**T.C.**
**KAHRAMANMARAŞ SÜTÇÜ İMAM ÜNİVERSİTESİ**
**BİLİMSEL ARAŞTIRMA PROJELERİ KOORDİNASYON BİRİMİ**
**PROJE YAYIN DİLEKÇESİ**

| **Proje Adı** | | |
|---|---|---|
| Damla Sulama Yöntemiyle Sulanan Yazlık Buğdayda Farklı Sulama Seviyelerinin Verim ve Verim Bileşenlerine Etkisi | | |
| **Proje No** | **Başlama Tarihi** | **Bitiş Tarihi** |
| 2018/5-13 M | 06-11-2018 | 06-11-2020 |
| **Yayın Türü** | **Yayın / Makele Başlığı** | |
| Makale | *Drought resistance, quality characteristics and water-yield relationships of some wheat (Triticum aestivum L.) lines and varieties* | |
| **Dergi ISSN** | **DOI** | **Cilt / Sayfa / Yıl** |
| 0931-2250 | https://doi.org/10.1111/jac.12678 | 1 / 1-9 / 2024 |
| **Yayınlandığı Dergi Kısa Ad** | **Yayınlandığı Dergi** | |
| J Agro Crop Sci | Journal of Agronomy and Crop Science | |
| | | |

**İLGİLİ MAKAMA**

Yukarıda bilgileri verilen ilgili otomasyona girilmiş yayın bilgileri içerisinde ; *"Söz konusu çalışma/yayın/sunum/poster/bildiri/ **KAHRAMANMARAŞ SÜTÇÜ İMAM ÜNİVERSİTESİ Bilimsel Araştırma Projeleri birimi** tarafından 2018/5-13 M proje numaralı "Damla Sulama Yöntemiyle Sulanan Yazlık Buğdayda Farklı Sulama Seviyelerinin Verim ve Verim Bileşenlerine Etkisi" konusu ile ilgili olup, ilgili birimce desteklenmiştir." ( "This work is supported by the **Scientific Research Project Fund of KAHRAMANMARAŞ SÜTÇÜ İMAM ÜNİVERSİTESİ** under the project number 2018/5-13 M" )* ifadesi yer almaktadır.

**PROJE YÜRÜTÜCÜSÜNÜN**

**Ünvanı, Adı-Soyadı :** Doç.Dr. Ziya DUMLUPINAR

**Tarih :** 22-04-2024

Bu belge, güvenli elektronik imza ile imzalanmıştır.

Belge Doğrulama Kodu :ba9fdcd88b　　Belge Takip Adresi : https://bapotomasyon.ksu.edu.tr/belgedogrula

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Received: 15 December 2022 | Revised: 9 October 2023 | Accepted: 23 October 2023

DOI: 10.1111/jac.12678

DROUGHT STRESS

Journal of Agronomy and Crop Science WILEY

# Drought resistance, quality characteristics and water-yield relationships of some wheat (*Triticum aestivum* L.) lines and varieties

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**Funding information**
Kahramanmaras Sutcu Imam University Scientific Research Projects Unit, Grant/Award Number: 2018/5-13M

## Abstract

The aim of this study was to determine the drought tolerance of four different genotypes, including two wheat varieties (Ceyhan 99 and Sagittario) and two wheat lines (Zdeb101 and Zdeb102), and create irrigation schedules. This study was performed with treatments applied at three irrigation levels (S100: treatment where the entire water need of the plant was met, S50: 50% of the water provided in the S100 treatment, S0: Rainfed), with four genotypes and four replications in a split-plot design in Kahramanmaras East Mediterranean Transitional Zone Agricultural Research Institute in 2019 and 2020. The Ceyhan 99 and Sagittario varieties, which are widely cultivated in the region and the Zeb101 and Zdeb102 lines that are candidates for varieties were used in the study. In the study, 217.1 and 213.77 mm of water was given to S100, 108.54 and 106.88 mm of water was given to S50, and no irrigation was provided to S0 in 2019 and 2020, respectively. The effects of different irrigation levels on yield, water use efficiency (WUE), irrigation water use efficiency (IWUE), protein content and wet gluten content were investigated. At the end of this study, seasonal evapotranspiration (ET), irrigation water and yield decreased from S100 to S0. WUE, IWUE and yield response factor (Ky) values showed different trends in both years. There was no significant difference in yield between the varieties. However, in the stress susceptibility index (SSI) analyses of the genotypes, it was found that the most drought-tolerant genotypes were Zdeb102 (0.50) and Ceyhan 99 (0.54). The highest protein content and wet gluten content were found as 11.38% and 22.24% in the Sagittario variety, respectively. It is recommended that Zdeb102 and Ceyhan 99 be cultivated in regions such as Kahramanmaras which have semi-arid climate characteristics in the Mediterranean.

