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THE EFFECT OF DIFFERENT IRRIGATION LEVELS ON THE YIELD AND SOME QUALITY TRAITS OF MAIZE CULTIVARS

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Abstract: This study was conducted in 2023 under the conditions of Eskisehir to determine the effects of different irrigation levels on the yield and quality traits of maize cultivars. Three maize cultivars (P0937, P0900, DKC5812) were subjected to five different irrigation levels (171, 342, 513, 684, and 855 mm). The experiment was designed as a split-plot arrangement with maize varieties as the main plots and irrigation levels as the subplots, replicated three times. According to the results obtained from the experiment, statistically significant differences were found among the cultivars in terms of plant height, first ear height, ear length, thousand-kernel weight, test weight, protein content, and starch content. Additionally, statistically significant differences were observed among the irrigation levels in terms of plant height, first ear height, ear length, ear diameter, thousand-kernel weight, test weight, fat content, protein content, and starch content. Concerning irrigation levels, plant height ranged from 206.0 cm (171 mm) to 282.3 cm (855 mm), first ear height ranged from 97.4 (171 mm) to 128.3 cm (513 mm), ear diameter ranged from 44.8 (171 mm) to 50.6 mm (855 mm), grain yield ranged from 800.7 (171 mm) to 1606.0 kg da^{-1} (855 mm), thousand-kernel weight varied from 232.2 (171 mm) to 316.3 g (855 mm), test weight ranged from 76.0 (171 mm) to 78.3 kg (684 mm), ash content varied between 1.30 (855 mm) and 1.35% (171 and 342 mm), fat content ranged from 3.54 (855 mm) to 3.80% (171 mm), protein content varied from 8.03 (855 mm) to 9.72% (171 mm), and starch content ranged from 73.42 (171 mm) to 74.61% (855 mm). Increasing irrigation levels generally had positive effects on yield components such as plant growth, ear development, and kernel yield. However, negative effects of irrigation were also observed in quality components such as protein and fat content. This highlights the necessity of considering not only yield improvement but also product quality when determining irrigation strategies. Therefore, when formulating irrigation strategies, a balance between yield and quality must be achieved, and the water response of each maize cultivar should be considered.

Keywords: Corn, Grain, Yield, Quality, Irrigation, Variety

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1. Introduction

Maize (*Zea mays* L.) is an important crop used for food, animal feed, and as a raw material in various industrial sectors. It is the leading cereal crop worldwide in terms of both total and per-unit-area yield. With a cultivation area of 205.8 million hectares, maize ranks second globally in terms of area planted, yet it holds first place in production volume with 1.2 billion tons (FAO, 2022). In Türkiye, maize ranks third among cereals after wheat and barley in terms of cultivated area. It is utilized in a wide range of applications, including food, feed, industrial products, and bioenergy production. Additionally, it plays a significant role in decorative uses, paper manufacturing, matting, nut and fat industries, sweetener production, and bioenergy generation (Ozturk et al., 2019).

To achieve high grain yields in maize, proper management of irrigation, fertilization, pest and disease control, and harvesting is crucial. While potential yield is determined by the genetic makeup of the cultivar, actual yield is shaped by the interaction of agronomic practices and environmental conditions (Fischer et al., 2014). The effects of irrigation and water stress during different developmental stages on maize growth and grain yield have been extensively evaluated in various studies (Cakır, 2004). Short-term water deficits during the vegetative stages can lead to reductions of 28–32% in final biomass. However, water shortages during critical growth stages such as tasseling and grain filling may result in yield losses of up to 40% (NeSmith and Ritchie, 1992; Cakır, 2004). Water availability, whether through irrigation or rainfall, significantly affects maize yield and profitability.

Irrigation is one of the most effective methods for increasing crop yields and improving quality in agricultural production. In water-sensitive crops such as maize, determining optimal irrigation strategies not only boosts yield but also enhances quality parameters. However, both insufficient and excessive irrigation can adversely affect plant performance, resulting in losses in yield and quality. Therefore, considering the scarcity and cost of water resources, it is essential to use water efficiently (Fereres and Soriano, 2007). In situations where water resources are limited, applying deficit irrigation strategies instead of fully meeting crop water requirements during the growing season can help save water without significantly compromising yield. Although a slight reduction in yield per unit area may occur under such conditions, it becomes possible to irrigate larger areas with the available water, leading to an overall increase in total production.

