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Research article

Integrated water, nutrient, and mulch management enhances yield efficiency and quality in globe artichoke

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ABSTRACT: The effect of two variables interacting on crops has been the focus of most agronomic research. This study looked into how three factors interact to affect artichokes. The purpose of this study was to investigate how mulching, fertilizer, and irrigation affected artichoke yield (Ya) and quality characteristics between 2019 and 2020. Three mulching treatments, three fertilization levels, and three irrigation levels were combined to yield 27 study conditions. To carry out fertilization and irrigation processes in a controlled manner, the study recommended the use of drip irrigation systems. For the 2019-2020 study years, the Ya values were a minimum of 20.7-30.5 t ha^{-1} and a maximum of 48.6-50 t ha^{-1}, respectively. Comparing the greatest artichoke head Ya data from 2019-2020 with those from other study subjects revealed Ya losses ranging from 2.7 to 57.4 and 4.0 to 39.2, respectively. The irrigation water (IW) levels ranged from a minimum of 240.0 to 246.0 mm and a maximum of 480.0 to 492.0 mm. The lowest and highest ET values ranged from 228.5-340.8 and 530.0-552.0 mm, respectively. When the interactions of irrigation-fertilization-mulching triple factors with Ya and quality losses in semi-arid climate conditions are evaluated, $I_{75}F_{75}M_1$ (I_{75} = 75 % irrigation; F_{75} = 75 % fertigation; M_1 = black mulching material) can be recommended.

Keywords: drip irrigation, factor interaction, irrigation planning, ky factor, plant nutrition

Introduction

Artichoke (*Cynara scolymus* L.), indigenous to the Mediterranean region, is abundant in both wild and cultivated varieties in Turkey, which lies within this basin. It is farmed and produced in Turkey, mirroring global trends, with production increasing every year (Öztürk et al., 2020). World artichoke output for 2019, 2020, and 2021 was recorded at 1,583,584 t, 1,519,336 t, and 1.551.288 t, respectively. In these years, artichoke production in Turkey was recorded at 39,071 t, 39,280 t, and 40.114 t, respectively (FAO, 2023).

The artichoke variety Bayrampaşa is suitable for both canned and fresh consumption, and is grown mainly in the Marmara region, Istanbul, and Bursa districts. (Demirci et al., 2023). In several studies conducted in Turkey, it has been observed that various curtailed irrigation practices have significant effects on artichoke yield (Ya) (Öztürk et al., 2020). A study on artichokes highlighted the importance of using irrigation technologies that conserve water by increasing water usage and irrigation efficiency (Deligios et al., 2019). In recent years, artichoke growers have been applying high doses of nitrogen, phosphorus, and potassium (NPK) fertilizers to accelerate plant growth and maximize economic Ya (Ismail et al., 2022; Salata et al., 2022; Lombardo et al., 2022).

Producers have long used mulching as a cultural practice and know that it provides significant benefits to the soil and plants. Many different materials are used for mulching, but polyethylene (plastic) has recently become the material of choice. Dark-colored mulches contribute much more to the growth and Ya of the plant due to the appropriate temperature, humidity, and reflection of sunlight from the mulch in the root zone of the plant (Abdalla et al., 2019; Goldberger et al., 2019).

This study was undertaken because of the lack of research on the interplay among irrigation, fertilization, and mulching in artichoke, despite the proliferation of studies on irrigation and fertilization alone.

