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Different irrigation and fertilization levels and mulching materials on the yield and quality of strawberry

Diferentes níveis de irrigação e adubação e cobertura morta na produção e qualidade de morango

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ABSTRACT

The strawberry (*Fragaria* spp.), one of the most important berry fruit, is cultivated in many regions of Turkey. Considering its agricultural importance, the objective of this study was to determine the interactions of three important factors affecting the yield of strawberries. Measurements of the physical and quality properties of strawberry were carried out in the laboratories of Bursa Uludağ University. In the research, four different irrigation topics, three different fertigation and three different mulching topics (without mulch (M_0),with PE black mulch material (M_1), with PE transparent mulch matterial (M_2) 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 380-95 mm and 420-105 mm, respectively, while the highest and lowest actual evapotranspiration values were calculated as 440-220 mm and 465-280 mm, respectively. The maximum and minimum yield values of the study years were calculated as 5.05-18.70 t ha^{-1} and 1.20-8.7 t ha^{-1}, respectively, from $I_{100}F_{100}M_1$ and $I_{25}F_{50}M_0$ 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} topics can be recommended. Also, in mulching treatments, black mulch material (M_1) should be chosen over clear mulch material (M_1) and no mulch (M_0).

Index terms: Yield; *Fragaria* spp.; ky factor.

RESUMO

O morango (*Fragaria* spp.), uma das frutas silvestres mais importantes, é cultivado em muitas regiões da Turquia. Considerando sua importância agrícola, o objetivo deste estudo foi determinar as interações de três fatores importantes que afetam a produção de morangos. As medições das propriedades físicas e de qualidade do morango foram realizadas nos laboratórios da Universidade Bursa Uludağ. Na pesquisa, quatro diferentes tópicos de irrigação, três diferentes fertirrigação e três diferentes tópicos de mulching (sem mulch (M0), com PE preto material de cobertura morta (M1), com material de cobertura vegetal transparente de PE (M2). 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 maiores e menores quantidades de água de irrigação em ambos os anos experimentais foram encontrados em 380-95 mm e 420-105 mm, respectivamente, enquanto os valores de evapotranspiração reais mais altos e mais baixos foram calculados como 440-220 mm e 465-280 mm, respectivamente. Os valores de rendimento máximo e mínimo dos anos de estudo foram calculados como 5,05-18,70 t ha-1 e 1,20-8,7 t ha-1, respectivamente, dos tratamentos I100F100M1 e I25F50M0 . No entanto, quando as reduções na produtividade e as perdas de qualidade são avaliadas em conjunto, apesar das reduções nos níveis de água de irrigação e fertirrigação, os tópicos I75 e F75 podem ser recomendados. Além disso, em tratamentos de mulching, o material de mulch preto (M1) deve ser usado sobre o material de mulch claro (M_1) e sem mulch (M_0).

Termos para indexação: Produtividade; *Fragaria* spp.; fator ky.

INTRODUCTION

The strawberry (Fragaria spp.), one of the most important berry fruit, is cultivated in many regions of the world. Due to its pleasant aroma, flavor, and vitamin and mineral content, it is consumed by much of the world and plays an important role in human nutrition and health. Until recently, strawberries were only grown in the regions of Istanbul, Bursa, and Karadeniz Ereğli; however, their cultivation is becoming increasingly common. In the Marmara Region, where Bursa is located, strawberries ripen during the first week of May; however, this ripening occurs earlier in, March and April in the Aegean and Mediterranean regions. In addition, high yields are obtained in the Mediterranean and Aegean regions as a result of their high annual temperatures, whereas low yields are correlated with the lower temperatures in the Marmara and Black Sea regions. Due to economic growth under varying ecological conditions, strawberry cultivation has gained prominence in the modern era. Fresh strawberries can be made into jam, marmalade, pastry, and fruit juice (Erdoğan Bayram, 2020).

The cultivation of strawberries has played a significant role in global agriculture. Global and Turkish strawberry production is approximately 8.8 million and 546,525 tons, respectively. Turkey ranks fourth worldwide in terms of strawberry production (Food and Agriculture Organization of the United Nations - FAO, 2020). Additionally, strawberries are one of the major fruits produced in the Marmara region, Turkey. In the province of Bursa in the Marmara Region, annual strawberry production is approximately 51 000 tons of fruit from 3 000 ha. Turkey ranks twelfth in the world in strawberry exports, with 47 912 tons (Turkish Statistical Institute - TUIK, 2020). Strawberry export in the province of Bursa for 2016 was approximately 19.4 tons (Tuik, 2017).

Weber et al. (2017) reported that strawberry growth is very sensitive to a lack of soil saturation resulting in the need for an equipped irrigation system for quality production. There have been many studies on deficit irrigation in strawberry agriculture worldwide (Rezaei et al., 2020; Põldma et al., 2021; Arıza et al. 2021). Climate, topography, water source, variety of cultural applications, and irrigation management techniques and practices influence fruit yield and quality, according to studies on strawberry irrigation. In our country, relatively few studies have been conducted on the irrigation of strawberries using drip irrigation techniques, and the yield response of strawberries to different irrigation water levels in the province of Bursa has not been thoroughly investigated. More N, P, K, and B accumulate in harvested fruits than in other plant organs. This situation demonstrates the significance of N, P, K, and B for the plant's fruit quality. The response of the strawberry to an increase in nitrogen (N) content shows an increase in the number of fruits; but no increase in fruit weight. Although the fruits and flowers of phosphorus (P)-deficient plants are smaller than usual, albinism developed in the fruits of susceptible varieties. During the later stages of potassium (K) deficiency, fruit wrinkles increased, and pedicles and peduncles began to dry. In addition, observable wilting was recorded in the fruits. It was determined that potassium (K) had no effect on the firmness of collected and ripened fruit. In a soilless closed system, excessive potassium intake reduces the sugar content and quality of strawberries.

Potassium (K) deficiency ultimately limits color development in fruits that are rough and tasteless (Khalil; Agah, 2017; Agehara; Nunes, 2021; Rostami et al., 2022).

Mulching is a cultural practice applied to the soil surface to benefit the soil and the plant. Polyethylene (plastic) materials are generally used in mulching applications. For mulching purposes, additional deep black or dark plastic covers have been used. In recent years, an increasing amount of polyethylene materials with different colors and properties have been used. Different colored mulches help plant growth and increase the yield of the crop by positively influencing the development effects. This increase is because reflected light is redirected back to the leaves from the root zone that has the appropriate temperature and humidity values from the mulch surface. Thanks to PE mulching applications, it is possible to provide better weed control, desired soil moisture and temperature, higher yield, and profit growth (Abdalla et al., 2019; Goldberger; Devetter; Dentzman, 2019).

Kumar and Kumar (2020) reported that the yield and growth of vegetables affect irrigation and the selection of mulch type. In addition, it has been reported that the use of plastic mulch provides 25-35% water savings and increases efficiency in all treatments. Many studies have been conducted on the irrigation, fertilization, and mulching of strawberries worldwide and in Turkey (Rannu et al., 2018; Dong et al., 2020; Erdoğan Bayram, 2020; Kapur et al., 2022). However, these studies cover a wide range of types. Unlike previous studies, this study was carried out by combining three distinct (irrigation-fertigation-mulching). The aim of this study is to determine the effects of irrigation, fertigation, and mulching on strawberry yield and quality parameters.

MATERIAL AND METHODS

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

The study was conducted at the Bursa Uludağ University Yenişehir Ibrahim Orhan Vocational School Agricultural Research Field (40°15'09"N latitude, 29°38'43"E longitude) in 2019-2020. During summer, the climate of Yenişehir is hot and partly rainy, withs a cold and rainy climate in winter. While the maximum and minimum temperature values during the experimental periods (March-July) in both study years were measured as 30.8-5.6 °C and 31.7-5.7 °C, the average precipitation amounts during the plant's growing season (March-July) were measured as 92.0 and 47.3 mm (Figures 1 and 2). The average relative humidity values of strawberries during both study years and the growth period (March-July) were calculated as 69.5 and 72.4% (Figure 3), respectively (Meteorological Report, 2021a). The lowest and highest radiation values of the same year and periods were measured as 1542-335 W m^{-2} and 1983-139 W m^{-2} (Figure 4), respectively (Meteorological Report, 2021b). The climatic characteristics of the place where the study was carried out in both years are given in Tables 1 and 2. In both study years, the soil was analyzed before the strawberry seedlings were planted, and the pH value of the soil was measured as 7.86 and 8.00, respectively (Table 3).

