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Different irrigation and fertilization levels on the yield and quality of dent corn

Diferentes níveis de irrigação e fertilização no rendimento e qualidade do milho dentado

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ABSTRACT

Dent Corn (Zea mays indentata indentata), one of the most important plants produced for industrial purposes in many regions of Türkiye. The aim of this study was to determine the interactions of two important factors affecting the yield of dent corn. The study was conducted at the Bursa Uludağ University Yenişehir Ibrahim Orhan Vocational School Agricultural Research Field in 2019-2020. The altitude of the study area was 240 m. Measurements of the physical and quality properties of dent corn were carried out in the laboratories of Bursa Uludağ University. In the research, four different irrigation topics and three different fertigation topics were selected. Drip irrigation method was preferred in order to apply water amounts at different irrigation and fertigation levels. In our study, the highest and lowest irrigation water amounts in both trial years were found to be 780-195 mm and 800-200 mm, respectively, while the highest and lowest actual evapotranspiration (ETa) values were calculated as 830-290 mm and 855-432 mm, respectively. The maximum and minimum yield values of the study years were calculated as 14.6-15.2 t ha^{-1} and 4.0-5.1 t ha^{-1}, respectively, from $I_{100}F_{100}$ and $I_{25}F_{50}$ treatments. However, when the reductions in yield and quality losses are evaluated together, despite the reductions in irrigation water and fertigation levels, I_{75} and F_{75} treatments can be recommended.

Index terms: *Zea mays indentata indentata*; ky factor; physical properties.

RESUMO

O milho dentado (*Zea mays indentata indentata*) é uma das plantas mais importantes produzidas para fins industriais em muitas regiões da Turquia. O objetivo deste estudo foi determinar as interações de dois fatores importantes que afetam o rendimento do milho dentado. O estudo foi conduzido no Campo de Pesquisa Agrícola da Escola Profissional Yenişehir Ibrahim Orhan da Universidade Bursa Uludağ em 2019-2020. A altitude da área de estudo foi de 240 m. As medições das propriedades físicas e de qualidade do milho dentado foram realizadas nos laboratórios da Universidade Bursa Uludağ. Na pesquisa, foram selecionados quatro tópicos diferentes de irrigação e três tópicos diferentes de fertirrigação. O método de irrigação por gotejamento foi o preferido para aplicar quantidades de água em diferentes níveis de irrigação e fertirrigação. Em nosso estudo, as quantidades de água de irrigação mais altas e mais baixas em ambos os anos de teste foram 780-195 mm e 800-200 mm, respectivamente, enquanto os valores mais altos e mais baixos de evapotranspiração real (ETa) foram calculados como 830-290 mm e 855-432 mm, respectivamente. Os valores de produtividade máxima e mínima dos anos de estudo foram calculados como 14,6-15,2 t ha^{-1} e 4,0-5,1 t ha^{-1}, respectivamente, dos tratamentos I100F100 e I25F50. No entanto, quando as reduções de produtividade e perdas de qualidade são avaliadas em conjunto, apesar das reduções nos níveis de água de irrigação e fertirrigação, os tratamentos I75 e F75 podem ser recomendados.

Termos para indexação: *Zea mays indentata indentata*; fator ky; propriedades físicas.

INTRODUCTION

Corn is an important source of industrial raw materials and food products and is, therefore, produced in significant amounts worldwide as well as in Turkey. Maize is a cereal crop grown in hot-climate regions and accounts for the third-largest cultivation area in Turkey after wheat and barley. Corn agriculture is prevalent in nearly 60 provinces across the Black Sea, Mediterranean, Aegean, Marmara, and Southeastern Anatolia regions. Corn production has increased considerably in recent years, particularly in the GAP project regions of South-East Anatolia. This increased corn production in Turkey is attributable to the increase in irrigation opportunities, use of hybrid seeds, selection of the seeds suitable for the regions, increased demand

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for corn in the feed industry, and an increase in the production of secondary products (United States Department of Agriculture - USDA, 2016; Bayramoğlu; Bozdemir, 2018; TMMOB, 2020).

According to the International Grain Council (IGC), 1.146 billion tons of corn was produced worldwide during the 2020–2021 period, while the consumption amount of corn was 1.169 billion tons during this period (Food and Agriculture Organization of the United Nations - FAOSTAT, 2020). The largest corn producer in the world is the USA, which produces 392.450.840 tons of corn every year, followed by the People's Republic of China, which produces 257.343.659 tons of corn, and Brazil, which produces 82.228.298 tons of corn per year. Turkey produces 5.700.000 tons of corn each year, thereby ranking 23rd among the nations worldwide (FAOSTAT, 2019). The qualification rate for the same marketing years was 70%. In Turkey, 6.5 million tons of corn was produced on 6.4 million decare of land. Bursa province in the Marmara Region holds an important position in terms of corn production which stands at 119 thousand tons of corn (Turkish Statistical Institute - TUİK, 2023).

Climate, topography, water source diversity, irrigation management techniques, and cultural practices have been studied for their effects on the per-year yield of maize and its quality. Certain studies conducted on irrigation deficit and its effect on maize production in Turkey revealed that water deficit, particularly during the vegetative developmental periods of the crop, led to fewer instances of yield decrease compared to the other phenological developmental periods (Budaklı Çarpıcı et al., 2017; Gönülal; Soylu, 2020; Tüfekçi; Kuşcu, 2021). In the case of corn plants, it is particularly necessary to consider plant nutrition. The amount of fertilizer to be applied to the corn plant depends on the soil and climatic conditions, (Sakin; Azapoğlu, 2017) conducted a study in Tokat-Kazova conditions in Turkey and reported that nitrogen provides earliness, improves ear characteristics, and increases the quality and fresh ear and grain yield per decare. However, the effects of different doses of phosphorus on the yield and quality characteristics were revealed to be insignificant in the same study. In another study conducted under Kahramanmaraş conditions in Turkey, Idikut and Yıldız (2018) reported that different doses of phosphorus led to significantly different effects on the ear silk period, ear diameter, single ear weight, and thousand-grain weight of the corn plant. In a similar context, the present study aims to determine the effects of different levels of irrigation and fertigation on the yield and quality parameters of the maize plant.