Materials and Methods

Experimental area and conditions

The Marmara Region of Bursa province, located at 40°15′09″ N, 29°38′43″ E, at an altitude of 225 m above mean sea level, was the study's site in 2019 and 2020. The Yenişehir region experiences a semi-arid climate in summer and moderate precipitation in winter. The minimum and maximum temperatures in the research region for two years were documented as 5.6-30.8 and 5.7-31.7 °C, respectively. The associated rainfall measurements were recorded as 92.0 and 47.3 mm, as illustrated in Figure 1. According to the MEVBIS (2021a), the mean relative humidity for 2019 and 2020 was 69.5 and 72.4 %, as depicted in Figure 1. The meteorological station located 6 km away from the trial area provided the minimum and maximum radiation values. The minimum and maximum solar radiation values were determined to be 335-1542 and 139-1983 W m^{-2}, respectively (Figure 1), as stated in the MEVBIS (2021b). The climate values of the research area in both experimental years are shown in Tables 1 and 2. One month prior to the planting of artichoke shoots in the research area, soil samples were collected from various locations and depths. The mean pH values for the 0-0.90 m soil profile were 7.85 and 8.18, respectively (Table 3). The IW sourced from a well in the trial area was analyzed prior to the commencement of the research, revealing that it fell within the C_2S_1 quality classification. Waters with a C_2S_1 classification, which have low sodium and moderate electrical conductivity, can be used for irrigation in a variety of vegetable crops (Table 4). IW of quality class C_2S_1 can be used for many artichoke cultivars (Ismail et al., 2022). As a base fertilizer, 0.5 t ha^{-1} 20-20-20 fertilizer was incorporated into the soil 20 days before the artichoke seedlings were planted. Against artichoke pests, chlorpyrifos-ethyl was used as a chemical pesticide.

Experimental treatments: irrigation, fertigation, and mulching

The study implemented three distinct irrigation levels and three fertilization levels, applied in a controlled manner across various treatment groups. IW was sourced from a well drilled in the field utilizing a sump pump. The well depth from which the water was sourced was18 m, with the pump operating at 12 m of water. With a flow rate of 16 m^3 h^{-1}, the sump pump efficiently provided the trial area with the water it needed. Plots were planted with artichoke seedlings spaced 0.50 m within and 1 m between rows. The preferred emitter spacing in the lateral pipes was 0.30 m, with each emitter delivering a flow rate of 4 L h^{-1}. To determine water quantities, it was essential to assess soil moisture content before and after irrigation. Moisture levels were evaluated using the gravimetric method, focusing on the 0-0.90 m soil depth, depending on the artichoke's root length. The water balance equation yielded the most precise estimate of evapotranspiration (ET); therefore, calculations were conducted using Eq. (1).

$$ET = I + P - Rf - Dp \pm \Delta S \quad (1)$$

Equation (1) defines the variables I, Rf, P, Dp, ET, and ΔS, corresponding to the IW amount during the period (mm), surface runoff (mm), total rainfall (mm), deep drainage (mm), evapotranspiration (mm), and soil water content (mm) at the beginning and end of the period, accordingly. The significance of deep drainage (Dp) was overlooked. Artichoke roots and water were unable to penetrate soil depths exceeding 120 cm. The calculation of surface runoff (Rf) is presented in Eq. (2):

$$Rf = P - (Dp + E) \quad (2)$$

In the equation, surface runoff is denoted by Rf, precipitation by P, infiltration by Dp, and evaporation by E. The runoff coefficient was found to be 0.50 for level agricultural regions with inclinations ranging from 0-5 % and clay silt loam soils in accordance with the rational technique (Q = C..i..A). The wet area ratio was determined using Eq. (3), as the spacing between plant rows exceeded the spacing between drippers.