A chemical analysis of the water was conducted, and it was determined that it was in the C_2S_1 quality class. Features of the C_2S_1 quality class; include low sodium risk and moderate electrical conductivity (EC) (Table 4). Strawberry plants can be grown easily in the C_2S_1 water class (Akaroğlu; Seferoğlu, 2018). During the study years, the soil and the water used were analyzed and it was determined that they were suitable for strawberries. These values are provided in Table 5. Likewise, before planting the strawberry seedlings, 90 kg da^{-1} of gold (15-15-15) was applied as a base fertilizer. Chlorpyrifos-ethyl was sprayed as a chemical drug (Control) against strawberry pests.

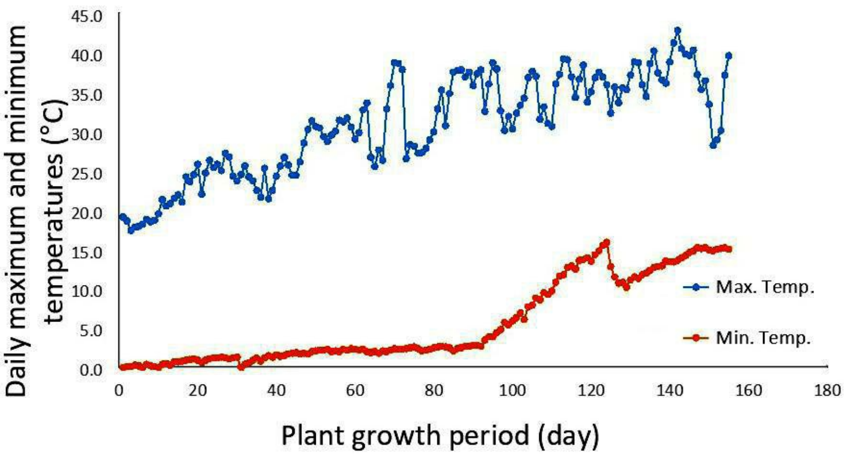

Figure 1: Maximum and minimum temperature values (°C) in 2019.

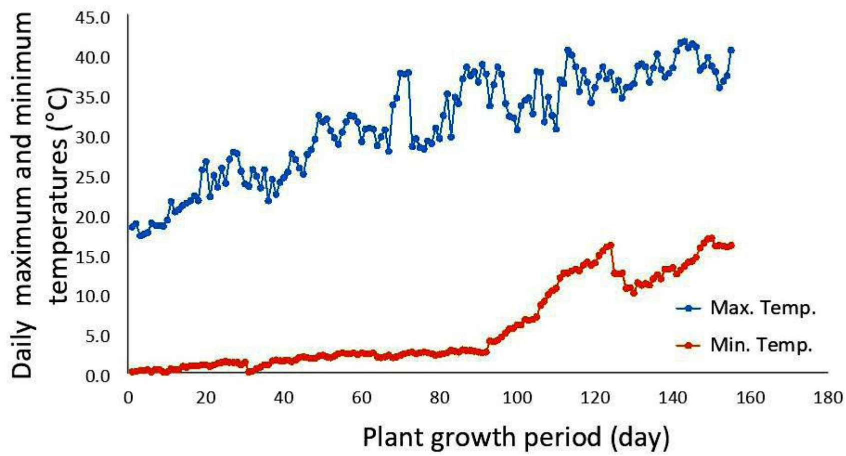

Figure 2: Maximum and minimum temperature values (°C) in 2020.

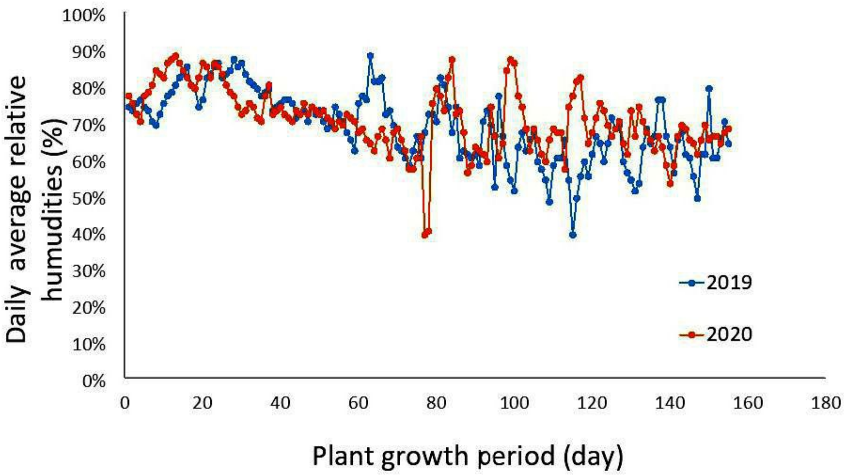

Figure 3: Daily average relative humudities (%) in 2019 and 2020.

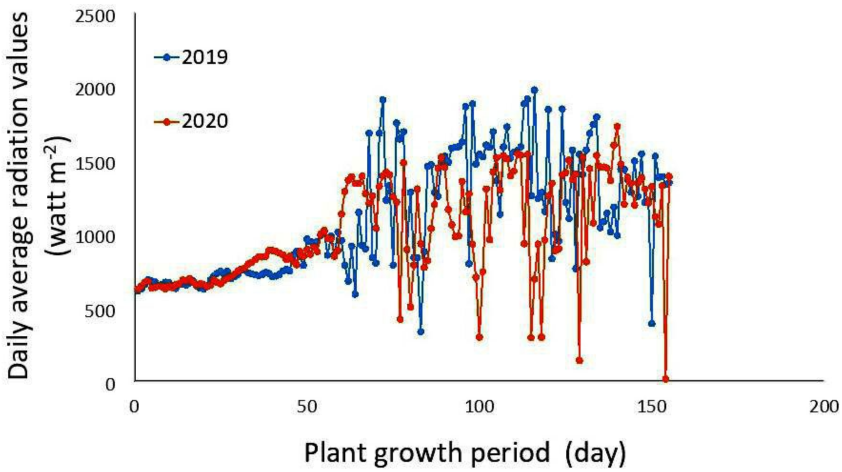

Figure 4: Daily average radiation values (watt m-2) in 2019 and 2020.

Characteristics of the variety

The Camarosa strawberry variety (*Fragaria x Camarosa*) is a productive and short-day variety. Its fruits are plump, red, and resistant to impact. This variety alsoexhibits and very pleasant aroma. The Camarosa strawberry variety is suitable for greenhouse and open-field cultivation. Pest control and fertilization of this variety should be applied in a scheduled and careful way (Roussos et al., 2022).

Features of the irrigation system and irrigation planning

The drip irrigation method was preferred for successful irrigation and fertigation treatments. Moreover drip irrigation was chosen to apply varying amounts of water at separate irrigation levels. The water is supplied from a well through the use of, a submersible pump with a flow of 16 m^3 h^{-1}. The well is 18 meters deep, and the sump pump draws water from a depth of 12 meters. In this study, in-line lateral pipes with a suitable dripper spacing and flow rate of 30 cm and 4 L h^{-1} were preferred for the strawberries. Moisture in the soil before and after irrigation was monitored using the gravimetric method up to 120 cm soil depth. Evapotranspiration (ET) was calculated using the water balance equation (Equation 1).