MATERIAL AND METHODS

Research site, plant variety, irrigation and fertigation treatments, and mulching treatments

The present study was conducted at the Agricultural Research Area of the Yenişehir Ibrahim Orhan Vocational School, Bursa Uludağ University (40°15'09" N latitude, 29°38'43" E longitude) between the years 2019 and 2020. The climate of the Yenişehir region is hot and partly rainy in the summer season, while the winters are cold and rainy. The average temperatures during the two study years were 22.3 °C and 21.3 °C, respectively (Figures 1 and 2). The average precipitation during the plant growing season in the two study years was 50.5 mm and 40.9 mm, respectively. The average relative humidity in both the years and during the development period was 68.6% and 70.6% (Figure 3), respectively (Meteorological Report, 2021a). The lowest and the highest radiation values during the two years were 1474–335 W m^{-2} and 1599–139 W m^{-2} (Figure 4), respectively (Meteorological Report, 2021b). The climatic characteristics of the study region are presented in Table 1 and Table 2. In both study years, the soil was analyzed prior to planting the corn seeds. Accordingly, the pH value of the soil was determined to be 7.85 and 8.18 for the two years, respectively (Table 3). A chemical analysis of the irrigation water revealed that this water belonged to the C_2S_1 quality class (Table 4), which is characterized by low sodium risk and moderate electrical conductivity (EC). The cultivation of dent corn in the C_2S_1 irrigation water quality class is convenient (Okay; Yazgan, 2016). In addition, farm manure was applied at 2 tons da^{-1} as the base fertilizer prior to planting the corn seeds. Chlorpyrifos-ethyl was sprayed for the chemical control of the pests of corn.

Characteristics of the corn plant variety

The DKC 6630 dent corn variety reaches harvest maturity in 110–155 days after sowing. Although the root and stem structures of this variety are strong, it does not exhibit soil selectivity. On the other hand, this variety is highly tolerant to leaf and root diseases, lodging, and stress conditions. The hectoliter weight of this variety is 70–75 kg hL^{-1}, the number of rows on the ear is 16–20, and the number of grains in the row is 40–42. The first product from this variety is used as granules (Poler Team, 2021).

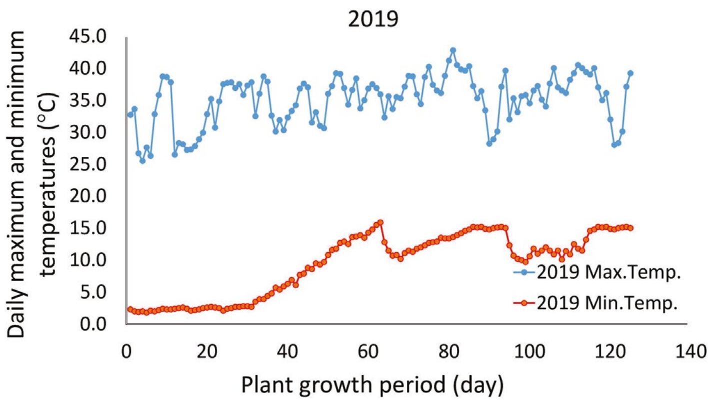

Figure 1: Maximum and minimum temperature values (°C) in 2019.

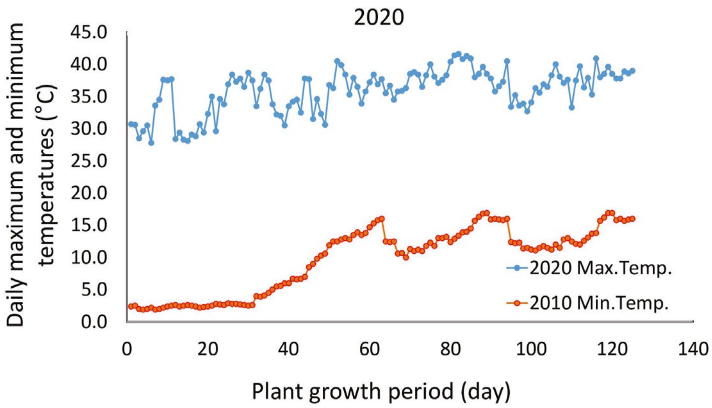

Figure 2: Maximum and minimum temperature values (°C) in 2019.

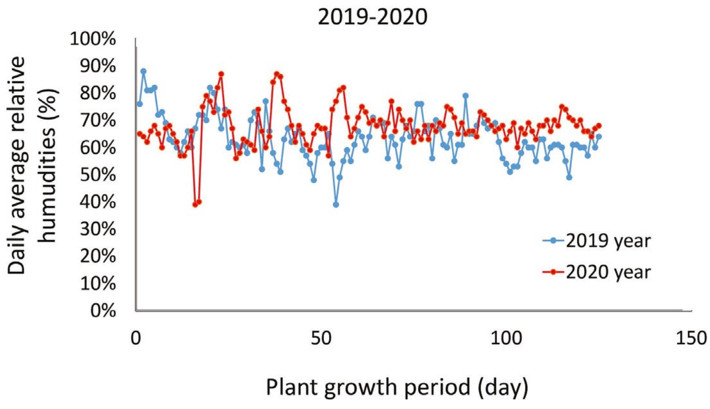

Figure 3: Daily average relative humudities (%) in 2019 and 2020.

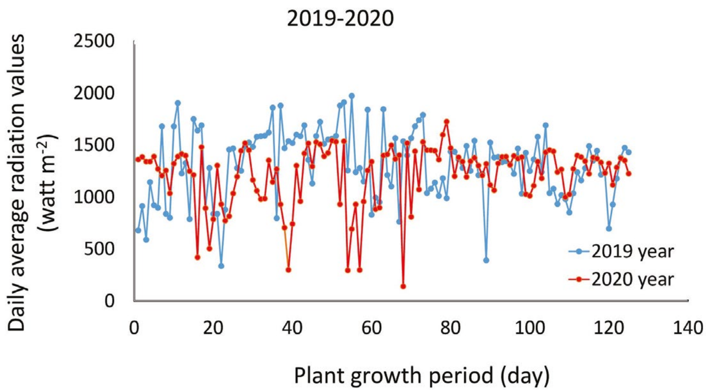

Figure 4: Daily average radiation values (watt m^{-2}) in 2019 and 2020.

Table 1: Climate characteristics of the study place in 2019.