KEYWORDS
deficit irrigation, drought stress, evapotranspiration, protein content

## Key points

- The lodging-resistant Zdeb2 line is the most drought-tolerant line.
- Ceyhan 99, known as a summer bread variety, can be grown in arid areas outside the Mediterranean.

- The decrease in the irrigation level caused decreases in wheat yield.
- There was no difference in genotype yields in severe drought cases when the water deficit rate was >50%.
- Protein content decreased with increasing drought stress.
- Wet gluten content was not affected by increasing drought.

## 1 | INTRODUCTION

In the face of climate change, more frequent drought events are expected in the Mediterranean region (Blanchet et al., 2021). Drought is one of most significant natural phenomena threatening agricultural production (Iqbal et al., 2022; Lesk et al., 2016). Agricultural production should be carried out by taking a series of measures to provide sufficient food for the growing population in drought conditions (Sisto et al., 2022). Irrigation is the most important input parameter in providing sufficient yield in agricultural production against drought (Xing et al., 2020). More responsible use of water has become very important today (Gong et al., 2020). Agricultural irrigation is a sector where the highest amounts of water are used (Vohra & Franklin, 2021). Therefore, in agriculture, the use of water, which is a scarce resource, requires Deficit Irrigation. Deficit irrigation is a strategy of reducing the consumption of water by providing resistance to water stress without causing a decrease or by a minimum decrease in the yield and quality of plants (Painagan & Ella, 2022). Thanks to deficit irrigation, more efficient use of water is ensured, and the optimum efficiency is targeted (Zhao et al., 2020).

The degree to which plants are affected by drought varies depending on plant varieties and species (Rapacz et al., 2010; Vassileva et al., 2012). Wheat is a plant that can be grown in several different geographies and under highly variable climate conditions. However, wheat farming is limited by many abiotic and biotic factors. Abiotic factors frequently include high temperatures and drought (Kaur et al., 2021). This is because many wheat genotypes are sensitive to drought. Soil moisture, which is also negatively affected by drought, is an important factor that limits the production of wheat in many regions of the world. Especially in semi-arid and arid environments, water restrictions usually limit the yield of wheat (Ozturk & Aydin, 2004).

Alongside deficit irrigation, drought-tolerant varieties should be grown to prevent drought from hindering agricultural production. For this reason, drought adaptation studies of different varieties of the same species can be carried out to increase the tolerance of varieties. Therefore, in response to drought and increasing food demand, obstacles to the feeding of the world's population can be prevented (Vadez et al., 2014). The production of wheat (*Triticum aestivum* L.), which is one of the basic food raw materials of human nutrition, has decreased in recent years due to extreme temperatures in major wheat-producing countries and drought that threatens production. This situation has caused an increase in wheat prices worldwide (USDA, 2022). Drought has necessitated development of drought-resistant varieties and appropriate irrigation schedules. Day by day, efforts to develop drought-resistant varieties gain momentum for arid and semi-arid regions.

In the province of Kahramanmaras in Turkey, usually due to altitude and distance to the sea, a Mediterranean climate transitioning into a terrestrial climate is dominant. The position of the province in the middle of the Southeastern Anatolia, Eastern Anatolia and Mediterranean Regions in Turkey has led to the differentiation of climate conditions in the area (Yuce et al., 2019). Wheat constitutes 20% of plant production in Kahramanmaras. Kahramanmaras earned 177.77 million dollars from wheat production in 2016. Within the scope of grain production taking place on an area of 184.3 thousand hectares in Kahramanmaras in 2016, wheat production takes the first place in terms of cultivation area with approximately 130.0 thousand hectares. In 2016, 274.5 thousand tons of wheat and 492 thousand tons of durum wheat were produced in Kahramanmaras. These values are higher than Turkey's yield averages of 2660 kg ha$^{-1}$ and 2970 kg ha$^{-1}$, respectively.

The aim of this study was to determine the response wheat grown in irrigated and non-irrigated conditions to drought and identify irrigation requirements and drought-tolerant wheat lines and varieties. Another aim was to compare the water-yield relationship quality characteristics (protein content, wet gluten content) among different genotypes in Kahramanmaras.

