irrigation system for 3 times during steam elongation, heading and milky stage. Weeds were removed manually and chemical pesticides were used for disease control. Harvesting was carried out on July 22, 2023 with the experimental combine harvester.

Table 1. Climatic data of the experimental area for 2023 and long years (1923-2023)

Months	Monthly Mean Temperature (°C)		Monthly Total Precipitation (mm)	
	2022-2023	Long-Term	2022-2023	Long-Term
December	7.3	4.1	4.7	71.2
January	3.9	1.8	17.9	69.7
Feburary	4.0	3.7	57.6	67.2
March	12.0	8.3	131.0	66.7
April	14.7	13.8	79.4	68.4
May	20.1	19.3	16.0	44.8
June	27.6	26.1	0.0	8.7
July	32.3	31.0	1.9	1.3
Average /Total	15.2	13.5	308.5	326.8

2.2. Traits investigated

The study examined heading time, plant height, thousand-grain weight, grain yield, protein content, starch content, NDVI (Normalized Difference Vegetation Index), and SPAD (Flag leaf chlorophyll content) values. Heading time were obtained by calculating the number of days from the day of sowing to the day 50 % of the plants in the plot spiked separately for each genotype. Plant height was determined by measuring the distance from the soil surface to the tip of the spike of 10 plants from each plot. Thousand-grain weight was calculated by weighing the seeds obtained from each plot 4 times 100 grains each, taking the average and multiplying by 10. Grain yield was calculated by weighing the grains obtained from each plot and converted to kg ha^{-1}. Protein and starch contents were determined with the assistance of the GrainSense device without milling the grain samples taken from each plot. The measurement of SPAD was conducted using a portable chlorophyll metre (Minolta SPAD-502, Osaka, Japan), which indirectly quantifies the chlorophyll content in the leaf. The measurements were conducted on the flag leaf of 10 plants chosen at random from each plot at the heading stage (GS 59) according to the development scale developed by Zadoks et al. (1974). The measurements were taken between 10:00 and 14:00 hours when the sky was cloudless (Öztürk et al., 2021). NDVI was measured with a portable GreenSeeker instrument between 12:00 and 13:00 when the plant was in the heading stage, the sky was cloudless and windless, and the plant surface was not wet from rain, dew, etc. All the means data were analyzed using randomized complete blocks design in JMP Pro-17 SAS Institute Ltd, USA to evaluate differences among genotypes. The significant differences between the genotypes were done with LSMeans Differences Student's t-test at 5% probability level and Scatterplot matrix correlation analyses were performed on the relationships between traits

3. Results and Discussion

The ANOVA results, mean values and the groupings among the traits examined in the study are presented in Table 2. According to the ANOVA results, there were statistically significant differences among genotypes heading time, plant height, thousand kernel weight, grain yield, SPAD and NDVI traits except for protein and starch content

Tablo 2. Mean values and ANOVA results of the investigated traits of triticale genotypes

Genotype	Heading time (day)	Plant height (cm)	Thousand kernel weight (g)	Grain yield (kg ha^{-1})	Protein content (%)	Starch content (%)	SPAD	NDVI
ADAY-8	136.0b	100.83b	46.88a	9971ab	13.86	84.61	58.5a	0.72b
DZ9-01-02	136.3b	110.67a	41.34b	10590a	12.77	85.96	54.5b	0.79a
ESIN	138.7a	108.07ab	45.19ab	8945b	13.66	85.25	56.6ab	0.78a
TBT6-11	139.3a	112.33a	43.85ab	10497a	13.20	85.24	56.3ab	0.79a
Mean	137.6	107.98	44.32	1000.1	13.37	85.26	56.5	0.77
MS	8.31**	77.3*	16.41*	17094.2*	0.71 ns	0.92 ns	7.89**	0.004**
CV (%)	0.58	3.07	3.27	4.74	6.88	1.04	1.49	3.27
LSD(0,05)	0.65	2.70	1.19	38.67	0.75	0.72	0.69	0.01

*:p<0.05,**:p<0.01 MS.:mean square CV: coefficient variance, LSD: least significant degree öd:non-significant

3.1. Heading time

Triticale generally earlier heading than wheat. In terms of escaping heat and drought, this can be an advantage. ADAY-8 and DZ9-01-02 were earlier than the other genotypes. TBT6-11 and ESIN had disadvantage to avoid drought stress by heading late (139.3 and 138.7 days) and shortening the number of days to heading and physiological maturity days but kept their high yield potential since they were grown under irrigated conditions. Kendal et al. (2016) reported that cold damage delayed the heading time in triticale genotypes as the reason for the extension of the heading period and that early-heading genotypes were more negatively affected by cold damage than late-heading ones, while late-heading genotypes could be seriously affected by drought.