Alongside other agronomic practices, achieving high yield and quality in maize production requires the efficient implementation of irrigation, including the use of drip irrigation systems and accurate scheduling of irrigation timing and amounts. Farmers generally base their irrigation practices on phenological observations rather than technical criteria, which often leads to over-irrigation due to the absence of water requirement-based management (Ucan, 2000). Uncontrolled irrigation practices may cause soil salinization and result in portions of land becoming unproductive each year due to excessive water use. Therefore, efficient use of soil and water resources and the evaluation of irrigation system performance are of great importance (Cakmak, 2002).

This study was conducted to determine the effects of different irrigation levels on the yield and quality characteristics of maize cultivars under the ecological conditions of Eskisehir.

2. Materials and Methods

This research was conducted in 2023 in the Alpu district of Eskişehir. In the study, hybrid maize cultivars P0937 (FAO 550) and P0900 (FAO 550) from the PIONEER company, and DKC5812 (FAO 550) from the DEKALB company were used. The experiment was established in a split-plot design with three replications. Cultivars were assigned to the main plots and irrigation levels to the sub-plots. Plots, each 6 meters in length, were sown with six rows at 70 × 16 cm inter-row and intra-row spacing. In the experiment, irrigation was applied ten times at 7-day intervals with five different irrigation durations: I6 – 6 hours (171 mm), I12 – 12 hours (342 mm), I18 – 18 hours (513 mm), I24 – 24 hours (684 mm), and I30 – 30 hours (855 mm). At sowing, 25 kg da^{-1} of di-ammonium phosphate (DAP) was applied as base fertilizer. For top-dressing, a total of 30 kg da^{-1} of urea fertilizer was divided into three parts: the first application was made at the 4–6 leaf stage, the second at the 8–10 leaf stage, and the final one at the beginning of flowering. After sowing, emergence irrigation was applied to all plots using a sprinkler irrigation method. Following plant emergence and the first hoeing, a drip irrigation system was installed, and irrigation was carried out every 7 days according to the treatments. Weed control was conducted through pre-emergence herbicide application and hoeing. During harvest, to eliminate border effects, the first rows and 50 cm sections from the beginning and end of the plots were excluded. Harvest was done manually, and the ears were shelled.

Measurements in the study were made on 15 randomly selected plants and ears from each plot. Grain yield, measurement, and analyses were performed based on a grain moisture content of 12%. Subsequently, physical and chemical analyses were conducted. Seeds were ground using a grinder with a 0.5 mm sieve and stored at +4 °C until analysis. In the study, 11 different traits were determined: plant height, first ear height, ear length, ear diameter, grain yield, thousand-kernel weight, hectoliter weight, ash content, fat content, protein content, and starch content. Morphological characteristics were evaluated according to the technical guidelines for maize value determination trials (Anonymous, 2018). Among the chemical properties, ash content was determined by AACC 08-01.01, hectoliter weight by AACC 55-10.01, protein content by AACC 46-11.02, starch content by AACC 76-13.01, and fat content by AOAC 920.39 (AOAC, 2012; AACC, 2020).

The obtained data were analyzed using the MSTAT-C statistical package program based on the split-plot experimental design, and the differences between the means were determined by Duncan's multiple comparison test.

2.1. Climatic and Soil Characteristics of the Experimental Site

During the maize growing season in Alpu district, where the study was conducted, the total precipitation, average temperature, and relative humidity were measured as 323.7 mm, 6.8 ºC, and 66.1%, respectively (Table 1).

Table 1. Climatic data of the experimental site for the year 2023

Months	Rainfall (mm)	Temperature (^{0}C)	Relative humidity (%)
March	90.2	7.1	78.3
April	58.8	10.1	71.1
May	68.1	14.4	74.5
June	77.2	19.3	69.8
July	21.1	22.6	57.0
August	0.0	25.2	53.4
September	8.3	19.3	58.9
Total	323.7	-	-
Average	-	16.8	66.1

According to the soil analysis results of the experimental field, the texture ratio of the soil is 86.9%, indicating that the soil is classified as "clayey." The lime ($CaCO_3$) content is 7.5%, which places it at a moderate lime level. The total salt concentration is measured at 0.0061 mS/cm, indicating no salinity issue in the soil. The soil pH value is 7.93, showing a slightly alkaline reaction. The phosphorus (P) content is very low at 1.71 ppm. The potassium (K) content is 266.4 ppm, which is considered adequate. The organic matter content is 1.87%, indicating a low level of organic matter in the soil.