$$P = \frac{Sd}{Sl} x100 \quad (3)$$

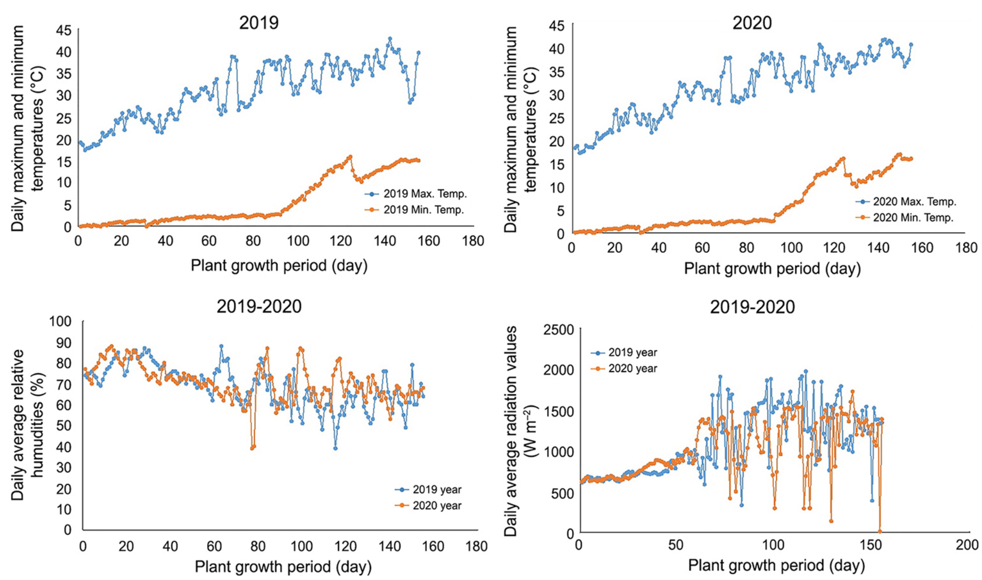

Figure 1 – Maximum (Max.) and minimum temperature (Temp.) values (°C), daily average relative humidities (%) and daily average radiation values (W m^{-2}) in 2019 and 2020.

Table 1 – Some climate characteristics of the research area and monthly artichoke head diameter growth in 2019.

	2019												
Meteological Elements	1	2	3	4	5	6	7	8	9	10	11	12	Annual
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 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
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
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 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 wind speed	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
Number of rainy days	3	7	6	9	9	9	9	8	9	8	9	9	95.0
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
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
Fastest blowing wind	22.1	19	18	14.9	25.7	15.9	15.4	14.9	25.2	15.9	25.7	20.5	19.4
Fastest wind direction	W	WSW	S	W	W	SSW	WSW	WSW	W	N	N	W	W
Average diameter growt (cm)													
$I_{100}F_{100}M_1$	-	-	-	0.5	2.5	5.5	9.8	13.4	13.2	-	-	-	13.3
$I_{100}F_{100}M_2$	-	-	-	0.6	2.8	5.3	9.2	13.0	13.4	-	-	-	13.2
$I_{100}F_{100}M_0$	-	-	-	0.5	3.0	5.7	9.5	13.4	13.0	-	-	-	13.2
$I_{100}F_{75}M_1$	-	-	-	0.6	2.7	6.0	9.4	13.0	13.0	-	-	-	13.0
$I_{100}F_{75}M_2$	-	-	-	0.4	2.4	6.2	9.0	12.8	13.0	-	-	-	12.9
$I_{100}F7_5M_0$	-	-	-	0.5	3.2	6.5	8.9	13.0	13.0	-	-	-	13.0
$I_{100}F_{50}M_1$	-	-	-	0.5	3.4	5.4	9.0	12.9	12.7	-	-	-	12.8
$I_{100}F_{50}M_2$	-	-	-	0.6	3.5	5.8	8.6	12.3	12.3	-	-	-	12.3
$I_{100}F_{50}M_0$	-	-	-	0.5	3.2	6.7	8.7	12.1	12.3	-	-	-	12.2
$I_{75}F_{100}M_1$	-	-	-	0.4	2.6	6.5	8.9	13.1	12.9	-	-	-	13.0
$I_{75}F_{100}M_2$	-	-	-	0.3	2.7	6.2	9.0	13.3	12.7	-	-	-	13.0
$I_{75}F_{100}M_0$	-	-	-	0.4	3.0	6.0	9.1	12.8	13.0	-	-	-	12.9
$I_{75}F_{75}M_1$	-	-	-	0.5	2.9	6.7	9.6	12.4	12.0	-	-	-	12.2
$I_{75}F_{75}M_2$	-	-	-	0.6	2.8	6.6	9.8	11.7	11.9	-	-	-	11.8
$I_{75}F_{75}M_0$	-	-	-	0.7	3.6	6.3	9.5	11.5	11.5	-	-	-	11.5
$I_{75}F_{50}M_1$	-	-	-	0.5	3.5	6.2	9.6	11.5	11.7	-	-	-	11.6
$I_{75}F_{50}M_2$	-	-	-	0.6	3.1	6.0	8.4	11.1	10.9	-	-	-	11.0
$I_{75}F_{50}M_0$	-	-	-	0.7	3.0	6.3	8.2	10.7	10.7	-	-	-	10.7
$I_{50}F_{100}M_1$	-	-	-	0.6	2.4	6.1	9.3	12.7	12.5	-	-	-	12.6
$I_{50}F_{100}M_2$	-	-	-	0.4	2.5	5.8	9.4	12.0	12.4	-	-	-	12.2
$I_{50}F_{100}M_0$	-	-	-	0.3	2.6	5.9	8.8	11.8	12.0	-	-	-	11.9
$I_{50}F_{75}M_1$	-	-	-	0.5	2.9	5.3	8.6	11.5	11.5	-	-	-	11.5
$I_{50}F_{75}M_2$	-	-	-	0.4	2.5	5.4	8.7	11.7	11.5	-	-	-	11.6
$I_{50}F_{75}M_0$	-	-	-	0.4	3.0	5.2	8.9	11.5	11.5	-	-	-	11.5
$I_{50}F_{50}M_1$	-	-	-	0.5	3.1	5.4	8.5	10.4	10.4	-	-	-	10.4
$I_{50}F_{50}M_2$	-	-	-	0.5	3.4	5.7	8.0	10.4	10.0	-	-	-	10.2
$I_{50}F_{50}M_0$	-	-	-	0.4	3.5	5.5	8.0	10.0	10.0	-	-	-	10.0