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

Symbols in Equation 1. ET: evapotranspiration (mm), I: irrigation water amount during the period (mm), P: total precipitation (mm), R_f: the amount of surface flow (mm), Dp: deep drainage (mm), and ΔS: soil water content at the beginning and end of the period (mm 120 cm^{-1}). Soil water deeper than 120 cm was accepted as the deep drainage (Dp), and the Dp value was neglected due to the outcropping of the strawberries. Since the lateral and plant row spacings (0.30x0.30 m) were equal in the study, the percentage of wetted area was calculated with Equation 2.

$$P = \frac{Sd}{Sl} \times 100 \quad (2)$$

Symbols in Equation 2. P: percentage of wetted area (%), Sd: interval of dripper (m), Sl: intervals of lateral (m), respectively. The amount of irrigation water applied in each irrigation event was calculated by Equation 3.

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

Symbols in Equation 3. FC: field capacity (%), WP: wilting point (%), γt: soil bulk density (g cm^{-3}), D: wetted soil depth (mm), P: percentage of wetted are (%). The relationship between yield and ET was explained with the Stewart model (Equation 4).

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

Symbols in Equation 4. Ya: actual yield (t ha^{-1}), Ym: maximal yield (t ha^{-1}), ETa: actual evapotranspiration (mm), ETm: maximal evapotranspiration (mm).

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

Ministry of Environment. Urbanization and Climate Change General Directorate of Meteorology													
2019													
Meteorological 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 covered 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 (m sn^{-1})	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.

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
Average local pressure	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 temperature	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 maximum 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 highest 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 minimum 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
Lowest temperature average	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
Average relative humidity	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 total precipitation	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
Number of rainy days	1	9	8	7	8	9	8	9	8	7	7	7	88.0
Average relative humidity	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
Number of days covered with snow	8.0	4.5											12.5
Number of foggy days	2.0	1.0	3.0				2.0		1.0	2.0	9.0	7.0	27.0
Average wind direction	N	N	NNW	W	SSW	SSW	S	N	WSW	WSW	SSE	WSW	W
Average wind speed (m sn^{-1})	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
Fastest wind direction	S	S	WNW	S	WNW	WSW	W	W	NNW	WSW	SSE	SSW	W
Fastest blowing wind speed (m sn^{-1})	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

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 (%)	$CaCO_3$ (%)	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

Four different irrigation subjects (I_{100}, I_{75}, $I_{50,}$ and I_{25}) were applied in the experiment. The subject of I_{100} was accepted as full irrigation, and according to the subject of $I_{100,}$ full irrigation, 75%, 50%, and 25% irrigation were applied in other subjects. Three different fertigation treatments (F_{100}, $F_{75,}$ and F_{50}) were applied along with four different irrigation treatments (I_{100}, I_{75}, $I_{50,}$ and I_{25}). The F_{100} treatment was accepted as the subject of complete fertigation, and fertigation was applied at rates of 75% and 50% in the other two treatments (F_{75} and F_{50} treatments). From the planting of strawberry seedlings to the end of the 4th week, 3.0 kg da^{-1} potassium nitrate (13% N and 46% K_2O) and 2.0 kg da^{-1} phosphoric acid (61% P_2O_5) were applied every week. In the 5th, 6th, and 7th weeks, 4 kg da^{-1} potassium nitrate (13% N and 46% K_2O) and 2.0 kg da-^{1} phosphoric acid (61% P_2O_5) were applied for the full fertigation treatment (F_{100}). In the F_{75} and F_{50} treatments, fertigation was applied at 75% and 50% of the fertilizer amounts applied in the F_{100} treatment. In the study, three different mulching treatments were applied as the third factor. These are the treatments without mulch (M_0), with PE black mulch material (M_1), and with PE transparent mulch material (M_2).

In accordance with the strawberry seedling planting dates in the Marmara Region of Turkey, the planting date of the Camarosa seedlings was 15 March 2019/20. There was a 5% loss during the first 10 days after the strawberry seedlings were planted. The drip irrigation system, main pipe and lateral pipes used in the study are shown in Figures 5a and 5b. If the seedlings died, they were replaced with new strawberry seedlings. The distance between the plant and the row was calculated to be 0.30 x 0.30 meters. Each parcel contained 30 strawberry seedlings, and each parcel was measured to 1.20 m by 1.50 m. Each parcel contained one harvest parcel containing twelve strawberry seedlings. A total of 36 application combinations for irrigation, fertigation, and mulching treatments were created.

The details of the strawberry plots are shown in Figure 6. The experiment was designed as two repetitions (two divided blocks). Because the experiment explored three factors that varied in importance, such an experimental design was preferred. Strawberry yield and quality values were subjected to variance analysis using the JMP 13 program. When the F test was significant, the LSD test was used to group irrigation, fertigation, and mulching factors. The fruit size of the strawberries taken as an example was measured with a caliper (İzeltaş caliper 150 mm), and the average of the measured values was calculated. The dry matter content of the fruit was determined by drying the sample fruit to a constant weight (at 65 °C in a drying oven). The amount of dry matter in the fruits was determined using (Öztürk Erdem; Cekic; Saracoglu, 2019).

The amount of water-soluble dry matter (WSDM), total sugar (TS), pH, titratable acid content, ascorbic acid (vitamin C) content, crude protein content, total anthocyanin content, and total phenolic content were determined.

Determination of the amount of water-soluble dry matter (%)

After the strawberry fruits were homogenized, the juice passed through coarse filter paper was determined by dripping on a hand refractometer (0-53 scale, Refractometer Pal-1), and the results were expressed as % (Öztürk Erdem; Cekic; Saracoglu, 2019; Erdoğan Bayram, 2020).

Determination of total sugar (%)

Total sugar, fructose, and sucrose amounts from fruit juice samples obtained from 100 gr strawberry samples were determined as grams and % using an HPLC (HP 1100 series) RID (Refraction Index) detector and Shim-Pack HRC NH2 (300X7, 8 mm, 5 um) column. (Becerikli; Başoğlu, 2018; Hewavitharana et al., 2020).

pH values

The pH values of strawberry fruits were determined by measuring with a digital pH meter (Akaroğlu; Seferoğlu, 2018; Öztürk Erdem; Cekic; Saracoglu, 2019).

Determination of titratable acid content (TA) (%)

Using the titration acidity method, the titratable acidity of strawberry fruits was determined in terms of citric acid, and the values were expressed as a % (Agehara; Nunes, 2021; Demirdöven; Tokatlı; Korkmaz, 2021).

Determination of ascorbic acid (vitamin C)

Vitamin C concentration of the strawberry was determined using the methods in Kilic et al. (2021) (Shimadzu IU-1800, Japan). The amount of vitamin C in the samples were determined to be mg 100 g^{-1} (Görgüç et al., 2019).