3. Results

In this study, conducted in the 2023 growing season under Eskisehir conditions, the effects of different irrigation levels on the yield and quality of certain maize varieties were determined. The data for the examined traits are presented in Tables 2 and 3. According to the results obtained from the experiment, significant statistical differences were found between the varieties for plant height, first ear height, ear length, thousand kernel weight, hectoliter weight, protein content, and starch content. Moreover, significant statistical differences were observed between the irrigation levels for plant height, first ear height, ear length, ear diameter, thousand kernel weight, hectoliter weight, fat content, protein content, and starch content. Additionally, the interaction between cultivar and irrigation level (C×I) had a statistically significant effect on plant height, first ear height, ear length, thousand kernel weight, ash content, fat content, protein content, and starch content (Tables 2 and 3).

Table 2. Mean values and statistical significance groups of the examined traits for cultivars and irrigation levels

	PH	FEH	EL	ED	GY	TKW	HW	AC	FC	PC	SC
Cultivar (C)	*	**	**	ns	ns	**	*	ns	ns	**	**
DKC5812	268.1a	127.1A	17.7B	48.4	1285.0	290.6A	76.5B	1.36	3.70	9.21A	72.73B
P0937	263.0b	118.1B	19.1A	48.4	1277.5	279.9B	76.9B	1.32	3.67	8.69B	74.38A
P0900	262.3b	117.2B	18.9A	47.3	1272.4	266.5C	78.2A	1.31	3.73	8.60B	74.54A
Irrigation (I)	**	**	**	**	**	**	**	ns	*	**	**
I_6	206.0C	97.4B	16.9E	44.8B	800.7D	232.2C	76.0B	1.35	3.80A	9.72A	73.42C
I_{12}	272.3B	125.3B	17.6D	45.6B	977.4C	242.0C	76.6AB	1.35	3.67AB	9.39B	73.57C
I_{18}	281.0A	126.1B	18.4C	49.7A	1464.5B	299.8B	78.1A	1.31	3.75AB	8.30D	73.70C
I_{24}	280.7A	126.8B	19.0B	49.6A	1542.9AB	304.9AB	78.3A	1.33	3.70AB	8.70C	74.11B
I_{30}	282.3A	128.3A	20.9A	50.6A	1606.0A	316.3A	77.1AB	1.30	3.54B	8.03D	74.61A

*: significant at the P<0.05 probability level, **: significant at the P<0.01 probability level, ns: non-significant, PH= plant height (cm), FEH= first ear height (cm), EL= ear length (cm), ED= ear diameter (mm), GY= grain yield (kg da^{-1}), TKW= thousand-kernel weight (g), HW= hectoliter weight (kg), AC= ash content (%), FC= fat content (%), PC= protein content (%), SC= starch content (%).

Table 3. Mean values and significance groups of the examined traits for the cultivar × irrigation level interactions