Table 1. Ministry of Environment. Urbanization and Climate Change General Directorate of Meteorology													
2019													
Meteological elements	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Average local pressure	988.1	983	989.7	988.9	985	983.2	984.2	983.8	986.9	989.5	989.1	987.3	986.6
Average temperature	4.9	7.6	9.9	14.0	17.3	21.7	24.0	26.2	20.1	13.2	13.3	7.8	15.0
Average maximum temperature	23.6	25.6	22.1	26.5	31.5	37.4	36.6	36.0	34.5	24.1	26.3	26.8	29.3
Average highest temperature	9.1	12.4	14.5	19.5	26.1	28.3	31.5	34.6	28.1	18.4	21.7	12.4	21.4
Average minimum temperature	-15.3	-11.5	0.6	1.7	2.4	10.2	13.3	12.6	6.6	0.5	0.3	-5.3	1.3
Lowest temperature average	-5.9	-4.7	2.5	6.9	11.9	16.8	20.8	22.4	16.4	7.4	8	-0.9	8.5
Average relative humidity	79.6	77.9	74.8	72.1	65.1	70.0	65.6	59.5	67.5	79.0	69.2	78.5	71.6
Average total precipitation	75.4	101.4	149.2	109.4	100.4	78.0	23.2	0.2	39.6	302.6	12.2	89.2	1080.8
Number of rainy days	3	7	6	9	9	9	9	8	9	8	9	9	95.0
Average relative humidity	79.6	77.9	77.0	75.0	71.0	74.0	70.0	59.5	67.5	79.0	69.2	78.5	73.0
Number of days with snow	4	4											8.0
Number of foggy days	1	1	1				1		2	1	8	6	21.0
Average wind direction	S	S	WSW	N	N	WSW	NNW	WSW	W	N	S	S	W
Average wind speed ($m\ sn^{-1}$)	2.6	2.7	2.3	2.2	2.1	2.3	2.5	2.4	2.3	1.6	2.1	2.5	2.3
Fastest wind direction	W	WSW	S	W	W	SSW	WSW	WSW	W	N	N	W	W
Fastest blowing wind speed	22.1	19	18	14.9	25.7	15.9	15.4	14.9	25.2	15.9	25.7	20.5	19.4

Table 2: Climate characteristics of the study place in 2020.

Table 2. Ministry of Environment. Urbanization and Climate Change General Directorate of Meteorology													
2020													
Meteological elements	1	2	3	4	5	6	7	8	9	10	11	12	Annual
	990.1	991.0	987.4	988.1	985.9	984.9	983.8	985.1	987.9	990.6	991.6	990.0	988.0
Average local pressure	3.7	6.1	7.2	12.8	17.3	20.9	23.4	23.4	19.7	14.6	9.8	6.4	13.8
Average temperature	19.2	20.2	21.9	27.7	32.9	37.8	38.2	37.0	36.7	36.3	26.8	22.3	29.8
Average maximum temperature	9.2	12.3	15.7	20.1	25.2	28.5	31.1	31.6	28.4	22.8	17.6	11.8	21.2
Average highest temperature	-19.7	-10.3	0.7	1.8	2.4	10.4	13.4	13.3	6.8	4.9	0.9	-7.6	1.4
Average minimum temperature	0.0	1.2	2.1	4.4	10.1	13.8	15.5	15.1	12.1	8.1	3.9	2..4	7.4
Lowest temperature average	80.9	77.8	75.8	71.2	73.4	73.2	68.3	67.6	70.7	77.6	80.0	82.4	74.9
Average relative humidity	56.1	47.6	45.5	35.0	69.7	69.0	17.1	7.9	17.2	38.5	30.9	67.4	41.8
Average total precipitation	1	9	8	7	8	9	8	9	8	7	7	7	88.0
Number of rainy days	80.9	77.8	75.8	71.2	73.4	73.2	68.3	67.6	70.7	77.6	80.0	82.4	74.9
Average relative humidity	8.0	4.5											12.5
Number of days with snow	2.0	1.0	3.0				2.0		1.0	2.0	9.0	7.0	27.0
Number of foggy days	N	N	NNW	W	SSW	SSW	S	N	WSW	WSW	SSE	WSW	W
Average wind direction	2.7	2.6	2.5	2.6	2.3	2.5	2.5	2.8	2.4	1.7	2.0	2.6	2.4
Average wind speed	S	S	WNW	S	WNW	WSW	W	W	NNW	WSW	SSE	SSW	W
Fastest wind direction	24.7	24.2	20.6	19.0	17.5	24.2	27.8	17.5	17.0	23.1	25.7	25.2	27.8
Fastest blowing wind speed													

Table 3: Some specific properties of the experimental soil.

Soil depth (cm)	Soil type	Unit weight (g cm^{-3})	Field capacity (%)	Wilting point (%)	pH	Total salt (%)	CaCO3 (%)	Organik matter (%)
0-30	SL	1.32	29.43	21.46	7.88	0.037	16.2	2.86
30-60	SL	1.35	27.86	20.35	7.90	0.031	29.2	1.59
60-90	SL	1.55	32.84	23.68	7.86	0.032	30.8	1.28
90-120	SL	1.50	34.45	27.7	8.00	0.034	32.5	0.92

SL: Sandy loam.

Table 4: Specific properties of irrigation water.

Water source	EC_{25}x (10^6)	Na^+	K^+	Ca^{2+}	Mg^{2+}	pH	Class	SAR
		(me L^{-1})						
Deep well	715	2.3	2.56	9.25	5.7	7.12	C_2S_1	0.85

Features of the irrigation system and irrigation planning

The drip irrigation method was adopted for successful irrigation and fertigation treatments. Moreover, drip irrigation was selected to apply varying amounts of water at different irrigation levels. The water was supplied from a well at a flow of 16 m^3 h^{-1} using a submersible pump.