Table 5: Relationship between yield and yield response factor (ky) with the decrease in water use, for strawberry 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
$I_{100}F1_{00}M_1$	5.05	380	440	0.000	18.70	420	465	0.000
$I_{100}F1_{00}M_2$	4.85	380	432	0.459	17.95	420	458	0.375
$I_{100}F1_{00}M_0$	4.65	380	420	0.574	17.70	420	455	0.402
$I_{100}F_{75}M_1$	4.85	380	430	0.574	18.10	315	460	0.335
$I_{100}F_{75}M_2$	4.90	380	430	0.765	17.40	315	450	0.464
$I_{100}F_{75}M_0$	4.05	380	380	0.689	16.95	315	442	0.529
$I_{100}F_{50}M_1$	3.90	380	350	0.898	14.05	210	375	0.778
$I_{100}F_{50}M_2$	3.95	380	348	0.960	13.55	210	350	0.898
$I_{100}F_{50}M_0$	3.90	380	325	1.148	13.60	210	340	0.986
$I_{75}F1_{00}M_1$	4.90	285	430	0.000	17.75	105	290	0.000
$I_{75}F1_{00}M_2$	4.85	285	427	0.684	17.50	105	288	0.490
$I_{75}F1_{00}M_0$	4.30	285	400	0.570	17.35	105	285	0.765
$I_{75}F_{75}M_1$	4.60	285	415	0.570	15.80	420	265	0.785
$I_{75}F_{75}M_2$	4.30	285	395	0.665	15.50	420	260	0.816
$I_{75}F_{75}M_0$	4.35	285	395	0.725	14.80	420	244	0.954
$I_{175}F_{50}M_1$	3.65	285	345	0.775	14.05	315	228	1.026
$I_{75}F_{50}M_2$	3.80	285	340	0.932	13.60	315	220	1.032
$I_{75}F_{50}M_0$	3.15	285	285	0.944	13.55	315	210	1.166
$I_{50}F1_{00}M_1$	3.55	190	370	0.000	13.50	210	380	0.000
$I_{50}F1_{00}M_2$	3.35	190	363	0.336	13.15	210	372	0.812
$I_{50}F1_{00}M_0$	2.55	190	290	0.768	13.05	210	370	0.789
$I_{50}F_{75}M_1$	2.50	190	260	1.005	13.00	105	372	0.568
$I_{50}F_{75}M_2$	2.45	190	205	0.954	12.95	105	370	0.646
$I_{50}F_{75}M_0$	2.65	190	200	1.084	12.90	105	365	0.888
$I_{150}F_{50}M_1$	2.60	190	215	1.565	12.80	420	362	0.914
$I_{50}F_{50}M_2$	2.45	190	210	1.396	12.75	420	360	0.947
$I_{50}F_{50}M_0$	2.15	190	190	1.234	12.50	420	352	0.995
$I_{25}F1_{00}M_1$	1.70	95	395	0.000	11.80	315	420	0.000
$I_{25}F1_{00}M_2$	1.65	95	382	1.119	11.55	315	412	0.899
$I_{25}F1_{00}M_0$	1.60	95	367	1.205	11.00	315	390	1.054
$I_{25}F_{75}M_1$	1.50	95	350	0.968	10.50	210	375	0.973
$I_{25}F_{75}M_2$	1.45	95	330	1.119	10.55	210	370	1.124
$I_{25}F_{75}M_0$	1.40	95	310	1.219	9.85	210	350	1.009
$I_{125}F_{50}M_1$	1.25	95	270	1.195	9.10	105	310	1.145
$I_{25}F_{50}M_2$	1.25	95	265	1.243	9.00	105	305	1.154
$I_{25}F_{50}M_0$	1.20	95	220	1.506	8.70	105	280	1.269

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

(a) (b)

Figure 5: (a) Drip irrigation system; (b) Main and lateral pipes.

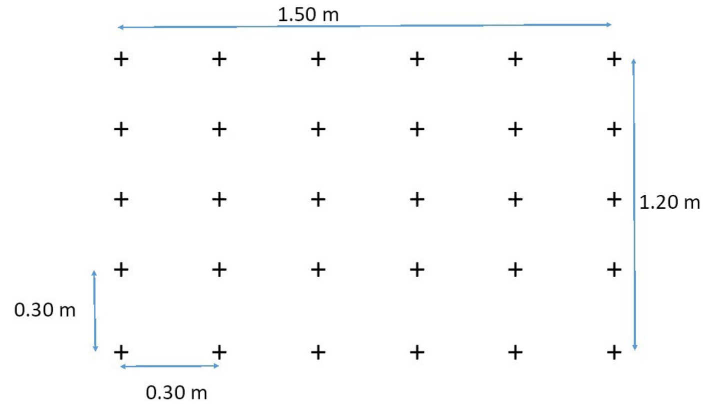

Figure 6: The detail of a plot.

Determination of crude protein ratio (%)

Protein determination was performed with the Kjeldahl method to determine the suitability of strawberries for current quality standards and human nutrition (Becerikli; Başoğlu, 2018).

Calculation;

% Nitrogen content (g/100 g) = Sample amount x 100
% Protein content = % Nitrogen content x 6.25

Determination of total anthocyanin content

After the fruit extract was prepared, the pH-differential method was applied to determine the total anthocyanin content. The amount of anthocyanin was calculated in terms of cyanidin 3-glucose in all samples (Abdalla et al., 2019; Demirdöven; Tokatlı; Korkmaz, 2021).

Determination of total phenolic content

After the extract was prepared from the strawberry fruits, the absorbance of the extract prepared at 725 nm wavelength was read using a spectrophotometer (Shimadzu UV - Vis 1800, Japan) (Demirdöven; Tokatlı; Korkmaz, 2021).

RESULTS AND DISCUSSION

Before planting strawberry seedlings, the moisture level in the soil was raised to the field capacity moisture level four days beforehand. The mulch was applied two days prior to planting. At the study site, 0 to 0.60 meters of soil depth was found to be at the correct field capacity moisture level. The first irrigation was completed one week after the strawberry seedlings were planted. During the duration of the study, the maximum and minimum irrigation water amounts were recorded to be 380-420 mm and 95-105 mm, respectively. The maximum and minimum evapotranspiration (ET) amounts in the 2019 and 2020 trial years were calculated as 440-465 mm and 220-280 mm, respectively (Table 5). The relationships between irrigation water (IW) and yield (Ya) and the relationship between evapotranspiration (ETa) and yield (Ya) for 2019 and 2020 are given in Figure 7. Tunc et al. (2019) applied

345.0, 272.4, and 218.9 mm of irrigation water from full irrigation application in the first year and 290.0, 236.1, and 181.6 mm of irrigation water from the second year of a two-year study conducted under Erzurum-Turkey conditions with three different drip irrigation systems (SD: surface drip irrigation, SSD: subsurface drip irrigation, and MD: surface drip irrigation with black polyethylene mulch) and four different irrigation levels (25%, 50, 75, and 100). In addition, it has been reported that the highest actual plant evapotranspiration values were measured at 529 mm in 2015 and 532 mm in 2016. Ariza et al. (2021) reported that while 400-510 mm of irrigation water was applied to Roceiera and Rabida strawberry varieties, where the highest yield was obtained, less irrigation water was applied to Sabrina (350 mm) and other strawberry varieties. In our study, the highest and lowest irrigation water amounts in both trial years were 380-95 mm and 420-105 mm, respectively, while the highest and lowest actual evapotranspiration values were 440-220 mm and 465-280 mm, respectively.

The highest evapotranspiration values were obtained from the $I_{100}F_{100}M_1$ subject, where full irrigation and fertigation were applied with black mulch material, while the lowest evapotranspiration values were obtained from the $I_{25}F_{50}M_0$ subject, where the lowest irrigation and fertigation were applied without mulch. These results were consistent with the irrigation water and plant water consumption values obtained from previous studies (Tunc et al., 2019; Ariza et al., 2021).

The crop yield response factor (ky) values in irrigation treatments I_{100}, I_{75}, $I_{50,}$ and I_{25} in both trial years were calculated as 0.76-0.60, 0.64-0.88, 1.04-0.82, and 1.20-1.08, respectively. The ky values increased with the decrease in irrigation water. The low ky values in the I_{75} treatments made it appropriate to reduce irrigation in the I_{75} treatments. The ky values in different irrigation level treatments during the trial years are given in Figure 8. There was a correlation between the crop yield response factor (ky) calculated in previous studies and the ky values calculated in this research (Tunc et al., 2019).

The maximum and minimum yield values of the study years were calculated as 5.05-18.70 t ha^{-1} and 1.20-8.7 t ha^{-1}, respectively, from the $I_{100}F_{100}M_1$ and $I_{25}F_{50}M_0$ treatments (Tables 6 and 7). In both years of the research, it was found to be significant at the 1% level in terms of yield values, irrigation water, fertigation amounts, and mulching treatments. The interaction of irrigation, fertigation, and mulching on yield was also found to be statistically significant at the 1% level. During the first year of the study, the yield values of strawberries were similar and differed in statistical classes; in the second year, statistical classes were formed as the primary statistical classes. While the yield values obtained from F_{100} and F_{75} irrigation subjects and the statistical classes containing these values were close to each other, it was determined that the yield values obtained, especially from the F_{25} irrigation treatments, were very low. During both research years, there was a decrease in yield that occurred with the decrease in fertigation level. Although the change in yield with mulching treatments showed differences in the first year of the study, it was determined that the highest yield was obtained from M_1 (black mulch treatment). M_1 was followed by M_2 (transparent mulch treatment) and M_0 (no mulch treatment). In the second year of the study, the highest yield values were obtained from the M_1 treatment, while the M_1 treatment was followed by the M_2 and M_0 treatments. When the treatments were evaluated in terms of mulching, it was determined that the yield values were in different statistical classes.