Cultivar	Irrigation	PH	FEH	EL	ED	GY	TKW	HW	AC	FC	PC	SC
		**	**	**	ns	**	**	ns	**	*	**	**
DKC5812	I_6	218.3d	111.7e	15.6j	45.0cd	885.7de	260.2de	75.9	1.37ab	3.94a	10.06a	71.72c
	I_{12}	272.7bc	128.7a-d	16.4ij	46.1cd	1001.7cd	263.2d	76.3	1.43a	3.65ab	10.12a	71.91c
	I_{18}	282.7a	130.0abc	18.4efg	49.5ab	1423.2b	307.5abc	77.4	1.34ab	3.77ab	8.63c-g	72.03c
	I_{24}	284.0a	130.7ab	18.1fg	50.7a	1566.0ab	307.1abc	77.5	1.33ab	3.90a	9.10cde	73.24b
	I_{30}	283.0a	134.7a	19.8bc	50.8a	1548.5ab	315.4ab	75.7	1.32ab	3.28b	8.14fgh	74.76a
P0937	I_6	203.7e	92.3f	18.2efg	45.7cd	819.0ef	218.2f	75.0	1.33ab	3.73ab	9.29bc	74.01ab
	I_{12}	271.7c	125.2bcd	17.7gh	45.7cd	868.0def	230.3f	75.2	1.32ab	3.66ab	9.26bcd	74.25a
	I_{18}	279.0abc	126.3bcd	19.2c-f	49.9ab	1484.4b	307.6abc	78.4	1.35ab	3.76ab	8.39fgh	74.54a
	I_{24}	279.0abc	123.7cd	19.3cde	50.4ab	1510.4b	314.3ab	78.8	1.36ab	3.66ab	8.60d-g	74.54a
	I_{30}	281.7ab	123.0d	20.9ab	50.5a	1706.1a	329.3a	77.4	1.20b	3.58ab	7.89h	74.55a
P0900	I_6	196.0e	88.3f	16.9hi	43.9d	697.5f	218.2f	77.2	1.34ab	3.90a	9.81ab	74.53a
	I_{12}	272.7bc	122.3d	18.6d-g	45.1cd	1062.7c	232.5ef	78.5	1.29ab	3.72ab	8.79c-f	74.54a
	I_{18}	281.3abc	122.0d	17.7gh	49.6ab	1486.0b	284.2cd	78.6	1.25b	3.74ab	7.87h	74.54a
	I_{24}	279.0abc	126.0bcd	19.7cd	47.6bc	1552.3ab	293.2bc	78.8	1.31ab	3.53ab	8.47e-h	74.53a
	I_{30}	282.3ab	127.3bcd	21.9a	50.4ab	1563.3ab	304.3abc	78.2	1.36ab	3.78ab	8.07gh	74.53a

*: significant at the P<0.05 probability level, **: significant at the P<0.01 probability level, ns: non-significant, PH= plant height (cm), FEH= first ear height (cm), EL= ear length (cm), ED= ear diameter (mm), GY= grain yield (kg da^{-1}), TKW= thousand-kernel weight (g), HW= hectoliter weight (kg), AC= ash content (%), FC= fat content (%), PC= protein content (%), SC= starch content (%).

3.1. Plant Height (cm)

The average plant height for the varieties was measured as 262.3 cm for P0900, 263.0 cm for P0937, and 268.1 cm for DKC5812. The highest plant height was observed at the S30 irrigation level (282.3 cm), while the lowest was observed at the S6 irrigation level (206.0 cm) (Table 2). According to the C×I interaction, the lowest plant height (196.0 cm) was observed in the P0900 cultivar with the S6 application, while the highest plant height (284.0 cm) was observed in the DKC5812 cultivar with the S24 application (Table 3). Plant height in maize is an important morphological characteristic that directly affects agricultural performance, such as yield, photosynthesis capacity, resistance to lodging, and ease of harvest. According to Vartanlı and Emeklier (2007), plant height is influenced by both genetic and environmental factors, ranging between 196.0 cm and 284.0 cm. In our study, statistical differences were found between the varieties (Table 2). In a study conducted under the ecological conditions of Konya, where the yield potential of 14 hybrid maize varieties was measured, the plant height ranged from 162.1 cm to 214.9 cm (Ayrancı and Sade, 2004). In our study, it was determined that as the irrigation water increased, plant height also increased (Table 2). In a study by Kuscu (2010) examining the effects of different irrigation levels on maize plant height, it was observed that the highest plant heights were obtained with full irrigation, and plant height decreased as the irrigation amount was reduced. Yang et al. (2024) found that the highest plant height was achieved at the full irrigation level in their study examining the effects of different irrigation and nitrogen applications on maize.