The well source was 18 m deep, and the submersible pump could draw water from a depth of 12 meters. In the present study, in-line lateral pipes with a suitable dripper spacing of 20 cm and a flow rate of 4 L h^{-1} were used for the mazes. The moisture in the soil prior to and after the irrigation was monitored up to a soil depth of 120 cm using the gravimetric method. Evapotranspiration (ET) was calculated using the water balance equation (Equation 1).

$$ET = I + P - R_f - D_p \pm \Delta S \quad (1)$$

In equation 1, ET denotes evapotranspiration (mm), I denotes the amount of irrigation water during the period (mm), P denotes the total precipitation (mm), R_f denotes the amount of surface flow (mm), Dp denotes deep drainage (mm), and ΔS denotes the soil water content at the beginning and end of the study period (mm 120 cm^{-1}). Soil water deeper than 120 cm was considered deep drainage (Dp), and the Dp value was neglected due to the outcropping of the mazes. Since the lateral and plant row spacings (0.20 m × 0.70 m) were equal in the present study, the percentage of the wetted area was calculated using Equation 2.

$$P = \frac{Sd}{Sl} x100 \quad (2)$$

In equation 2, P denotes the percentage wetted area (%), Sd denotes the interval of the dripper (m), and Sl denotes the intervals of the lateral (m). The amount of irrigation water applied during each irrigation event was calculated using Equation 3.

$$dn = \frac{(FC - WP)\, XRy}{100} x\ \gamma t\ x\ D\ x \frac{P}{100} \quad (3)$$

In equation 3, FC denotes the field capacity (%), WP denotes the wilting point (%), ɣt denotes the soil bulk density (g cm^{-3}), D denotes the wetted soil depth (mm), and P denotes the percentage wetted area (%). The relationship between yield and ET was explained based on the Stewart model (Equation 4).

$$\left(1 - \frac{Ya}{Ym}\right) = ky\ x\left(1 - \frac{ETa}{ETm}\right) \quad (4)$$

In Equation 4, Ya denotes the actual yield (t ha^{-1}), Ym denotes the maximal yield (t ha^{-1}), ETa denotes the actual evapotranspiration (mm), and ETm denotes the maximal evapotranspiration (mm).

Four different irrigation treatments (I_{100}, I_{75}, I_{50}, and I_{25}) were applied in the experiments. I_{100} represented full irrigation. Accordingly, the three groups of I_{75}, I_{50}, and I_{25} represented the irrigation levels of 75%, 50%, and 25%, respectively, relative to I_{100}. The drip irrigation method was adopted to apply the water amounts corresponding to the above irrigation levels (Figure 5). The water was supplied from a well at a flow of 16 m^3 h^{-1} using a submersible pump. The depth of the well source was 18 m, and the submersible pump drew water from a depth of 12 m. Three different fertigation levels (F_{100}, F_{75}, and F_{50}) were applied along with the above four irrigation levels (I_{100}, I_{75}, I_{50}, and I_{25}). F_{100} was considered complete fertigation, and accordingly, the F_{75} and F_{50} fertigation levels represented fertilizer application at 75% and 50%, respectively, relative to F_{100}. In complete fertigation (F_{100}), nitrogen fertilizer was applied in two steps. In the first step, the nitrogen fertilizer (33% N) was applied to the soil during seed sowing. In the second step, fertilizer was applied when the plants reached a height of 50–60 cm. Fertigation was performed using pure nitrogen (N) at 20 kg da^{-1} by adopting a drip irrigation system. The phosphorus fertilizer (42%–44% P_2O_5) was applied at the beginning of the vegetative developmental period of maize, at a rate of 10 kg da^{-1}. Among the applied fertilizers, the least applied amount was that of the potassium fertilizer. The potassium nitrate (KNO_3: 33% N and 46% K_2O) fertilizer was applied at a rate of 5 kg da^{-1} prior to sowing using the drip irrigation system.

The sowing periods of maize seeds according to the conditions of the Marmara Region of Turkey were referred to, based on which 5 May 2019 and 5 May 2020 were selected as the maize seed sowing dates in the present study. The duration between maize sowing and harvesting was 110 days in 2019 and 112 days in 2020. The area between the plants in consequent rows was 0.20 m × 0.20 m. Each irrigation plus fertigation group contained 176 corn plants within the plot area of 2.0 m × 3.0 m. Each plot contained a harvest plot with 20 corn plants (Figure 6). The moisture level in the soil was brought to the field capacity level 4 days prior to sowing the corn seeds. Since corn plants are fringe-rooted, it was deemed appropriate that the soil depth of 0–0.90 m should be at the moisture level of field capacity.

Figure 5: (A) Drip irrigation system. (B) Main and lateral pipes.

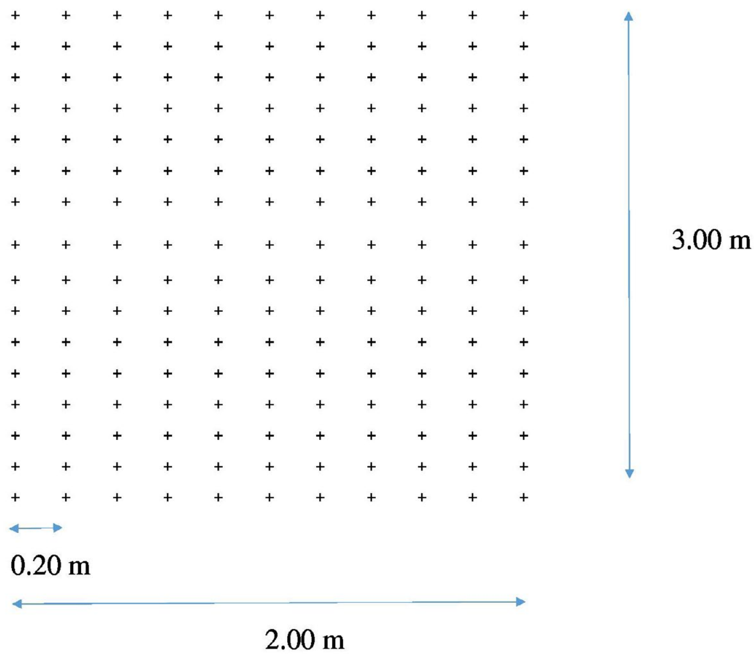

Figure 6: The detail of a plot.