When statistically evaluating the quality parameters of strawberries, only the ascorbic acid values in 2020 were found to be insignificant in terms of irrigation factor. In terms of factors (irrigation, fertigation, and mulching) for the first year of the study, a 1% level of significance was found. Except for two fruit quality characteristics, all quality parameter values were found to be insignificant at the block level. Regarding blocks, fruit diameter was found to be significant at a level of 1%, while total acidity was found to be significant at a level of 5%. The interaction of irrigation-fertigation-mulching factors on fruit diameter, fruit weight, number of fruits per plant (NFPP), total soluble solids, total sugar, pH, titratable acidity, ascorbic acid, crude protein, anthocyanin, total phenolic content, and total flavonoids was also found to be significant at the 1% level. In terms of fruit length and dry matter, the interaction of irrigation, fertigation, and mulching was found to be significant at the 5% level. When the factors in the second year of the study were evaluated separately, all strawberry quality parameters were found to be statistically significant at the 1% level, except for one quality parameter (ascorbic acid). When the ascorbic acid values were evaluated in terms of the irrigation factor, they were found to be insignificant. Ascorbic acid values were found to be significant at a level of 1% in terms of fertigation and mulching. When evaluated at the level of blocks, it was found to be significant at the level of 1% in terms of total sugar and crude protein and at the level of 5% in terms of pH. Other quality parameters of strawberries were found to be insignificant at the block level. As in the first research year, the interaction of irrigation-fertigation-mulching factors on TSS and ascorbic acid was insignificant but significant at the 5% level in terms of titratable acidity. Other quality parameters were found to be significant at the 1% level. When the strawberry quality parameters in both research years were evaluated in terms of statistical classification, the fruit length, fruit diameter, fruit weight, number of fruits per plant (NFPP), ascorbic acid, crude protein, anthocyanin, total phenolic content, and total flavonoid amount increased with the increase in irrigation amount; and fertigation level. The amount of dry matter, TSS, and total sugar decreased as the amount of irrigation water increased. In addition, titratable acidity and pH values did not differ in terms of irrigation, fertigation, and mulching. When the effect of mulching treatments (M_1-M_2-M_0) on the quality parameters of strawberries was evaluated, it was observed that the average values obtained from the application with black mulch material (M_1) were higher, and the average values obtained from the M_2 and M_0 treatments were close to each other. Previous studies on the effects of irrigation-fertigation-mulching factors on the yield and quality parameters of strawberries and the values obtained from our present study were in agreement with each other (Rannu et al., 2018; Görgüç et al., 2019; Abdalla et al., 2019; Kumar; Kumar, 2020; Lewers et al., 2020; Erdoğan Bayram, 2020; Samtani; Rajevıch; Das, 2020; Ariza et al., 2021; Agehara; Nunes, 2021; Sarıdaş et al., 2021; Roussos et al., 2022; Kapur et al., 2022). The values and statistical classes of the quality parameters of strawberries are given in Tables 6, 7, 8, and 9 in detail.

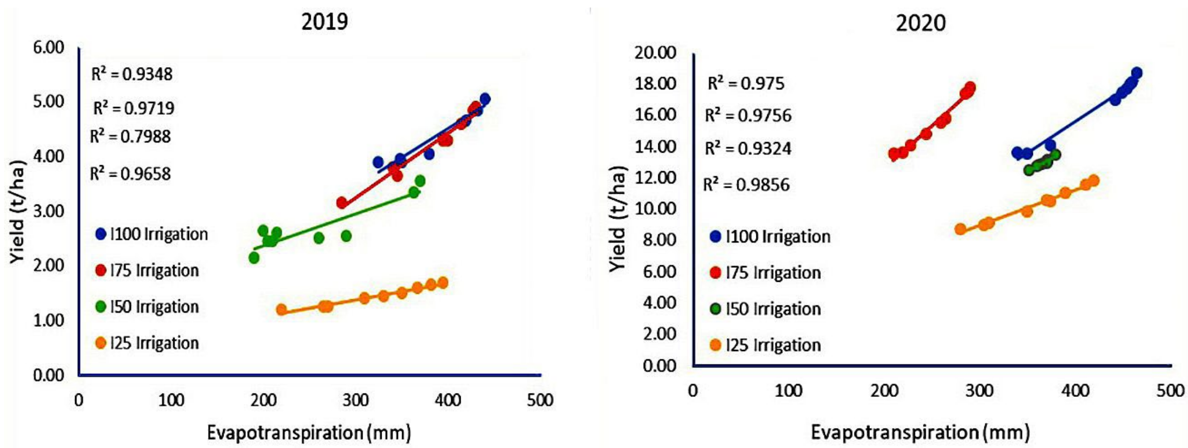

Figure 7: The relationship between Evapotranspiration (ETa) with yield (Ya) for 2019 and 2020 years.

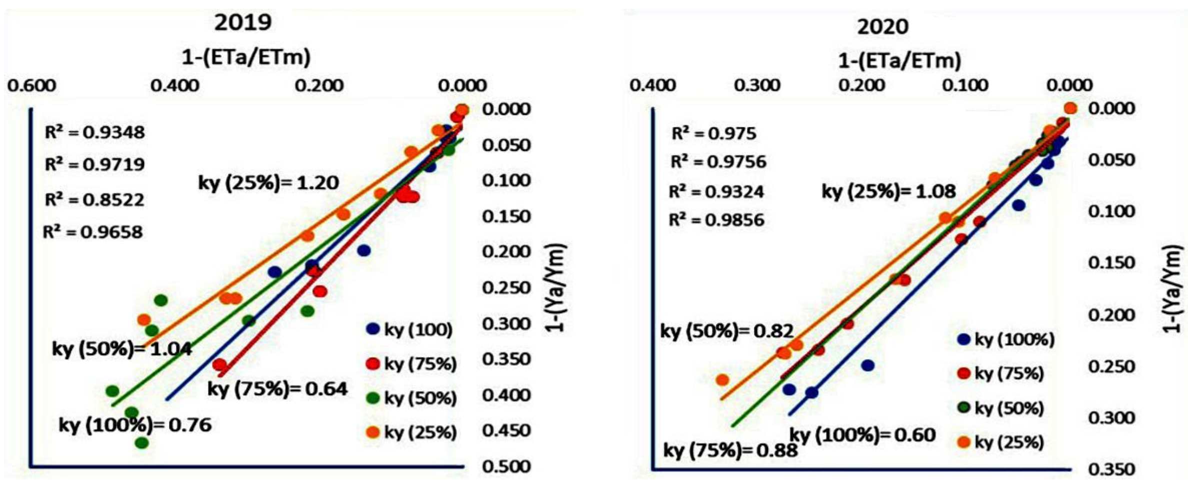

Figure 8: The relationship between relative yield (Ya) decrease and relative evapotranspiration (ETa) deficit for the experimental years (2019 and 2020).

Table 6: Quality parameters of strawberries in 2019.