3.2. First Ear Height (cm)

The average first ear height for the varieties was measured as 117.2 cm for P0900, 118.1 cm for P0937, and 268.1 cm for DKC5812. The highest first ear height was observed at the S30 irrigation level (126.1 cm), while the lowest was observed at the S6 irrigation level (97.4 cm) (Table 2). According to the C×I interaction, the lowest first ear height (88.3 cm) was observed in the P0900 cultivar with the S6 irrigation application, while the highest first ear height (134.7 cm) was observed in the DKC5812 cultivar with the S24 application (Table 3). First ear height is one of the factors that determine yield and quality in maize. It plays a critical role in the development of the maize plant and is strongly related to yield. First ear height is influenced by the plant's genetic characteristics, climate conditions, as well as agricultural practices such as irrigation regimes and fertilization (Han et al., 2016). The height of the first ear is an important breeding criterion for harvest suitability and resistance to lodging. If the first ear is positioned higher, it allows the plants to utilize nutrients more efficiently, while a lower first ear height can result in yield loss (Song et al., 2019). In particular, the relationship between ear height and the plant's consumption of water and nutrients indicates that irrigation and fertilization practices should be applied in the most optimal manner. Yang et al. (2024) reported that as irrigation level increases, first ear height also increases (120-150 cm under full irrigation), whereas at lower irrigation levels, ears develop at lower positions (restricted irrigation 90-120 cm).

3.3. Ear Length (cm)

The average ear length of the varieties was measured as 17.7 cm for DKC5812, 18.9 cm for P0900, and 19.1 cm for P0937. The highest average ear length was recorded at the S30 irrigation level (20.9 cm), while the lowest was observed at the S6 irrigation level (16.9 cm) (Table 2). According to the cultivar × irrigation level interaction, the smallest ear length (15.6 cm) was found in the DKC5812 cultivar under the S6 irrigation treatment, while the largest ear length (21.9 cm) was recorded in the P0900 cultivar under the S30 irrigation treatment (Table 3). Ear length is an important morphological characteristic that directly affects the total yield of maize. The size of the ear varies depending on the plant's photosynthetic capacity, agricultural practices, climatic factors, and genetic traits (Marković et al., 2017). Ear length is considered an indicator of maize's yield potential, and larger ears typically contain more kernels, thereby increasing yield. In our study, it was observed that as the irrigation duration increased, ear length also increased (Table 2). Karasu et al. (2015) reported that increasing irrigation amounts resulted in larger ear lengths.

3.4. Ear Diameter (mm)

The average ear diameter of the varieties was measured as 47.3 mm for P0900, 48.42 mm for DKC5812, and 48.47 mm for P0937. The ear diameter varied between 44.8 mm (S6) and 50.6 mm (S30) according to the irrigation levels. In maize, ear diameter is an important characteristic in terms of yield and quality. This trait is influenced by factors such as the plant's genetic makeup, environmental conditions, and agricultural practices. Ear diameter is generally directly related to the total grain yield of maize. Arıoglu and Erekul (2022) reported that restricted irrigation practices narrowed ear diameter, leading to significant yield losses, and emphasized that ear diameter, a critical trait for yield, is sensitive to agricultural practices like water management. In our study, the applications with lower water amounts resulted in smaller ear diameters (Table 2). Karasahin and Sade (2011) also reported that different irrigation methods affected ear diameter.

3.5. Grain Yield (kg da^{-1})

The average grain yield of the varieties was determined as 1272.4 kg da^{-1} for P0900, 1277.5 kg da^{-1} for P0937, and 1285.0 kg da^{-1} for DKC5812. The highest grain yield was recorded at the S30 irrigation level (1606.0 kg da^{-1}), while the lowest was observed at the S6 irrigation level (800.7 kg da^{-1}) (Table 2). According to the cultivar × irrigation level interaction, the lowest grain yield (697.5 kg da^{-1}) was obtained in the P0900 cultivar under the S6 irrigation treatment, while the highest yield (1706.1 kg da^{-1}) was recorded in the P0937 cultivar under the S30 irrigation treatment (Table 3). Grain yield is determined by the interaction of various factors such as genetic traits, environmental conditions, and agricultural techniques. In particular, cultural practices such as irrigation, fertilization, planting density, and soil cultivation are critical factors that directly affect maize grain yield (Wanjura et al., 2003). In our study, the highest grain yield was achieved with a 30-hour water application (Table 2). Pinnamaneni et al. (2023) reported that full irrigation conditions increased yield by 15.3% compared to non-irrigated conditions. Ashine et al. (2024) found that as the irrigation level increased, the yield also increased in their study on maize. Previous studies have shown that irrigation practices have significant effects on maize grain yield, with yields ranging between 6.5 and 12.8 t ha^{-1} (Demir et al., 2021; Pinnamaneni et al., 2023; Simić et al., 2023; Ashine et al., 2024).