## 2 | MATERIALS AND METHODS

### 2.1 | Study area and agricultural operations

The study was carried out in fields belonging to Kahramanmaras Eastern Mediterranean Transition Zone Agricultural Research Institute, during 2019 and 2020. The climatic data of the study area for the two plant growing seasons are presented in Figure 1.

Typical Mediterranean climate characteristics (cold and rainy winters, hot and dry summers) are observed in the region where the study was conducted. In the growth season of 2019, the total amount of precipitation was 488.5 mm, while the total amount of precipitation in the growth season of 2020 was 542.8 mm. Some physical properties of the soil of the study area are given in Table 1. The studied soil has a silty-loamy and sandy-loamy texture. These textural characteristics, along with other physical properties, are suitable for wheat cultivation. In this study, two wheat (*Triticum aestivum* L.) varieties (Ceyhan 99 and Sagittario bread wheat) and two wheat (*Triticum aestivum* L.) lines (Zdeb101 and Zdeb102) were included. The Zdeb101 and Zdeb102 lines were selected based on the

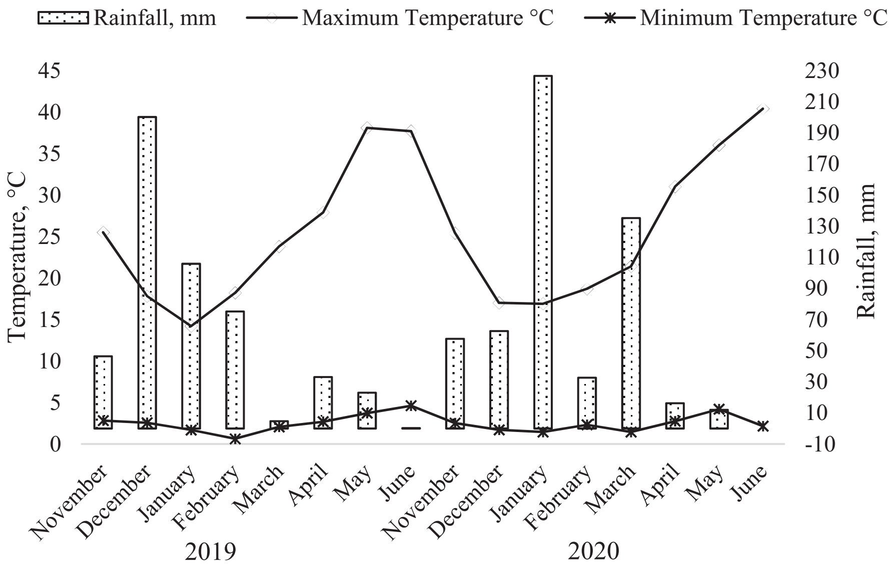


FIGURE 1 Maximum and minimum temperature values and total precipitation data of wheat genotypes in Kahramanmaras for 2019–2020 according to months in growth seasons. The bars indicate precipitation, while the lines indicate the maximum and minimum temperature values. The period between November and June is the growth period.

TABLE 1 Some physical properties of the soils in the study area. Field capacity, wilting point, usable water holding capacity, bulk density and textural characteristics of the samples collected from soil depths of 0–30 cm, 30–60 cm and 60–90 cm.

| Soil depth (cm) | Field capacity (mm) | Wilting point (mm) | Bulk density ($g\,cm^{-3}$) | Usable water holding capacity (mm) | Soil texture |
|---|---|---|---|---|---|
| 0–30 | 105.50 | 59.90 | 1.60 | 45.56 | Silty loam |
| 30–60 | 107.80 | 65.90 | 1.50 | 41.90 | Silty loam |
| 60–90 | 114.40 | 63.02 | 1.62 | 51.08 | Sandy loam |

FIGURE 2 View of the plots according to the irrigation treatments in the entire process from wheat emergence to harvest. The top three photographs belong to the germination and emergence stages of the plants. The bottom three photographs show the appearance of the plants from the flowering to the harvest periods.

similarity of their growing conditions to those of the Ceyhan 99 and Sagittario varieties. Ceyhan 99 is a drought-tolerant soft wheat variety that is grown in the Mediterranean region. Sagittario is a wheat variety that is moderately tolerant to drought and suitable for growing in the Mediterranean region. Zdeb101 and Zdeb102 are wheat lines developed against lodging. The soil to be used in this study was ploughed deep with a plough to prepare the field for planting. Sowing was performed with a seeder in the November of both years. Eight kg of N and 8 kg of $P_2O_5$ were provided during sowing. Seven kg of urea fertilizer was given as a top fertilizer. Herbicides were used for weed control in the plots, and no fungicides or pesticides were applied because diseases or pests were not encountered.