The first irrigation was performed one week after sowing the corn seeds. Twelve application groups were formed with different combinations of irrigation and fertigation levels. The experiment design included three replicates (three blocks) based on the randomized block split-plot design. The relationship between evapotranspiration (ETa) and yield (Ya) was determined for the years 2019 and 2020 (Figure 7). The corn yield and quality values were subjected to a variance analysis using the SPSS 23 program. When the F-test was significant, the LSD test was performed to group the irrigation and fertigation factors. Corn yield, ear height, ear diameter, ear weight, percentage of separation into grains, thousand-grain weight, biomass yield, harvest moisture, the row number of ears, and the row number of kernels were determined for both study years. The average of the measured values was calculated by measuring the fruit size of the corn ears and grains, for example, using a caliper. In order to determine the above-ground dry matter (biomass) yield of corn, ten plants representing each plot were obtained from the soil level after harvest, and the leaves and ears were separated from the stem. The plants were then left to dry in the open air for one week. Afterward, the sample plants were cut and dried in an oven at 70 °C for 24 h. The above-ground dry matter (biomass) yield was calculated as the weight of the dried plants in the area proportion occupied by the plants per decare and expressed as kg/da (Poler Team, 2021). İn addition, water-soluble dry matter (WSDM), starch amount per grain, pH, crude fat content per grain, and protein ratio per grain were determined.

Determination of water-soluble dry matter (WSDM) (°Briks)

After soaking the corn grains in water for a certain duration, water was squeezed out from the grains using cheesecloth, and 10 mL of this water sample was centrifuged at 10000 rpm for 2 min. The supernatant was used for calculating the WSDM values (Sakin; Azapoğlu, 2017).

Determination of the amount of starch per grain (%)

Corn kernel samples were weighed (5 g) and placed inside a 100 mL measuring balloon, to which 50 mL of 1% HCl solution was added using a pipette. The balloon was then placed in a water bath at a temperature of 95–100 °C for 15 min. In order to precipitate nitrogen, 10 mL of 4% phosphorus wolfram acid was added, and the mixture was then filtered through a filter paper until a clear solution was obtained. The filtrate was placed inside a polarimeter tube for reading, and the percentage of starch was determined using the formula (İdikut; Yıldız, 2018; İdikut; Ekinci; Gençolan, 2020).

Determination of the pH values

Ground corn kernels were weighed and 50 g samples were mixed with water and left undisturbed for a certain duration. The pH of these samples was then measured using a digital pH meter (Budaklı Çarpıcı et al., 2017).

Determination of the crude fat content per grain (%)

Crude fat analysis was conducted using the ANKOM (2008) method, for which ground samples weighing 2 g each were placed on filter papers. The 10 samples were then placed on the Soxhlet device, and crude fat extraction was performed by applying n-hexane to the samples at 70 °C for 6 h. The crude fat content of the samples was calculated using the formula (Kılınç; Karademir; Ekin, 2018; İdikut; Ekinci; Gencolan, 2020).

Determination of protein ratio per grain (%)

The protein ratio of corn kernels was determined using the method of Kjeldahl (Corn Refiners Association - CRA, 1986). The corn kernels harvested from the plots were ground, placed into burning tubes, and treated with chemicals. The total nitrogen content was then determined using the standard formula. The total protein ratio of the samples was calculated by multiplying the calculated nitrogen ratio with the coefficient of 6.25 (Kılınç; Karademir; Ekin, 2018; İdikut; Ekinci; Gencolan, 2020).

RESULTS AND DISCUSSION

Demirok and Tuylu (2019) conducted a study in which they applied 421.5 mm of irrigation water using the drip irrigation system and 1264.5 mm of water using the

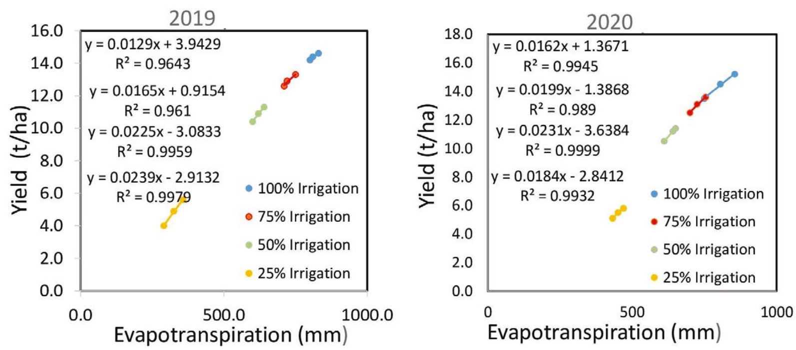

Figure 7: The relationship between Evapotranspiration (ETa) with yield (Ya) for 2019 and 2020 years.

sub-soil drip irrigation system to corn plants in the Harran Plain conditions in Turkey. The authors reported that the plant water consumption values varied between 585.7 mm and 1294.6 mm when using the drip irrigation system and between 572.5 mm and 1286.7 mm when using the sub-soil drip irrigation system. In another study conducted in Turkey's Konya Karapnar conditions, Özbahçe and Gönülal (2019) reported that when the amount of irrigation water applied to maize plants varied between 221.0 mm and 442 mm, the ET values varied between 358 mm and 602 mm, respectively. Gönülal and Soylu (2020) applied irrigation water to corn plants in Turkey's Konya Plain in amounts varying between 637 mm and 742 mm. In the present study, the maximum and minimum amount of irrigation water during the study years was calculated to be 195–780 mm and 200–800 mm, respectively. In addition, the maximum and minimum evapotranspiration (ET) values during the study years (2019 and 2020) were 290–830 mm and 432–855 mm, respectively (Table 5). The relationship between irrigation water (IW) and yield (Ya) and the relationship between ETa and yield (Ya) for the years 2019 and 2020 are presented in Figure 7.

In the two study years, the highest irrigation water and evapotranspiration values were obtained for the $I_{100}F_{100}$ treatment group, in which full irrigation and full fertigation were applied. On the other hand, the lowest irrigation and evapotranspiration values were obtained for the $I_{25}F_{50}$ treatment group, in which the lowest irrigation and fertigation levels were applied. These results were consistent with the irrigation water and plant water consumption values reported in previous studies conducted on maize (Gönülal; Soylu, 2019; Jafarikouhini; Kazemeini; Sinclair, 2020; Thenmozhi et al., 2022).

The relationship between yield (Ya) and evapotranspiration (ETa) for the 2019–2020 period is illustrated in Figure 7. The crop yield response factor (ky) values in the I_{100}, I_{75}, I_{50}, and I_{25} irrigation treatment groups during the two study years were 0.66–0.87–1.20–1.46 and 0.85–1.20–1.29–1.39, respectively. The ky values increased with the decrease in the amount of irrigation water applied. The low ky values in the I_{75} treatment compared to the I_{100} treatment indicated that it would be appropriate to reduce the irrigation levels in I_{75} applications. The ky values obtained for the different irrigation level groups during the study years are presented in Figure 8. The yield response factor (ky) values obtained in the present study were consistent with the ky values reported in previous studies (Da Silva; Rezende; Flumignan, 2019; Hajirad et al., 2021; Tüfekçi; Kuşcu, 2021).