Irrigation treatments	Fertigation treatments	Mulching treatments	Yield (t ha^{-1})	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits per plant	Dry matter (%)	Total soluble solids (°Brix)
I100 Irrigation (I_{100}: %100)	F1 (%100)	M1	5.05 a	4.05 a	3.90 ab	16.55 a	11.05 a	7.95 op	7.55 m
	F1 (%100)	M2	4.85 ab	3.95 ab	3.95 a	16.15 b	10.80 ab	8.25 mn	7.75 klm
	F1 (%100)	M0	4.65 bc	3.90 ab	3.90 ab	14.95 d	10.60 bc	8.55 hijk	7.90 ijk
	F2 (%75)	M1	4.85 ab	4.00 a	3.95 a	15.50 c	10.55 bc	7.80 pq	8.25 cdef
	F2 (%75)	M2	4.90 a	3.95 ab	3.80 bcd	15.55 c	10.35 cd	8.05 no	7.80 jkl
	F2 (%75)	M0	4.05 e	3.90 ab	3.85 abc	14.95 d	10.90 ab	8.30 lm	7.78 jklm
	F3 (%50)	M1	3.90 ef	3.80 bc	3.75 cd	12.25 k	10.35 cd	7.60 q	7.55 m
	F3 (%50)	M2	3.95 ef	3.55 defg	3.50 fg	11.70 l	10.00 defg	7.95 op	7.63 lm
	F3 (%50)	M0	3.90 ef	3.40 ghi	3.55 f	10.35 op	9.95 defgh	8.40 jkllm	7.73 klm
I75 Irrigation (I75: %75)	F1 (%100)	M1	4.90 a	3.80 bc	3.95 a	14.35 e	10.55 bc	8.45 ijklm	7.86 jkl
	F1 (%100)	M2	4.85 ab	3.70 cd	3.90 ab	13.75 g	10.05 def	8.55 hijk	7.82 jkl
	F1 (%100)	M0	4.30 d	3.65 cde	3.85 abc	12.95 i	10.00 defg	8.85 fg	7.93 hijk
	F2 (%75)	M1	4.60 c	3.80 bc	3.70 de	14.15 ef	10.35 cd	8.25 mn	7.90 ijk
	F2 (%75)	M2	4.30 d	3.60 def	3.60 ef	14.05 f	10.05 def	8.30 lm	7.90 ijk
	F2 (%75)	M0	4.35 d	3.40 ghi	3.50 fg	13.35 h	9.75 efghi	8.45 ijklm	7.95 hijk
	F3 (%50)	M1	3.65 gh	3.30 ij	3.55 f	10.40 op	10.10 de	8.35 klm	7.73 klm
	F3 (%50)	M2	3.80 fg	3.15 jk	3.40 g	10.50 o	9.85 efghi	8.35 klm	7.80 jkl
	F3 (%50)	M0	3.15 j	3.00 klm	3.25 h	9.55 s	9.60 ghi	8.50 hijkl	7.93 hijk
I50 Irrigation (I50: %50)	F1 (%100)	M1	3.55 hi	3.45 fghi	3.70 de	12.60 j	9.75 efghi	9.10 e	8.15 efgh
	F1 (%100)	M2	3.35 ij	3.50 efgh	3.60 ef	11.60 lm	9.65 fghi	9.45 bcd	8.23 cdefg
	F1 (%100)	M0	2.55 k	3.30 ij	3.55 f	11.50 lm	10.05 def	9.40 bcd	8.20 defg
	F2 (%75)	M1	2.50 k	3.35 hi	3.40 g	12.85 i	9.50 i	8.50 hijkl	7.95 hijk
	F2 (%75)	M2	2.45 k	3.00 klm	3.50 fg	11.45 m	9.05 j	8.70 gh	7.93 hijk
	F2 (%75)	M0	2.65 k	3.10 kl	3.55 f	10.95 n	8.95 jk	9.05 ef	8.85 b
	F3 (%50)	M1	2.60 k	2.75 no	3.05 i	10.20 p	9.55 hi	8.65 ghi	7.93 hijk
	F3 (%50)	M2	2.45 k	2.65 op	3.00 i	9.90 qr	8.85 jkl	8.60 hij	8.00 ghij
	F3 (%50)	M0	2.15 l	2.55 p	2.80 j	9.70 rs	8.55 kl	9.10 e	8.13 efghi
I25 Irrigation (I25: %25)	F1 (%100)	M1	1.70 m	3.05 klm	3.25 h	10.20 p	9.05 j	9.60 ab	8.25 cdef
	F1 (%100)	M2	1.65 mn	2.90 mn	3.00 i	11.10 n	8.90 jkl	9.50 bc	8.20 defg
	F1 (%100)	M0	1.60 mno	2.90 mn	2.75 j	10.35 op	9.65 fghi	9.75 a	8.40 cd
	F2 (%75)	M1	1.50 mno	2.90 mn	3.00 i	10.45 o	9.05 j	9.40 bcd	8.82 b
	F2 (%75)	M2	1.45 nop	3.05 klm	3.00 i	9.95 q	8.50 l	9.35 cd	9.25 a
	F2 (%75)	M0	1.40 opq	2.95 lm	3.10 i	9.55 s	8.60 kl	9.55 abc	9.35 a
	F3 (%50)	M1	1.25 pq	2.00 q	2.80 j	8.80 t	8.55 kl	9.25 de	8.28 cdef
	F3 (%50)	M2	1.25 pq	1.95 q	2.80 j	7.55 u	8.55 kl	9.45 bcd	8.35 cde
	F3 (%50)	M0	1.20 q	1.70 r	2.75 j	7.15 v	8.05 m	9.60 ab	8.45 c
Irrigation			**	**	**	**	**	**	**
Fertigation			**	**	**	**	**	**	**
Mulching			**	**	**	**	**	**	**
Blocks			ns	ns	**	ns	ns	ns	ns
I*F*M Interaction			**	*	**	**	**	*	**

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

Table 7: Quality parameters of strawberries in 2019.