I = irrigation (%); F = fertigation (%); M_1 = black mulching material; M_2 = transparent mulch; M_0 = no mulch. W = west; WSW = west-southwest; S = south; SSW = south-southwest; N = north.

The symbols *P*, *Sd*, and *Sl* in Eq. (3) refer to the wetted area ratio (%), dripper spacing (m), and lateral spacing (m), respectively.

$$dn = \frac{(FC - WP)}{100} xRyx\gamma txD \tag{4}$$

In Eq. (4), the symbols *FC*, *WP*, R_y, γt, *D*, and *P* stand for field capacity (%), wilting point (%), the portion of the usable water storage capacity that is permitted to be consumed (%), soil volume weight (g cm^{-3}), and wet soil depth (mm), respectively.

$$\left(1 - \frac{Ya}{Ym}\right) = kyx\left(1 - \frac{ETa}{ETm}\right) \tag{5}$$

The symbols *Ya*, *Ym*, *ETa*, and *ETm* refer to the actual yield (t ha^{-1}), maximum yield (t ha^{-1}), actual evapotranspiration (mm), and maximum evapotranspiration (mm), respectively, in Eq. (5). The yield response factor (ky) expresses the relative yield reductions that occur in yield in response to relative reductions in plant water consumption.

Three different irrigation levels (I_{100}, I_{75}, I_{50}) were applied in the study. In I_{100}, the plant's IW need was

Table 2 – Some climate characteristics of the research area and monthly artichoke head diameter growth in 2020.