Furthermore, the maximum and minimum yield values obtained in the two study years were 14.6–4.0 t ha^{-1} and 15.2–5.1 t ha^{-1}, respectively, and were obtained for the $I_{100}F_{100}$ and $I_{25}F_{50}$ treatments, respectively (Table 6 and 7; Table 8 and 9). In both years, the differences in the yield values among the different irrigation water levels and different fertigation levels were significant at the threshold of 1%. Furthermore, the effect of the interaction between

Table 5: Relationship between yield and yield response factor (ky) with the decrease in water use, for dent corn in 2019 and 2020.

	2019				2020			
Treatments	Yield (t ha^{-1})	AW (mm)	ETa (mm)	ky	Yield (t ha^{-1})	AW (mm)	ETa (mm)	ky
$I_{100}F_{100}$	14.6	780.0	830.0	0.000	15.2	800	855	0.000
$I_{100}F_{75}$	14.4	780.0	810.0	0.568	14.5	800	805	0.788
$I_{100}F_{50}$	14.2	780.0	800.0	0.758	13.5	800	750	0.911
$I_{75}F_{100}$	13.3	585.0	750.0	0.000	13.6	600	755	0.000
$I_{75}F_{75}$	12.9	585.0	720.0	0.752	13.1	600	725	0.925
$I_{75}F_{50}$	12.6	585.0	710.0	0.987	12.5	600	700	1.110
$I_{50}F_{100}$	11.3	390.0	640.0	0.000	11.4	400	650	0.000
$I_{50}F_{75}$	10.9	390.0	620.0	1.133	11.2	400	641	1.267
$I_{50}F_{50}$	10.4	390.0	600.0	1.274	10.5	400	611	1.316
$I_{25}F_{100}$	5.6	195.0	357.0	0.000	5.8	200	470	0.000
$I_{25}F_{75}$	4.9	195.0	325.0	1.395	5.5	200	451	1.279
$I_{25}F_{50}$	4.0	195.0	290.0	1.522	5.1	200	432	1.493

AW: Applied water, ETa: Actual evapotranspiration, ky: Yield response factor.

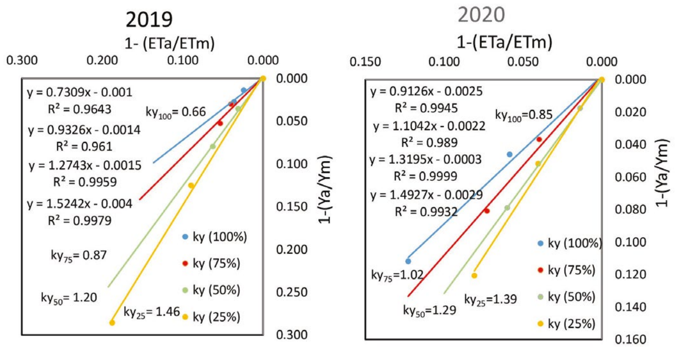

Figure 8: The relationship between relative yield (Ya) decrease and relative evapotranspiration (ETa) deficit for the experimental years (2019 and 2020).

the irrigation and fertigation factors on yield was revealed to be insignificant at the block level. In the first year of the study, the maize yield values were similar between the I_{100} and I_{50} treatments, and the yield values in the I_{25} treatments were much lower than the values obtained in other irrigation level groups. However, the yield values of the irrigation treatments other than I_{100} and I_{50} were significantly different statistically. In the second year of the study, the values in the I_{25} treatment group were statistically in the same class as those in the I_{100} treatment group, while the values in the other groups were statistically different although close to each other.

Furthermore, the ear height values were similar in all groups, even at different irrigation levels, in both years. In the first year, the ear height values in I_{100} were in the same statistical class, while in the second year, the values were close to each other. Moreover, while the differences in the ear height values among different irrigation and fertigation levels in both years were significant at 1% and 5% threshold levels, respectively, the differences were insignificant at the block level. In both years, the ear diameter values were considerably similar, and the differences were statistically insignificant. While the differences in the ear diameter values among different irrigation and fertigation levels were significant at the 1% threshold level, the differences at the block level were statistically insignificant. Significant differences in ear weights were observed between the statistical classes in both years. The irrigation levels were almost in different statistical classes. While the differences among the different irrigation and fertigation level groups were significant at the threshold of 1%, the differences were significant at the block level. The percentage of separate grains and thousand-grain weight values were close to each other in both years.

In both study years, the 'percentage of separate grain' values were significantly different at the 1% threshold level among different irrigation levels, and the differences in the values of different fertigation levels were significant at the 1% level. The differences in these values were, however, insignificant at the block level. The thousand-grain weight values were significantly different at the 1% threshold among the different irrigation and fertigation treatment groups, the differences were insignificant at the block level. Furthermore, in both years, the amount of dry matter was significantly different at the 1% threshold level among the different irrigation level groups. The differences in the dry matter values among different fertigation groups were significant at the levels of 1% and 5% in the two years. However, the differences were insignificant at the block level. The harvest moisture values were close to each other in both years, and there were few differences in terms of the main statistical classes. However, while the differences were statistically significant at 1% among different irrigation and fertigation treatment groups, they were insignificant at the block level. The row number of the ear and the kernel number of the row were significant at the level of 1% among different irrigation levels, and the row number of the ear was significant at the level of 1% among the different fertigation levels. In addition, the 'kernel number of row' values were insignificantly different among different fertigation levels in both study years (Bayramoğlu; Bozdemir, 2018; Idikut; Yıldız, 2018; Demirok; Tuylu, 2019; Wu et al., 2019; Gönülal; Soylu, 2019; Akçalı; Gözübenli, 2020; Gönülal; Soylu, 2020; Filiz; Topal, 2021).

Table 6: Quality parameters of dent corns in 2019.