3.2. Plant height

The highest plant height was determined in TBT6-11 (112.33 cm). However, it was statistically in the same group with DZ9-01-02. The lowest value was observed in ADAY-8 with 100.83 cm (Table 2). The amount of rainfall in May, the grain-filling period, was lower than in the long-term (Table 1). While the plant height was expected to be short due to the high daily temperature difference, the development of the vegetative parts continued with the effect of the irrigation applied and excessive shortening of the plant height was prevented. For this reason, the plant height values obtained in our research were similar to the values obtained in most studies conducted under normal conditions (Kozak et al., 2007; Karan et al., 2011; Geren et al., 2012; Kavut et al., 2012).

3.3. Thousand-kernel weight

Thousand-kernel weight is one of the critical criteria affecting grain quality in cereals. The highest thousand-kernel weight value was observed in ADAY-8 with 46.88 g and the lowest value was observed in DZ9-01-02 with 41.34 g (Tablo 2). Kutlu and Kinaci (2010) stated that the difference in the thousand grain weight values was affected by the environmental conditions, especially the different daily temperature values and irrigation. Thousand-kernel weight values obtained in the study were higher than the values reported by Kızılgeçi and Yıldırım, (2017), Demir et al. (2024) and Kızılgeçi (2019) and in a similar range with the findings of Kozak et al. (2007) and Karan et al. (2011).

3.4. Grain yield

Grain yield was highest in DZ9-01-02 (1059.0 kg da^{-1}) but it was in the same statistical group with TBT6-11 (1049.7 kg da^{-1}). ESIN (894.5 kg da^{-1}) had the lowest grain yield value (Table 2). In this study conducted under irrigated conditions, the average grain yield of 1000.1 kg da^{-1} showed that triticale genotypes have high yield potential. Especially the higher average grain yields of DZ9-01-02 and TBT6-11 lines are promising that they can be used as variety candidates and the average yield can be further increased.

Kızılgeçi et al. (2017) determined the average grain yield as 519.3 kg da^{-1} and 748.8 kg da^{-1} under dry conditions in Diyarbakır and Mardin locations, respectively. The values they found were found to be lower than our study. In the same ecology but under rainfall conditions, the grain yield obtained by Akıncı et al. (2001) was 86% less than this study. Kızılgeçi et al. (2017) reported that triticale responded positively to favorable environmental conditions. Yağbasanlar et al. (2003) reported that the triticale variety Tacettinbey, developed for the Çukurova region, gave a higher grain yield than bread wheat and durum wheat. In our study, the high grain yield values showed that it was caused by irrigation. The grain yield values obtained in our study were similar or different from the values found by most of the researchers who reported that triticale grain yield was affected by different environmental conditions (Kozak et al., 2007; Kutlu and Kinaci, 2010 Tababtabaei and Ranjbar, 2012; Dumbravă et al., 2016; Terzic et al., 2018; Genç Lermi and Palta 2018).

3.5. Protein and starch content

The protein and starch content traits are fundamental quality parameters in cereals. The investigation of these traits revealed no statistically significant differences between the genotypes. ADAY-8 genotype had the highest value for protein content and the lowest value for starch content. Similarly, TBT6-11 had the lowest protein content value and the highest starch content value. In our study, starch content was higher than the values reported by many researchers (Dumbravă et al., 2016; Kızılgeçi et al., 2016; Kızılgeçi, 2019). Kızılgeçi et al. (2016) reported that moisture had a significant effect on starch content. The high starch content in our findings is probably due to the fact that our study was carried out under irrigated conditions. Protein content was similar to the values of Dumbravă et al. (2016), higher than the protein content value found by Kızılgeçi (2019) at Mardin location, but lower than the value found at Diyarbakır location. It was lower than the values reported by Kızılgeçi and Yıldırım (2017).