Experimental design for irrigation and measurements: In the present study, plots at dimensions of 5 m by 1.2 m with an area of 6 $m^2$ were created. Four different genotypes (Ceyhan 99, Sagittario, Zdeb1, Zdeb2) and three different irrigation levels (S100, S50, S0) were applied. The S100 treatment involved providing the entirety of the water needed by the plant (100% irrigation), the S50 treatment involved the provision of 50% of the water used in the S100 treatment, while the plants allocated to the S0 treatment were rainfed (no irrigation). The treatments were arranged according to a split-plot design with four replications each. Each of the blocks had 12 plots with the four varieties and three irrigation levels. Visuals of parcels belonging to irrigation treatments are given in Figure 2. Soil moisture was monitored with the gravimetric method to determine times of irrigation. The effective root depth for the wheat plants was taken as 90 cm. Therefore, soil moisture samples were also taken from a 90-cm depth. Moisture changes in the soil were determined in terms of dry weight percentage by the gravimetric method. When determining the amount of irrigation water to provide to the plots in each irrigation treatment, an expression for the available water holding capacity of the soil in terms of depth was used. The net irrigation water amount calculated in mm was multiplied by the plot area, and the amount of water that should be given to each plot was calculated in volume. The net amount of irrigation water to be provided in each irrigation treatment was determined according to the net irrigation amount formula in terms of depth (Gungor et al., 2012). Irrigation was started when 30% of the usable water holding capacity of the control treatment was exhausted. The irrigation interval varied between 8 and 10 days. A drip irrigation system was used to water the plants.

## 2.2 | Crop-water relationships, yield, protein content and wet gluten content

Water use efficiency (WUE) and irrigation water use efficiency (IWUE) were determined according to the water consumption values of the plant, the irrigation water that was given and harvested yield (Zhang et al., 2004). Formulae for WUE and IWUE are given in Equations 1 and 2.

$$\mathrm{WUE} = \frac{\mathrm{Ey}}{\mathrm{ET}} \times 100 \qquad (1)$$

where, Ey: Economic yield, kg $ha^{-1}$; ET: Plant water consumption, $m^3$.

$$\mathrm{IWUE} = \frac{\mathrm{Ey}}{1} \times 100 \qquad (2)$$

where, I: Seasonal irrigation water amount, mm.

The moisture reduction method based on the water budget equation was used in the calculation of evapotranspiration (Howell et al., 1986).

$$\mathrm{ET} = \mathrm{I} + \mathrm{P} - \mathrm{Rf} - \mathrm{Cr} - \mathrm{Dp} \pm \Delta \mathrm{S} \qquad (3)$$

where, I: irrigation water, mm; P: precipitation, mm; Rf: runoff losses, mm; Dp: amount of penetration, mm; Cr: capillary rise, mm; ΔS: change in soil water content in root zone, mm $90^{-1}$ cm.

Water-production functions were determined depending on the relationship between the irrigation water given to the plants and the resulting plant water consumption versus yield (Howell et al., 1990). For this purpose, the Stewart model was used (Kadayifci & Yildirim, 2000). Equation 4 shows the formula of the yield response factor (Ky).

$$\left(1 - \frac{\mathrm{Y}}{\mathrm{Ym}}\right) = \mathrm{ky}\left(1 - \frac{\mathrm{ET}}{\mathrm{ETm}}\right) \qquad (4)$$

where, Y: Actual yield, kg $ha^{-1}$; Ym: Maximum yield, kg $ha^{-1}$; ET: Actual water consumption, mm; ETm: Maximum water consumption, mm.

At harvest, wheat was cut with a sickle, at a height of about 5 cm from the ground, it was threshed, the grain yield of each plot was determined, and yield was calculated in units of kg dry grain $ha^{-1}$. Protein content was determined by the Kjeldahl method by passing samples with known dry matter yield values through a 1-mm sieve. These samples, which were obtained according to the Kjeldahl method, were burned with sulfuric acid ($H_2SO_4$), and nitrogen (N) was converted to ammonium sulphate and then to ammonia. Crude protein was determined based on the amount of nitrogen in ammonia measured by titration (Saez-Plaza et al., 2013). The wet gluten ratio (YG) was measured using a Near-Infrared (NIR) spectroscopy (Thermo Fisher Scientific) device.