	2019									
Treatments	Yield (t ha^{-1})	Ear height (cm)	Ear diameter (cm)	Ear weight (g)	Per.of sep. into grains (%)	Tho. grain weight (g)	Biomas yield (kg/da)	Harvest moisture (%)	Row number of ear	Kernel number of row
$I_{100}F_{100}$	14.6 a	22.2 a	5.37 a	325.5 a	0.91 a	541.4 a	3462 a	20.3 a	13.8 a	48.2 a
$I_{100}F_{75}$	14.4 a	22.0 a	5.33 ab	317.8 b	0.90 ab	539.8 ab	3426 a	20.0 a	13.7 ab	48.0 a
$I_{100}F_{50}$	14.2 a	21.9 a	5.21 abc	312.7 b	0.89 abc	537.9 abc	3412 a	19.6 b	13.7 ab	48.0 a
$I_{75}F_{100}$	13.3 b	21.9 a	5.17 bc	292.4 c	0.88 bc	535.1 bc	3405 a	19.3 b	13.7 ab	47.8 a
$I_{75}F_{75}$	12.9 bc	21.8 a	5.12 c	289.5 c	0.87 cd	533.6 c	3394 a	18.8 c	13.7 ab	47.8 a
$I_{75}F_{50}$	12.6 c	21.3 ab	5.08 c	282.3 d	0.85 de	532.7 c	3385 a	18.5 c	13.6 ab	47.7 a
$I_{50}F_{100}$	11.3 d	20.5 bc	4.85 d	246.8 e	0.84 e	523.5 d	3012 b	18.1 d	13.4 bc	45.4 b
$I_{50}F_{75}$	10.9 d	20.1 c	4.80 d	236.1 f	0.83 e	519.2 d	2987 b	17.4 e	13.2 cd	44.7 bc
$I_{50}F_{50}$	10.4 d	19.7 cd	4.73 d	229.6 f	0.83 e	512.5 e	2886 b	17.0 f	13.2 cd	44.2 c
$I_{25}F_{100}$	5.6 f	19.0 de	4.46 e	187.5 g	0.80 f	486.4 f	2645 c	16.7 f	13.0 d	42.0 d
$I_{25}F_{75}$	4.9 g	18.8 de	4.33 ef	174.2 h	0.79 f	473.6 g	2546 c	16.2 g	12.9 d	40.6 e
$I_{25}F_{50}$	4.0 h	18.1 e	4.28 f	154.9 i	0.78 f	465.7 h	2345 d	15.8 h	12.9 d	39.8 e
Irrigation	**	**	**	**	**	**	**	**	**	**
Fertigation	**	**	**	**	**	**	**	**	**	**
Blocks	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
I*F Inter.	**	**	**	**	**	**	*	*	*	*

t the 0.01 level, * Correlation is significant at the 0.05 level, ns non-significant.

Table 7: Quality parameters of dent corn in 2019.

	2019							
Treatments	Water sol. dry matter (%)	Starch am. per grain (%)	Protein ratio per grain (%)	Crude fat content per grain (%)	pH	Fiber ratio per grain (%)	Ash ratio per grain (%)	Total Phen. Comp. (µg GAE g^{-1})
$I_{100}F_{100}$	17.3 a	63.18 a	8.26 a	4.82 a	3.96 a	2.20 a	1.23 a	254.26 a
$I_{100}F_{75}$	17.2 a	63.05 a	8.13 ab	4.77 a	3.95 a	2.10 b	1.22 ab	252.87 a
$I_{100}F_{50}$	17.0 ab	63.00 a	8.05 abc	4.63 b	3.93 ab	2.00 c	1.20 abc	250.43 ab
$I_{75}F_{100}$	16.8 bc	62.94 a	7.96 bc	4.60 bc	3.92 ab	1.98 c	1.19 bcd	244.32 ab
$I_{75}F_{75}$	16.5 cd	62.89 a	7.85 bc	4.48 cd	3.90 abc	1.93 cd	1.17 cde	242.21 ab
$I_{75}F_{50}$	16.4 d	62.86 a	7.82 c	4.39 d	3.88 bcd	1.89 de	1.16 de	240.26 b
$I_{50}F_{100}$	14.7 e	60.24 b	6.43 d	3.88 e	3.85 cde	1.85 def	1.15 ef	202.63 c
$I_{50}F_{75}$	14.5 ef	59.28 bc	6.40 de	3.77 ef	3.82 def	1.81 efg	1.14 efg	178.17 d
$I_{50}F_{50}$	14.2 fg	58.46 cd	6.24 de	3.68 f	3.81 ef	1.80 fg	1.12 fgh	165.24 e
$I_{25}F_{100}$	14.0 gh	57.64 d	6.18 de	2.92 g	3.80 ef	1.73 gh	1.12 fgh	158.31 ef
$I_{25}F_{75}$	13.8 hi	57.32 d	6.14 de	2.78 h	3.78 f	1.70 h	1.11gh	150.13 f
$I_{25}F_{50}$	13.6 i	57.21 d	6.11 e	2.56 i	3.76 f	1.67 h	1.10 h	133.28 g
Irrigation	**	**	**	**	*	*	*	**
Fertigation	**	**	*	*	*	*	*	**
Blocks	ns	ns	ns	ns	ns	ns	ns	ns
I*F Inter.	**	**	**	**	*	**	*	**

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level, ns non-significant.

Table 8: Quality parameters of dent corn in 2020.