3.6. Thousand-Kernel Weight (g)

The average thousand-kernel weight was measured as 266.5 g for P0900, 279.95 g for P0937, and 290.6 g for DKC5812. The highest thousand-kernel weight (316.3 g) was obtained with the S30 treatment, and both the S30 and S24 irrigation treatments were grouped in the same statistical category for grain yield (Table 2). The lowest thousand-kernel weight was recorded at the S6 (232.2 g) and S12 (242.0 g) irrigation levels. According to the cultivar × irrigation level interaction, the lowest thousand-kernel weight (218.2 g) was observed in the P0900 and P0937 varieties under the S6 irrigation treatment, while the highest weight (329.3 g) was recorded in the P0937 cultivar under the S30 irrigation treatment (Table 3). Wang et al. (2017) reported that thousand-kernel weight, ear number, and kernel number per ear are important factors determining maize grain yield. Thousand-kernel weight is a trait that reflects the genetic potential of the maize plant and the effects of environmental conditions on plant development. This trait plays a critical role in understanding the effects of irrigation, fertilization, and climatic conditions on kernel development. Thousand-kernel weight has been shown to depend on genotype, environmental factors, and agricultural practices such as planting time and irrigation (Idikut et al., 2020). Previous studies have indicated that irrigation practices increase thousand-kernel weight and subsequently enhance yield in maize (Demir et al., 2021; Gonulal et al., 2021; Ashine et al., 2024).

3.7. Hectoliter Weight (kg)

The average hectoliter weight was measured as 76.5 kg for DKC5812, 76.9 kg for P0937, and 78.2 kg for P0900. The highest hectoliter weight (78.3 kg) was recorded at the S24 irrigation level, while the lowest hectoliter weight (76.04 kg) was observed at the S6 irrigation level (Table 2). Hectoliter weight, one of the quality parameters of cereals such as maize, is of great importance, especially for the food industry, animal feed industry, and biotechnological applications. Hectoliter weight is a key factor affecting the density, kernel quality, processability, transportability, and storability of maize. This trait, directly related to the kernel size and shape, indicates larger and more robust kernels when higher. Hectoliter weight is a factor that enhances the durability and ease of transport of maize. Gonulal et al. (2021) reported that the lowest hectoliter weight was obtained with the least irrigation treatment. In our study, it was observed that as the irrigation level decreased, hectoliter weight also decreased. Additionally, it was determined that hectoliter weight varied across the different varieties (Table 2).

3.8. Ash Content (%)

Although no statistically significant differences were found between varieties and irrigation levels in terms of ash content, the ash content ranged from 1.31% to 1.36% among the varieties, and from 1.31% to 1.35% among the irrigation treatments (Table 2). According to the cultivar × irrigation level interaction, the lowest ash content (1.20%) was found in the P0937 cultivar under the S30 irrigation treatment, while the highest ash content (1.43%) was recorded in the DKC5812 cultivar under the S24 irrigation treatment (Table 3). The ash content of maize is influenced by factors such as cultivation conditions, soil properties, and applied fertilization strategies. Additionally, ash content is an important indicator in quality control during maize processing and is especially used in evaluating product purity and mineral content in the animal feed and food industries. It is reported that the ash content of maize generally ranges from 1.0% to 1.16%, and this value can vary depending on the soil and environmental conditions where the maize is grown (Ali et al., 2010). Irrigation can directly affect the plant’s water and nutrient uptake, influencing mineral accumulation and, therefore, ash content. Water restriction may limit the plant's mineral uptake, reducing ash content. Kale et al. (2018) reported that ash content increased with higher irrigation levels in maize.