## 2.3 | Stress susceptibility index (SSI)

To determine the drought tolerance of the wheat varieties and lines, SSI was calculated as in Equation 5 according to the method reported by Fischer and Maurer (1978).

$$\mathrm{SSI} = (1 - \mathrm{Ys} - \mathrm{Yp}) / (1 - \overline{\mathrm{Ys}} / \overline{\mathrm{Yp}}) \qquad (5)$$

where, Ys: Yield under stress conditions, Yp: Potential yield, $\overline{\mathrm{Ys}}$: All genotypes under stress conditions, $\overline{\mathrm{Yp}}$: All genotypes under non-stress conditions.

## 2.4 | Statistical analysis

The study was arranged in a split-plot experimental design with four replications. The data were analysed using the ANOVA method with the SAS software (SAS 9.1 Institute Inc., 2020). The LSD test was used to compare mean results, and the level of statistical significance was taken determined as 0.5% probability if not stated otherwise. The homogeneity test results showed that there was no significant difference between the years ($p < .05$). Accordingly, the ANOVA was performed by combining the data of 2 years (Levene, 1960).

## 3 | RESULTS

### 3.1 | Irrigation amounts, ET, WUE, IWUE and Ky values

The amounts of irrigation water, ET, WUE, IWUE and Ky values are given in Table 2. In 2019, while the S100 and S50 treatment groups were given, respectively, 217.10 mm and 108.5 mm of water, they were given, respectively, 213.8 mm and 106.9 mm of water in 2020. In both years, no irrigation was applied in the S0 treatment group. In both years of study, ET decreased from S100 to S0. In 2019, from S100 to S0, the ET values were, respectively, 341.31 mm, 297.36 mm and 197.16 mm, while they were, respectively, 332.81 mm, 307.97 mm and 210 mm in 2020.

WUE increased from S100 to S0 in 2019. The WUE value for S100 was found to be 20.6 kg m$^{-3}$, that for S50 was 22.7 kg m$^{-3}$ and that for S0 was 31.9 kg m$^{-3}$. Similarly, WUE values increased from S100 to S0 in 2020. The highest WUE value was found to be 28.3 kg m$^{-3}$ in S0. IWUE values were found to be 32.4 kg m$^{-3}$ for S100 and 62.3 kg m$^{-3}$ for S50 in 2019. In 2020, these values were found as 32.6 kg m$^{-3}$ for S100 and 57.8 kg m$^{-3}$ for S0.

Ky values were 0.25 in 2019 and 0.44 in 2020. The Ky of wheat is given in Figure 3. Doorenboos and Kassam (1979) stated that when Ky is smaller than 1, the yield loss is less significant than the ET gap; when Ky is >1, the yield loss is more significant than the ET gap, and when Ky is equal to 1, the yield loss is equal to the ET gap. It was found that Ky was smaller than 1 in all irrigation treatments in this. While this situation was considered normal in S100, its observation in S50, and especially in S0, showed that the yield loss of S0 due to drought stress was at an insignificant level. In this case, it can be stated that the S100 treatment was not as economical as the S0 treatment.

**TABLE 2** Irrigation (I), ET, WUE and IWUE values of wheat genotypes in the 2019 and 2020 growing seasons.

| Years | Treatment | I, mm | Et, mm | WUE, kg m$^{-3}$ | IWUE, kg m$^{-3}$ |
|---|---|---|---|---|---|
| 2019 | S100 | 217.1 | 341.31 | 20.6 | 32.4 |
| | S50 | 108.5 | 297.36 | 22.7 | 62.3 |
| | S0 | 0 | 197.16 | 31.9 | – |
| 2020 | S100 | 213.8 | 332.81 | 20.9 | 32.6 |
| | S50 | 106.9 | 307.97 | 20.0 | 57.8 |
| | S0 | 0 | 210 | 28.3 | – |

Abbreviations: ET, Evapotranspiration; I, Irrigation amount; IWUE, Irrigation water use efficiency; WUE, Water use efficiency.