Irrigation treatments	Fertigation treatments	Mulching treatments	Total sugar (%)	pH	Titratable acidity (%)	Ascorbic asid (mg 100g^{-1})	Crude protein (%)	Anthocyanins (mg 100g^{-1})	Fenolic compound (mg GAE 100G^{-1})	Flavonoids (mg CE 100g^{-1})
I100 Irrigation (I_{100}: %100)	F1 (%100)	M1	7.20 qr	3.45 jk	0.75 cd	91.35 a	8.32 fgh	37.45 b	245.65 a	68.80 a
	F1 (%100)	M2	7.33 nop	3.45 jk	0.71 fgh	84.35 gh	8.06 ij	38.55 a	243.30 b	68.35 a
	F1 (%100)	M0	7.33 nop	3.50 ij	0.65 i	63.25 o	7.98 j	35.00 e	240.75 cd	66.05 d
	F2 (%75)	M1	7.18 r	3.45 jk	0.75 cd	84.05 h	7.81 k	36.65 bc	241.10 c	66.90 c
	F2 (%75)	M2	7.20 qr	3.33 lm	0.74 cde	64.75 mn	7.80 k	35.95 cd	239.30 e	66.45 cd
	F2 (%75)	M0	7.30 op	3.38 kl	0.71 fgh	60.25 q	7.63 l	35.50 de	235.25 f	65.20 ef
	F3 (%50)	M1	7.27 pqr	3.32 lm	0.70 gh	56.70 tu	7.32 nop	30.10 hi	229.45 h	50.00 m
	F3 (%50)	M2	7.28 pq	3.35 lm	0.70 gh	58.85 r	7.30 op	30.25 hi	226.20 j	48.90 n
	F3 (%50)	M0	7.30 op	3.28 m	0.69 h	55.80 v	7.16 q	27.65 jk	220.35 l	47.65 o
I75 Irrigation (I75: %75)	F1 (%100)	M1	7.38 lmno	3.83 e	0.73 def	70.70 k	8.28 gh	32.25 g	238.65 e	68.70 a
	F1 (%100)	M2	7.36 mnop	3.98 d	0.74 cde	72.40 j	8.24 h	30.40 h	239.55 de	68.75 a
	F1 (%100)	M0	7.46 ijkl	3.95 d	0.63 i	60.10 q	8.05 j	30.25 hi	238.85 e	67.45 b
	F2 (%75)	M1	7.38 lmno	3.40 kl	0.72 efg	65.10 m	8.26 h	33.95 f	231.40 g	64.75 f
	F2 (%75)	M2	7.40 klmn	3.35 lm	0.74 cde	64.50 mn	8.14 i	33.80 f	231.45 g	65.05 ef
	F2 (%75)	M0	7.40 klmn	3.33 lm	0.71 fgh	64.20 n	8.14 i	33.45 f	227.85 i	64.75 f
	F3 (%50)	M1	7.40 klmn	3.40 kl	0.71 fgh	58.10 s	7.28 op	24.40 mn	214.55 n	48.95 n
	F3 (%50)	M2	7.40 klmn	3.33 lm	0.69 h	57.40 st	7.15 q	23.75 no	204.05 o	46.25 p
	F3 (%50)	M0	7.45 jklm	3.40 kl	0.64 i	54.80 w	7.17 q	20.95 q	196.85 p	43.20 q
I50 Irrigation (I50: %50)	F1 (%100)	M1	7.48 ijk	4.00 d	0.79 a	90.60 bc	8.43 de	25.55 l	235.75 f	65.35 e
	F1 (%100)	M2	7.68 fg	4.15 c	0.73 def	90.00 cd	8.36 efg	26.85 k	235.10 f	65.05 ef
	F1 (%100)	M0	7.55 hi	4.48 a	0.71 fgh	84.95 fg	8.38 def	24.95 lm	229.50 h	64.95 ef
	F2 (%75)	M1	7.40 klmn	3.55 hi	0.70 gh	70.15 k	8.30 fgh	27.75 jk	225.20 j	62.35 g
	F2 (%75)	M2	7.50 ij	3.55 hi	0.71 fgh	89.70 d	8.36 efg	29.45 i	226.10 j	60.50 ij
	F2 (%75)	M0	8.00 e	3.58 ghi	0.72 efg	68.15 l	8.50 gh	28.50 j	225.00 j	60.75 ij
	F3 (%50)	M1	7.54 hij	3.50 ij	0.71 fgh	58.85 r	7.26 p	19.75 r	190.50 q	40.25 r
	F3 (%50)	M2	7.63 gh	3.50 ij	0.74 cde	59.10 r	7.31 nop	19.25 rs	181.65 r	39.00 s
	F3 (%50)	M0	7.75 f	3.50 ij	0.75 cd	56.50 uv	7.34 nop	18.60 st	174.80 s	36.50 t
I25 Irrigation (I25: %25)	F1 (%100)	M1	7.60 gh	4.49 a	0.76 bc	91.30 ab	8.60 ab	23.15 op	222.85 k	62.85 g
	F1 (%100)	M2	8.00 e	4.45 ab	0.78 ab	90.90 ab	8.62 a	22.90 op	220.65 l	61.75 h
	F1 (%100)	M0	8.00 e	4.38 b	0.79 a	84.15 h	8.58 ab	22.65 p	219.70 l	60.90 i
	F2 (%75)	M1	8.18 cd	3.73 f	0.74 cde	85.70 e	8.46 cd	25.75 l	220.70 l	60.30 j
	F2 (%75)	M2	8.40 b	3.70 f	0.74 cde	85.10 ef	8.43 de	24.55 mn	219.75 l	58.95 k
	F2 (%75)	M0	8.68 a	3.83 e	0.73 def	83.15 i	8.53 bc	22.95 op	217.80 m	58.40 l
	F3 (%50)	M1	8.27 c	3.60 gh	0.73 def	62.10 p	7.39 mn	18.10 tu	170.90 t	33.35 u
	F3 (%50)	M2	8.00 e	3.70 f	0.75 cd	60.75 q	7.46 m	17.90 tu	167.00 u	32.75 v
	F3 (%50)	M0	8.10 d	3.65 g	0.72 efg	60.25 q	7.36 no	17.6 u	164.75 v	31.20 w
Irrigation			**	**	**	**	**	**	**	**
Fertigation			**	**	**	**	**	**	**	**
Mulching			**	**	**	**	**	**	**	**
Blocks			ns	ns	*	ns	ns	ns	ns	ns
I*F*M Interaction			**	**	**	**	**	**	**	**

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

Table 8: Quality parameters of strawberries in 2020.

Fertilization treatments	Irrigation treatments	Mulching treatments	Yield (t ha^{-1})	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits per plant	Dry matter (%)	Total soluble solids (°Brix)
	F1 (%100)	M1	18.70 a	4.05 b	4.05 ab	18.35 a	11.55 bc	7.65 o	7.20 p
	F1 (%100)	M2	17.95 c	4.23 a	4.00 ab	18.15 ab	11.45 c	7.70 no	7.25 op
	F1 (%100)	M0	17.70 d	3.95 bcd	3.95 bc	18.00 b	11.40 cd	8.00 lm	7.33 nop
	F2 (%75)	M1	18.10 b	4.00 bc	3.85 cd	16.95 d	11.85 ab	7.85 mno	7.53 klmnop
I100 Irrigation (I_{100}: %100)	F2 (%75)	M2	17.40 ef	3.95 bcd	3.95 bc	17.55 c	12.10 a	8.00 lm	7.73 ijklm
	F2 (%75)	M0	16.95 g	3.90 cd	3.95 bc	16.85 d	11.50 c	7.95 lm	7.63 jklmn
	F3 (%50)	M1	14.05 k	3.95 bcd	3.85 cd	14.35 j	11.00 e	8.00 lm	7.50 lmnop
	F3 (%50)	M2	13.44 m	3.95 bcd	3.70 efg	13.90 k	10.55 f	7.95 lm	7.44 mnop
	F3 (%50)	M0	13.60 l	3.90 cd	3.75 def	13.30 l	10.35 fg	8.45 hij	7.53 klmnop
	F1 (%100)	M1	17.75 d	3.90 cd	4.10 a	16.55 e	11.10 de	7.90 lmn	7.20 p
	F1 (%100)	M2	17.50 e	4.20 a	4.05 ab	16.50 e	11.05 e	8.00 lm	7.43 mnop
	F1 (%100)	M0	17.35 f	4.05 b	3.80 de	16.05 f	11.55 bc	8.55 ghi	7.58 jklmno
	F2 (%75)	M1	15.80 h	3.85 de	3.80 de	16.50 e	11.55 bc	7.85 mno	7.78 hijklm
I75 Irrigation (I75: %75)	F2 (%75)	M2	15.50 i	4.00 bc	3.65 fgh	16.05 f	11.50 c	8.30 jk	7.85 ghijkl
	F2 (%75)	M0	14.80 j	3.70 fg	3.50 ijk	16.05 f	11.05 e	8.65 fgh	7.88 ghijk
	F3 (%50)	M1	14.05 k	3.60 ghi	3.60 ghi	12.95 m	11.00 e	8.40 ij	7.50 lmnop
	F3 (%50)	M2	13.60 l	3.50 ij	3.45 jkl	12.45 op	10.00 h	8.10 kl	7.60 jklmno
	F3 (%50)	M0	13.55 lm	3.75 ef	3.55 hij	12.00 q	9.00 k	8.80 ef	7.75 hijklm
	F1 (%100)	M1	13.50 lm	4.00 bc	3.85 cd	13.25 l	10.45 f	8.80 ef	8.00 efghi
	F1 (%100)	M2	13.15 mn	3.55 hij	3.75 def	12.70 n	10.55 f	8.75 fg	7.93 fghij
	F1 (%100)	M0	13.05 n	3.90 cd	3.80 de	12.25 p	10.05 gh	9.05 d	8.30 cde
	F2 (%75)	M1	13.00 no	3.50 ij	3.60 ghi	15.75 g	11.00 e	8.85 def	8.25 cdef
I50 Irrigation (I50: %50)	F2 (%75)	M2	12.95 no	3.65 fgh	3.40 klm	15.40 h	10.50 f	9.00 de	8.40 cd
	F2 (%75)	M0	12.90 op	3.45 j	3.35 lmn	14.85 i	10.05 gh	9.40 c	8.28 cdef
	F3 (%50)	M1	12.80 pq	3.60 ghi	3.30 mn	10.60 u	10.90 e	9.00 de	7.75 hijklm
	F3 (%50)	M2	12.75 q	3.45 j	3.25 n	10.25 v	10.40 f	9.00 de	7.85 ghijkl
	F3 (%50)	M0	12.50 r	3.45 j	2.95 o	9.55 x	9.40 ij	9.55 bc	7.88 ghijk
	F1 (%100)	M1	11.80 s	3.45 j	3.50 ijk	11.95 q	9.95 h	9.35 c	8.48 c
	F1 (%100)	M2	11.55 t	3.50 ij	3.55 hij	11.40 s	9.40 ij	9.55 bc	8.48 c
	F1 (%100)	M0	11.00 u	3.45 j	3.35 lmn	11.15 t	8.95 k	10.30 a	8.85 b
	F2 (%75)	M1	10.50 v	3.00 lm	3.00 o	13.35 l	9.55 i	9.35 c	8.85 b
I25 Irrigation (I25: %25)	F2 (%75)	M2	10.55 v	2.90 m	2.90 op	12.55 no	9.55 i	9.50 bc	9.45 a
	F2 (%75)	M0	9.85 w	2.95 m	2.90 op	11.65 r	8.90 k	9.50 bc	8.43 cd
	F3 (%50)	M1	9.10 x	3.30 k	3.00 o	9.85 w	9.15 jk	9.45 c	7.88 ghijk
	F3 (%50)	M2	8.93 y	3.10 l	2.80 q	9.35 x	8.50 l	9.50 bc	8.10 defgh
	F3 (%50)	M0	8.70 z	2.95 m	2.75 q	9.40 x	7.90 m	9.70 b	8.15 cdefg
Irrigation			**	**	**	**	**	**	**
Fertigation			**	**	**	**	**	**	**
Mulching			**	**	**	**	**	**	**
Blocks			ns	ns	ns	ns	ns	ns	ns
I*F*M Interaction			**	**	**	**	**	**	ns

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

Table 9: Quality parameters of strawberries in 2020.