	2020 year									
Treatments	Yield (t ha^{-1})	Ear height (cm)	Ear diameter (cm)	Ear weight (g)	Per.of sep. into grains (%)	Tho.grain weight (g)	Biomas yield (kg/da)	Harvest moisture (%)	Row number of ear	Kernel number of row
$I_{100}F_{100}$	15.2 a	22.3 a	5.35 a	332.7 a	0.91 a	540.0 a	3543 a	21.8 a	13.9 a	48.0 a
$I_{100}F_{75}$	14.5 a	22.1 a	5.32 ab	326.5 b	0.91 a	538.6 ab	3537 a	21.1 b	13.9 a	47.9 a
$I_{100}F_{50}$	13.5 b	22.0 ab	5.29 abc	319.9 c	0.90 ab	538.1 abc	3532 a	20.7 bc	13.8 a	47.8 a
$I_{75}F_{100}$	13.6 b	21.8 ab	5.28 bc	318.8 c	0.89 abc	537.5 abc	3530 a	20.3 cd	13.8 a	46.5 b
$I_{75}F_{75}$	13.1 bc	21.5 ab	5.25 c	315.9 c	0.89 abc	532.3 bcd	3521 a	19.7 de	13.7 ab	46.3 b
$I_{75}F_{50}$	12.5 c	21.1 bc	5.24 c	310.6 d	0.88 bcd	530.6 cd	3519 a	19.1 ef	13.7 ab	46.2 b
$I_{50}F_{100}$	11.4 d	20.3 cd	4.92 d	298.7 e	0.87 cde	525.4 de	3345 b	18.8 fg	13.5 bc	44.8 c
$I_{50}F_{75}$	11.2 de	20.0 de	4.88 de	283.5 f	0.86 de	522.5 e	3256 c	18.4 gh	13.4 c	43.9 c
$I_{50}F_{50}$	10.5 e	19.6 de	4.83 e	277.4 g	0.85 ef	519.7 e	3218 c	18.1 hi	13.3 c	42.6 d
$I_{25}F_{100}$	5.8 f	19.1 ef	4.56 f	206.5 h	0.83 fg	505.4 f	2986 d	17.7 ij	13.0 d	40.7 e
$I_{25}F_{75}$	5.5 f	18.4 fg	4.41 g	192.8 i	0.81 gh	492.3 g	2869 e	17.3 j	12.9 d	40.3 e
$I_{25}F_{50}$	5.1 f	17.9 g	4.35 g	188.1 i	0.79 h	478.9 h	2734 f	16.6 k	12.8 d	40.0 e
Irrigation	**	**	**	**	**	**	**	**	**	**
Fertigation	**	**	**	**	**	**	**	**	**	**
Blocks	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
I*F Inter.	**	**	*	**	*	**	**	*	*	**

**Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level, ns non-significant.

Table 9: Quality parameters of dent corn in 2020.

	2020							
Treatments	Water-soluble dry matter (%)	Starch amount per grain (%)	Protein ratio per grain (%)	Crude fat content per grain (%)	pH	Fiber ratio per grain (%)	Ash ratio per grain (%)	Total phenolic compound (μg GAE g^{-1})
$I_{100}F_{100}$	17.5 a	63.24 a	8.12 a	4.80 a	3.95 a	2.22 a	1.24 a	250.86 a
$I_{100}F_{75}$	17.2 ab	63.17 a	8.04 ab	4.73 ab	3.92 ab	2.18 ab	1.23 a	250.42 a
$I_{100}F_{50}$	17.1 bc	63.08 a	8.00 bc	4.70 ab	3.90 abc	2.15 ab	1.21 ab	250.17 a
$I_{75}F_{100}$	17.0 bcd	63.00 a	7.98 bc	4.70 ab	3.90 abcd	2.14 ab	1.21 ab	246.23 a
$I_{75}F_{75}$	16.8 cd	62.94 a	7.93 cd	4.65 b	3.87 bcd	2.12 b	1.20 abc	245.38 a
$I_{75}F_{50}$	16.7 d	62.89 a	7.87 d	4.62 b	3.84 cde	2.10 b	1.18 bcd	244.82 a
$I_{50}F_{100}$	15.1 e	60.42 b	6.85 e	4.24 c	3.81 def	1.95 c	1.16 cde	220.41 b
$I_{50}F_{75}$	14.8 ef	60.17 b	6.79 e	4.02 d	3.80 defg	1.92 c	1.15 de	206.38 c
$I_{50}F_{50}$	14.5 fg	59.94 c	6.67 f	3.93 d	3.79 efg	1.90 cd	1.13 ef	188.21 d
$I_{25}F_{100}$	14.3 gh	58.95 c	6.32 g	3.28 e	3.73 fg	1.82 de	1.12 ef	174.55 e
$I_{25}F_{75}$	14.1 hi	58.73 c	6.27 gh	3.10 f	3.71 g	1.77 ef	1.10 f	163.67 e
$I_{25}F_{50}$	13.8 i	58.41 c	6.21 h	2.92 g	3.70 g	1.71 f	1.09 f	142.39 f
Irrigation	**	**	**	**	**	*	*	**
Fertigation	**	**	**	**	**	*	*	**
Blocks	ns	ns	ns	ns	ns	ns	ns	ns
I*F Inter.	**	**	**	*	**	*	*	**

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level, ns non-significant.

The values of water-soluble dry matter content and starch content per grain which are the quality parameters for corn, were revealed to be significantly different at the level of 1% among different irrigation levels. However, the water-soluble dry matter values were significantly different at the level of 1% among the different fertigation levels. On the other hand, the starch content per grain was insignificantly different among different fertigation levels and at the block level. In regard to both water-soluble dry matter content and starch content per grain, the values were close to each other, and the starch content per grain values were statistically similar. The 'protein ratio per grain' values were significantly different at 1% among different irrigation levels and insignificantly different among different fertigation levels in the two years. The 'crude fat content per grain' values were significant at 1% among different irrigation and fertigation levels in both years. In both years, the crude fat content per grain values were close to each other. The pH values in both years were significantly different at the 1% level among different irrigation levels, while the differences were insignificant among different fertigation levels and at the block level.

The 'fiber ratio per grain' values were significantly different at 1% among different irrigation levels during the two years. Among different fertigation levels, the fiber ratio values were significant at the level of 1% in the first year and 5% in the second year. At the block level, the differences in the 'fiber ratio' values were insignificant in both years. The 'ash ratio per grain' values were significant among different irrigation levels in both study years, and these values were significant at 5% among different fertigation levels. At the block level, the differences in the ash ratio per grain values were insignificant. Total phenolic compound values were significant at 1% among different irrigation and fertigation levels in both study years, and the differences were insignificant at the block level (Sakin; Azapoğlu, 2017**; I**dikut; Ekinci; Gençolan, 2020; Jafarikouhini; Kazemeini; Sinclair, 2020; Thenmozhi et al., 2022**).** The values and the statistical classes of different quality parameters for maize are listed in Table 6–9**.**

CONCLUSIONS

The present study revealed that with the decrease in the levels of irrigation and fertigation, the dent corn yield also decreased. The two factors of irrigation and fertigation significantly affected the yield and quality of dent corn. However, it was observed that despite the reduced levels of irrigation water and fertigation, I_{75} irrigation and F_{75} fertigation treatments were effective and are, therefore, recommended.

AUTHOR CONTRIBUTION

Conceptual idea: Ayas, S.; Methodology design: Ayas, S.; Data collection: Ayas, S.; Data analysis and interpretation: Ayas, S. and Writing and editing: Ayas, S.

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