### 3.2 | Yield, protein content and wet gluten content

The yield, protein content and wet gluten content of the wheat genotypes are given in Table 3. Year x Genotype, Year x Irrigation levels, Genotype x Irrigation levels and Year x Genotype x Irrigation levels were not significant in yield. In terms of the average yield values in both years, there was no statistically significant difference among the genotypes, but there was a significant difference among the irrigation levels. Although there is no difference in yield between genotypes, it is seen that there are relatively differences. It is understood that from Zdeb101 6.5% more yield is obtained than Sagittario. Higher yield was obtained from the S100 treatment compared to S50 and S0. The finding that the yield value in S0 was not significantly lower than that in S50 showed that the S0 group may have used water more effectively.

As seen in Table 3, protein content values differed based on irrigation treatments and genotypes. While the highest protein content was observed in the Sagittario variety, the lowest protein content was observed in the Zdeb102 line. It was observed that the protein content increased as the rate of irrigation increased. The results showed that the increase in irrigation facilitated an increase in the protein content of the plants. The results also showed that yield and protein content may have an inverse relationship.

Wet gluten content did not change significantly according to irrigation treatments. However, three different groups were formed according to the genotypes. The highest content of wet gluten was obtained in the Sagittario variety. Wet gluten content is one of the most important parameters in evaluating flour quality. In this case, it can be stated that the Sagittario variety was superior to the other variety/lines in terms of flour/dough quality. These results thought that wet gluten content may vary inversely with yield and linearly with protein content.

The results of the ANOVA for the yield, protein content and wet gluten content of the wheat genotype are given in Table 4. There was a significant difference in yield values among the irrigation treatments. Significant differences were also observed in protein content values according to years, genotype and irrigation treatments. It was also found that there were significant differences between the years and among the genotype in terms of wet gluten content.

### 3.3 | Stress susceptibility index (SSI)

The stress susceptibility index (SSI) values of the wheat varieties and lines are given in Table 5. It was found that the most drought-tolerant line was Zdeb102 with a value of 0.50, and the most drought-tolerant variety was Ceyhan 99 with a value of 0.54. The fact that the SSI values of the Sagittario variety and the Zdeb101 line were close to 1 and >1 suggested that Sagittario and Zdeb101 were sensitive to drought.

## 4 | DISCUSSION

In this study, ET decreased depending on the amount of irrigation water applied to the plants from complete irrigation towards

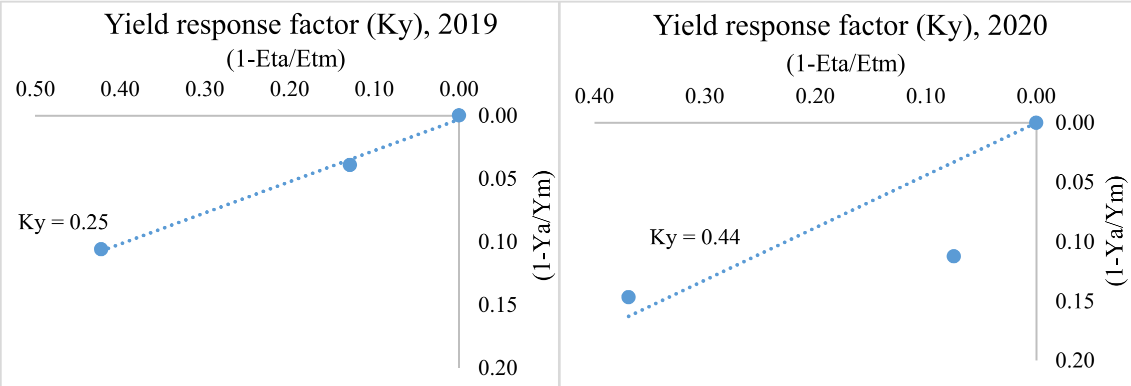


**FIGURE 3** Ky values, that is slope of regression line of wheat genotypes in the 2019 and 2020 growing seasons.

**TABLE 3** Yield, protein content and wet gluten content of wheat genotypes in 2019, 2020 and the average of both years in the growing seasons.