Irrigation treatments	Fertigation treatments	Mulching treatments	Total sugar (%)	pH	Titratable acidity (%)	Ascorbic asid (mg 100g^{-1})	Crude protein (%)	Anthocyanins (mg 100g^{-1})	Fenolic compound (mg GAE 100G^{-1})	Total flavonoids (mg CE 100g^{-1})
I100 Irrigation (I_{100}: %100)	F1 (%100)	M1	6.95 lm	3.42 ijk	0.76 cde	95.45 ab	8.54 efgh	42.30 a	245.10 a	68.80 b
	F1 (%100)	M2	7.00 l	3.40 jk	0.77 bcd	96.35 a	8.55 defg	40.20 b	243.70 b	69.45 a
	F1 (%100)	M0	7.00 l	3.45 hij	0.75 def	90.35 ab	8.56 defg	37.80 c	241.10 c	69.30 a
	F2 (%75)	M1	7.30 k	3.40 jk	0.76 cde	95.00 ab	8.50 ghi	37.10 de	240.80 c	68.00 c
	F2 (%75)	M2	7.50 i	3.47 hi	0.76 cde	93.60 ab	8.53 efgh	37.60 cd	239.70 d	67.15 d
	F2 (%75)	M0	7.30 k	3.43 hijk	0.76 cde	87.55 ab	8.43 ij	36.90 e	235.60 e	66.85 de
	F3 (%50)	M1	7.28 k	3.40 jk	0.74 efg	59.80 e	7.99 k	30.05 ij	224.50 j	51.10 o
	F3 (%50)	M2	7.24 k	3.45 hij	0.74 efg	60.50 e	7.96 kl	28.40 l	219.90 n	49.05 p
	F3 (%50)	M0	7.28 k	3.33 lm	0.72 ghi	56.05 e	7.85 no	27.35 mn	217.75 o	47.90 q
I75 Irrigation (I75: %75)	F1 (%100)	M1	7.00 l	3.69 d	0.77 bcd	92.60 ab	8.62 bcd	33.10 g	241.10 c	68.80 b
	F1 (%100)	M2	6.90 m	3.68 d	0.73 fgh	93.80 ab	8.58 cdef	30.60 h	239.65 d	68.40 bc
	F1 (%100)	M0	7.25 k	3.60 ef	0.70 ij	88.10 ab	8.55 defgh	30.10 hi	238.85 d	68.00 c
	F2 (%75)	M1	7.48 ij	3.39 k	0.75 def	85.15 abc	8.48 hi	35.35 f	230.65 f	65.75 g
	F2 (%75)	M2	7.48 ij	3.33 lm	0.73 fgh	83.05 abc	8.50 ghi	35.20 f	228.85 g	64.95 h
	F2 (%75)	M0	7.65 h	3.30 m	0.70 ih	80.25 bcd	8.43 ij	33.45 g	228.60 h	65.15 h
	F3 (%50)	M1	7.30 k	3.43 hijk	0.70 ij	64.00 e	7.98 k	24.60 op	212.40 o	48.90 p
	F3 (%50)	M2	7.41 j	3.28 m	0.71 hi	63.40 e	7.73 q	23.80 qr	207.90 p	46.45 r
	F3 (%50)	M0	7.50 i	3.20 n	0.67 k	60.45 e	7.75 pq	20.50 u	194.35 q	42.90 s
I50 Irrigation (I50: %50)	F1 (%100)	M1	7.40 j	3.87 c	0.79 ab	93.80 ab	8.64 bc	27.85 m	236.30 e	66.55 ef
	F1 (%100)	M2	7.50 i	3.88 bc	0.77 bcd	94.75 ab	8.54 efgh	27.00 n	233.15 e	66.85 de
	F1 (%100)	M0	7.70 fgh	3.83 c	0.75 def	90.90 ab	8.40 j	24.15 pq	227.95 hi	66.40 f
	F2 (%75)	M1	7.70 fgh	3.65 de	0.70 ij	87.55 ab	8.60 cde	29.60 ijk	228.30 hi	61.90 j
	F2 (%75)	M2	7.78 f	3.61 ef	0.75 def	64.75 de	8.55 defgh	29.25 k	227.80 ij	60.20 k
	F2 (%75)	M0	8.00 e	3.53 g	0.75 def	61.75 e	8.53 efgh	29.55 jk	227.35 ij	59.90 kl
	F3 (%50)	M1	7.63 h	3.38 kl	0.70 ij	61.85 e	7.88 mno	19.35 v	189.35 r	40.10 t
	F3 (%50)	M2	7.65 h	3.38 kl	0.71 hi	57.35 e	7.90 lmn	19.35 v	180.50 s	38.90 u
	F3 (%50)	M0	7.67 gh	3.31 m	0.68 jk	56.85 e	7.81 op	18.50 w	171.40 t	37.20 v
I25 Irrigation (I25: %25)	F1 (%100)	M1	7.78 f	4.03 a	0.80 a	91.25 ab	8.74 a	21.45 s	223.20 k	63.90 i
	F1 (%100)	M2	8.00 e	3.93 b	0.78 bc	90.75 ab	8.68 ab	21.15 st	220.60 n	64.00 i
	F1 (%100)	M0	8.20 d	3.93 b	0.75 def	88.15 ab	8.72 a	20.70 tu	218.25 n	62.10 j
	F2 (%75)	M1	8.30 c	3.68 d	0.73 fgh	71.05 cde	8.54 efgh	24.90 o	222.20 l	59.75 lm
	F2 (%75)	M2	8.41 b	3.69 d	0.71 hi	71.05 cde	8.62 bcd	23.90 qr	220.65 m	59.45 mn
	F2 (%75)	M0	8.50 a	3.59 f	0.70 ij	70.25 cde	8.51 fgh	23.50 r	219.80 n	59.25 n
	F3 (%50)	M1	7.75 fg	3.45 hij	0.70 ij	63.80 e	7.94 klm	17.55 x	169.95 u	34.85 w
	F3 (%50)	M2	8.05 e	3.48 gh	0.68 jk	62.35 e	7.99 k	17.65 x	166.00 v	33.65 x
	F3 (%50)	M0	8.00 e	3.43 hijk	0.66 k	60.70 e	7.88 mno	16.95 y	162.25 x	30.60 y
Irrigation			**	**	**	ns	**	**	**	**
Fertigation			**	**	**	**	**	**	**	**
Mulching			**	**	**	**	**	**	**	**
Blocks			**	*	ns	ns	**	ns	ns	ns
I*F*M Interaction			**	**	*	ns	**	**	**	**

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

CONCLUSIONS

A three-factor study determined that irrigation, fertigation, and mulching had significant effects on the yield and quality characteristics of strawberries. However, I_{75} and F_{75} types can be recommended when the reductions in yield and quality losses are evaluated together, despite the reductions in irrigation water and fertigation levels. Additionally, in mulching treatments, black mulch material (M_1) should be chosen over clear mulch material (M_1) and no mulch (M_0).

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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