3.9. Fat Content (%)

The average fat content was measured as 3.67% for P0937, 3.70% for DKC5812, and 3.73% for P0900. According to the irrigation treatments, fat content ranged from 3.54% (S30) to 3.80% (S6). All irrigation levels, except for S30, were grouped in the same statistical category regarding this trait (Table 2). According to the cultivar × irrigation level interaction, the lowest fat content (3.28%) was found in the DKC5812 cultivar under the S30 irrigation treatment, while the highest fat content (3.94%) was recorded in the DKC5812 cultivar under the S6 irrigation treatment. In terms of fat content, all varieties, except for DKC5812 under the S30 treatment, were statistically in the same group (Table 3). It is known that maize has a relatively high fat content among cereals, second only to oats. Ullah et al. (2010) reported that the fat content in maize varies widely, ranging from 3.21% to 7.71%. The fat content in maize can vary due to several factors, including genotype (Cetin and Soylu, 2021), environmental conditions (Mut et al., 2022), and agricultural practices (Dag et al., 2024). Adequate irrigation can enhance the plant’s ability to absorb nutrients more efficiently, which is thought to increase fat content. However, water stress may inhibit fat synthesis and reduce fat content. Arıoglu and Erekul (2022) reported that irrigation practices have significant effects on fat content. In our study, it was determined that as the irrigation level decreased, fat content increased (Table 2). Ulus and Koca (2023) reported that fat content in maize ranged from 2.82% to 3.59%.

3.10. Protein Content (%)

The average protein content was determined to be 8.6% for P0900, 8.69% for P0937, and 9.21% for DKC5812. The highest protein content (9.72%) was found at the S6 irrigation level, while the lowest (8.03%) was observed at the S30 irrigation level (Table 2). According to the cultivar × irrigation level interaction, the lowest protein content (7.89%) was found in the P0937 cultivar under the S30 irrigation treatment, while the highest (10.12%) was found in the DKC5812 cultivar under the S12 irrigation treatment (Table 3). Protein content is an important quality trait in maize. In a study by Mut et al. (2022), it was reported that the protein content in maize is influenced by both genetic and environmental factors. Arıoglu and Erekul (2022) found that irrigation treatments have significant effects on protein content, with protein levels being higher under limited irrigation compared to full irrigation. On the other hand, Kresović et al. (2018) reported that increased irrigation levels reduced the protein content in maize kernels.

3.11. Starch Content (%)

The average starch content was determined to be 72.73% for DKC5812, 74.38% for P0937, and 74.54% for P0900. The highest starch content (74.61%) was found at the S30 irrigation level, while the lowest (73.42%) was observed at the S6 irrigation level (Table 2). According to the cultivar × irrigation level interaction, the lowest starch content (71.72%) was found in the DKC5812 cultivar under the S6 irrigation treatment, while the highest (74.76%) was found in the DKC5812 cultivar under the S30 irrigation treatment (Table 3). Starch, a primary digestible carbohydrate in plants, is an important energy source in human and animal nutrition. Beckles and Thitisaksakul (2014) reported that factors such as cultivar, rainfall, temperature, soil type, and growth conditions may have a greater effect on starch content in grains than genetic factors. Arıoglu and Erekul (2022) found that starch content in maize under 100% irrigation was higher compared to 60% irrigation. Kaplan et al. (2019) reported that as the amount of water applied increased, the starch content in maize kernels also increased. In our study, it was observed that as the irrigation time increased, the starch content in the kernels also increased (Table 2).

4. Conclusion

This study was conducted in the 2023 growing season under the conditions of Eskisehir to determine the effects of different water levels on the agricultural traits and quality parameters of various maize cultivars. The findings revealed that the applied irrigation levels had significant effects on all examined traits, except for ash content. Increasing irrigation levels generally had positive effects on yield components such as plant growth, ear development, and kernel yield. However, negative effects of irrigation were also observed in quality components such as protein and fat content. This highlights the necessity of considering not only yield improvement but also product quality when determining irrigation strategies. Therefore, when formulating irrigation strategies, a balance between yield and quality must be achieved, and the water response of each maize cultivar should be taken into account. Since different maize varieties respond differently to irrigation, it is recommended to develop irrigation management strategies tailored to each cultivar. Such studies will serve as an important guide to enhance the effectiveness of irrigation management in maize farming and contribute to sustainable agricultural practices.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	Z.M	N.D.	O.D.E.K.
C	40	60	
D	50	50	
S	100		
DCP		60	30
DAI	60	20	20
L	20	80	
W	30	40	30
CR	40	20	40
SR	30	40	30
PM	40	60	
FA	40	60	

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Since no studies involving humans or animals were conducted, ethical committee approval was not required for this study.

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