| | Yield (kg ha$^{-1}$) | Protein content (%) | Wet gluten (%) |
|---|---|---|---|
| | ns | ** | ** |
| Years | | | |
| 2019 | 6697 | 10.17$^{b}$ | 19.59$^{b}$ |
| 2020 | 6368 | 11.92$^{a}$ | 23.48$^{a}$ |
| Avg. | 6532 | 11.04 | 21.53 |
| LSD | 35.96 | 0.30 | 0.69 |
| | ns | ** | ** |
| Genotypes | | | |
| Ceyhan 99 | 6533 | 11.02$^{ab}$ | 21.45$^{ab}$ |
| Sagittario | 6326 | 11.38$^{a}$ | 22.24$^{a}$ |
| Zdeb101 | 6764 | 11.07$^{ab}$ | 21.70$^{ab}$ |
| Zdeb102 | 6509 | 10.72$^{b}$ | 20.79$^{b}$ |
| Avg. | 6533 | 11.05 | 21.55 |
| LSD | 50.86 | 0.43 | 0.98 |
| | ** | * | ns |
| Irrigation levels | | | |
| 100 | 7004$^{a}$ | 11.26$^{a}$ | 21.88 |
| 50 | 6475$^{b}$ | 10.79$^{b}$ | 21.66 |
| 0 | 6140$^{b}$ | 11.08$^{ab}$ | 21.13 |
| Avg. | 6539 | 11.04 | 21.56 |
| LSD | 44.04 | 0.37 | 0.85 |
| Mean | 6533 | 11.04 | 21.54 |
| CV (%) | 13.45 | 6.71 | 7.86 |
| Year × Genotype | ns | ns | ns |
| Year × Irrigation levels | ns | ** | ** |
| Genotype × Irrigation levels | ns | ns | ns |
| Year × Genotype × Irrigation levels | ns | ns | ns |

*Note*: Different letters in mean values indicate significant differences at $p \le .05$ based on LSD test comparisons. ns indicates a non-significant result. * and ** indicate significance at $p \le .05$ and $p \le .01$, respectively.

deficit irrigation. Tekin (2011) found the ET of wheat to vary between 328 mm and 497 mm in Adana conditions. In this study, a decrease in irrigation degrees caused the efficiency of irrigation water to increase in both years. The reason why IWUE was higher than WUE was the fact that ET was higher than the irrigation amount, and this additional water consumption was derived from stored soil water and precipitation. Payero et al. (2008) obtained positive linear relationships between WUE values and the amounts of irrigation water applied.

**TABLE 4** Results of ANOVA of yield, protein content and wet gluten content values.

| | Mean square | F-value |
|---|---|---|
| Yield | | |
| Year | 26,004 | 3.37 |
| Genotype | 7740 | 1.00 |
| Irrigation levels | 63,387 | 8.21** |
| Year × Genotype × Irrigation | 5850.00 | 0.76 |
| Protein content | | |
| Year | 73.24 | 133.14** |
| Genotype | 1.73 | 3.13* |
| Irrigation levels | 1.79 | 3.26* |
| Year × Variety/line × Irrigation | 0.36 | 0.65 |
| Wet gluten | | |
| Year | 362.74 | 126.42** |
| Genotype | 8.72 | 3.04* |
| Irrigation levels | 4.69 | 1.63 |
| Year × Genotype × Irrigation | 1.00 | 0.35 |

*Note*: * and ** indicate significance at $p \leq .05$ and $p \leq .01$, respectively.

**TABLE 5** Stress susceptible index (SSI) of wheat genotype average of 2 years.

| Years | Genotype | SSI |
|---|---|---|
| Avg. of 2 years | Ceyhan 99 | 0.54 |
| | Sagittario | 0.98 |
| | Zdeb101 | 1.33 |
| | Zdeb102 | 0.50 |

Steduto et al. (2012) conducted a comprehensive review of the literature on winter wheat grown in deficit irrigation conditions and reported a general yield response value of 1.05 Ky. This value was considerably higher than the values of 0.25 and 0.44 that were obtained in this study. This difference suggested that the wheat genotypes that were examined in this study were more tolerant to drought conditions. Steduto et al. (2012) reported that the period of wheat yield that is generally considered to be the most sensitive to drought stress is tillering. In the present study, the high amounts of rainfall during the tillering period of wheat may be the reason why the S0 treatment was not more adversely affected by water stress. Orta et al. (2002) stated that the Ky value in wheat varied between 0.56 and 0.79 in Tekirdag conditions. Considering that there is no constant Ky value for different varieties of plants, climatic conditions or growth periods according to Rhenals and Bras (1981), the variables in the equation are influenced by plant characteristics and environmental factors, such as the aforementioned differences in sensitivity in various growth stages.