3.6. SPAD and NDVI measurements

SPAD and NDVI measurement allowing farmers to make informed decisions about nutrient management and crop health (Gören, 2024). These measurements can help optimize fertilizer application, detect nutrient deficiencies, and monitor plant stress levels throughout the growing season. (Eliş et al., 2024; Gören ve ark., 2024). Kızılgeçi et al. (2017) reported that high chlorophyll content value in the plant is a desirable trait, and genotypes with high SPAD value have more photosynthetic capacity and higher grain yield under appropriate conditions. SPAD and NDVI values showed that there were statistically quite significant differences among the genotypes. SPAD and NDVI values measured at heading stage ranged between 54.5-58.5 and 0.72-0.79, respectively. SPAD values were generally high, indicating that triticale genotypes have high chlorophyll content during the heading stage. The highest SPAD value was 58.5 in ADAY-8. However, the same genotype had a lower NDVI value than the other genotypes. SPAD values found by many researchers were lower than the findings of the study, while NDVI values were in a similar range with the findings (Kızılgeçi et al., 2017; Kızılgeçi, 2019).

3.7. Scatterplot matrix correlation analysis

Scatterplot Matrix correlation analysis of the investigated traits of triticale genotypes is given in Figure 1. Scatterplot Matrix correlation analysis is an effective method for analyzing the relationship between traits.

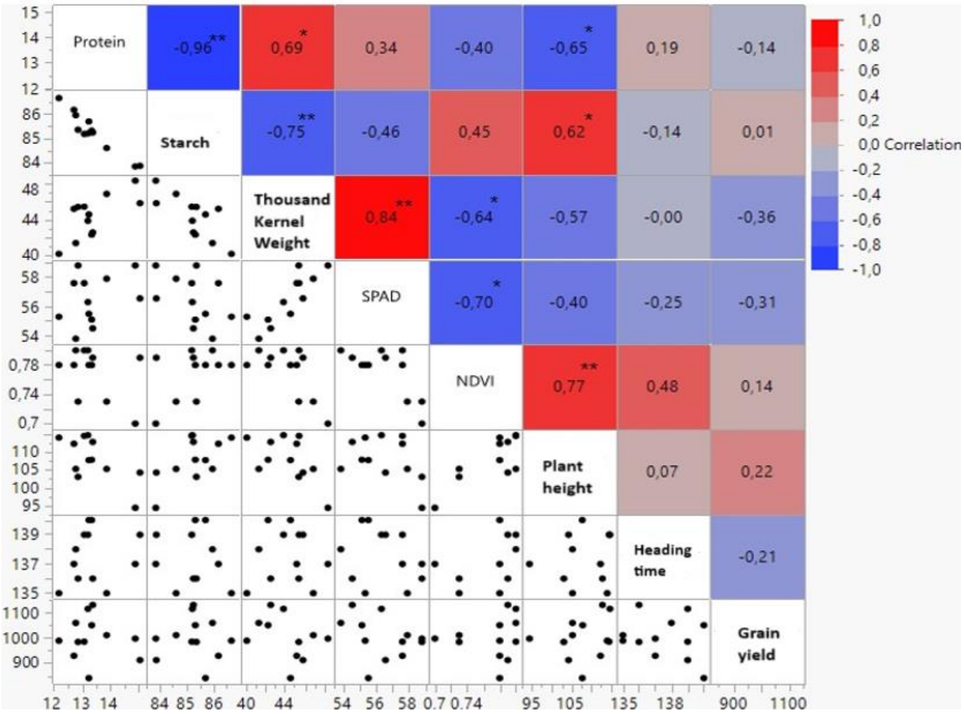

Figure 2. Scatterplot Matrix correlation diagram of the traits analyzed in the study

Correlation analysis showed a negative correlation between protein content with starch content and plant height. Kızılgeçi (2019) reported a negative and significant correlation between starch content and plant height for protein content. While a significant and negative correlation was observed between NDVI and SPAD measurement values, a positive and significant correlation relationship was determined between NDVI and plant height. Kızılgeçi and Yıldırım (2019) reported a negative correlation between SPAD and NDVI measured at heading stage. The positive correlation between NDVI and plant height is an indication of healthy plant growth. There was a positive and significant relationship between thousand-kernel weight with protein content and SPAD, while there was a negative and significant relationship between starch content and NDVI.

4. Conclusion

In our study, DZ9-01-02 and TBT6-11 advanced lines were noted with high grain yield. ADAY-8 line stood out with its SPAD and thousand-grain weight traits. Overall, the study shows that triticale genotypes respond positively to irrigation and environmental conditions, and yield potential can be increased under these conditions. Moreover, the positive correlation between plant height and NDVI can be considered as an indicator of healthy plant growth. As a result; it is considered that the triticale advanced lines included in the research are potential variety candidates that can be used in agricultural production and adaptation to the region.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

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