Mut et al. (2017) found yield values in the range of 2905 to 3722 kg ha$^{-1}$ in Yozgat conditions. Tekin (2011) reported yield values in Adana conditions between 4290 and 5500 kg ha$^{-1}$, whereas Gungor and Dumlupınar (2019) found yield values in the range of 5150 to 7900 kg ha$^{-1}$ in Bolu. The reason why the wheat yield in Yozgat conditions was lower than the results of this study and those of other researchers can be that the annual rainfall in Yozgat is usually lower than those in Bolu and Kahramanmaras.

In this study, the highest protein content was obtained in the S100 treatment, while the lowest was in S50. Accordingly, the protein content values decreased in the moderate drought conditions in the S50 treatment. Vassileva et al. (2012) observed that drought stress affected protein synthesis and protein catabolism, and this reduced the protein content of the plant because some proteins are directly involved in the resistance of the plant to stress. Dai et al. (2016) obtained protein contents of 15.3% and 12.7%, respectively, from wheat grown in irrigated and non-irrigated conditions in China. Abubakar and Zigla (2021) found protein content values between 11.4% and 16.4% under Nigeria conditions. Similarly, Meng et al. (2016) observed that light to moderate water stress did not significantly reduce yield and protein content compared to complete irrigation. The reason for all these results obtained in non-arid environmental conditions such as well-irrigated wheat farming conditions may be that the plant can make a better use of nitrogen in the soil to form a high-protein grains.

In this study, the irrigation treatments did not affect the wet gluten content values significantly, but there were significant differences among the varieties/lines. While Sagittario had the highest wet gluten content, the lowest value was observed in Zdeb102. Ozturk and Aydin (2004) observed that there was a clear relationship between wet gluten content and protein content in the absence of drought. In this study, in all varieties/lines, it was clearly seen that wet gluten content and protein content were related to each other. Mut et al. (2017) determined that wet gluten contents ranged from 23.9% to 28.0% in Yozgat conditions. Evlice et al. (2016) found the wet gluten contents of wheat plants to be between 14.8% and 47.5%. The results obtained in this study, thus, broadly overlap with the results of other studies.

SSI values can change stressed and unstressed yield conditions for each variety/line. An SSI value smaller than 1 indicates drought tolerance, and an SSI value >1 indicates sensitivity to drought (Singh et al., 2015). The finding that the Sagittario variety and Zdeb101 line had values close to and >1 suggested that they were sensitive to drought. Aslani and Mehrvar (2012) found SSI values between 0.89 and 1.13 for wheat varieties under the conditions of Iran.

## 5 | CONCLUSION

In this study, ET values decreased from the S100 treatment to the S0 treatment, while WUE, IWUE, and Ky values showed different trends in both years. Although there was no significant difference in yield values among the varieties, the highest yield was found in the S100 treatment. While there were no significant differences among the genotypes in terms of yield in severe drought conditions and in complete irrigation conditions, the yield values were higher in complete irrigation conditions, albeit insignificantly. As yield results are not considered sufficient in the determination of the drought-tolerant of genotypes, SSI values were calculated. This way, it was understood that the most drought-tolerant line was Zdeb102 (0.50), and the most drought-tolerant variety was Ceyhan 99 (0.54). Therefore, it is recommended that these genotypes be grown in in Mediterranean and semi-arid climatic conditions worldwide. The fact that the highest protein content (11.38%) and wet gluten content (22.24%) values were found in Sagittario supported this result. The highest yield was obtained in the treatment without drought conditions, but it was concluded that severe drought conditions were more economical when water and irrigation costs were taken into account.

## AUTHOR CONTRIBUTIONS

**Mualla Keten Gokkuş:** Conceptualization; data curation; investigation; methodology; visualization; formal analysis; writing – original draft; writing – review and editing. **Ziya Dumlupinar:** Writing – review and editing; writing – original draft; project administration; data curation; supervision. **Hasan Degirmenci:** Data curation; supervision; writing – original draft; writing – review and editing.

## ACKNOWLEDGEMENTS

This study was supported by Kahramanmaras Sutcu Imam University Scientific Research Projects Unit in the scope of the project numbered 2018/5-13 M.

## CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflict of interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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**How to cite this article:** Gokkuş, M. K., Dumlupinar, Z., & Degirmenci, H. (2024). Drought resistance, quality characteristics and water-yield relationships of some wheat (*Triticum aestivum* L.) lines and varieties. *Journal of Agronomy and Crop Science*, *210*, e12678. https://doi.org/10.1111/jac.12678