	2020												
Meteological Elements	1	2	3	4	5	6	7	8	9	10	11	12	Annual
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 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
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 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 local pressure	990.1	991	987.4	988.1	985.9	984.9	983.8	985.1	987.9	990.6	991.6	990	988
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 wind speed	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
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
Fastest blowing wind	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 wind direction	S	S	WNW	S	WNW	WSW	W	W	NNW	WSW	SSE	SSW	W
Average diameter growth (cm)													
$I_{100}F_{100}M_1$	-	-	-	-	0.3	3.5	7.4	10.7	13.2	13.6	-	-	13.4
$I_{100}F_{100}M_2$	-	-	-	-	0.4	3.6	7.5	10.6	13.0	13.4	-	-	13.2
$I_{100}F_{100}M_0$	-	-	-	-	0.2	3.7	7.5	10.9	12.9	13.1	-	-	13.0
$I_{100}F_{75}M_1$	-	-	-	-	0.4	3.5	7.3	10.5	12.8	12.8	-	-	12.8
$I_{100}F_{75}M_2$	-	-	-	-	0.3	3.5	7.5	10.2	12.8	13.0	-	-	12.9
$I_{100}F_{75}M_0$	-	-	-	-	0.5	3.4	7.2	10.0	12.7	13.1	-	-	12.9
$I_{100}F_{50}M_1$	-	-	-	-	0.3	3.6	7.4	10.1	12.7	12.9	-	-	12.8
$I_{100}F_{50}M_2$	-	-	-	-	0.4	3.6	7.5	10.4	12.0	12.4	-	-	12.2
$I_{100}F_{50}M_0$	-	-	-	-	0.5	3.8	7.6	10.5	12.0	12.6	-	-	12.3
$I_{75}F_{100}M_1$	-	-	-	-	0.3	3.9	7.7	10.2	13.0	13.6	-	-	13.3
$I_{75}F_{100}M_2$	-	-	-	-	0.2	4.0	7.5	10.6	13.1	13.3	-	-	13.2
$I_{75}F_{100}M_0$	-	-	-	-	0.3	3.5	7.3	10.4	12.3	12.3	-	-	12.3
$I_{75}F_{75}M_1$	-	-	-	-	0.4	3.6	7.2	10.0	12.3	12.5	-	-	12.4
$I_{75}F_{75}M_2$	-	-	-	-	0.5	3.8	7.1	9.7	11.7	11.9	-	-	11.8
$I_{75}F_{75}M_0$	-	-	-	-	0.4	4.1	7.3	9.9	11.5	11.3	-	-	11.4
$I_{75}F_{50}M_1$	-	-	-	-	0.3	4.2	7.0	9.8	11.5	11.7	-	-	11.6
$I_{75}F_{50}M_2$	-	-	-	-	0.2	4.3	7.0	10.0	11.2	11.2	-	-	11.2
$I_{75}F_{50}M_0$	-	-	-	-	0.3	4.0	7.1	10.5	11.5	11.3	-	-	11.4
$I_{50}F_{100}M_1$	-	-	-	-	0.3	3.9	6.9	10.6	12.5	12.9	-	-	12.7
$I_{50}F_{100}M_2$	-	-	-	-	0.4	3.8	6.8	10.5	12.4	12.6	-	-	12.5
$I_{50}F_{100}M_0$	-	-	-	-	0.3	3.5	7.0	10.2	12.5	12.3	-	-	12.4
$I_{50}F_{75}M_1$	-	-	-	-	0.2	3.8	7.1	10.3	12.3	12.7	-	-	12.5
$I_{50}F_{75}M_2$	-	-	-	-	0.2	3.5	6.7	10.0	11.5	11.5	-	-	11.5
$I_{50}F_{75}M_0$	-	-	-	-	0.3	3.9	6.8	9.6	11.1	11.3	-	-	11.2
$I_{50}F_{50}M_1$	-	-	-	-	0.5	3.7	6.5	9.4	11.0	11.0	-	-	11.0
$I_{50}F_{50}M_2$	-	-	-	-	0.4	3.4	6.4	9.1	10.9	11.1	-	-	11.0
$I_{50}F_{50}M_0$	-	-	-	-	0.3	3.3	6.2	9.0	10.2	10.4	-	-	10.3

I = irrigation (%); F = fertigation (%); M_1 = black mulching material; M_2 = transparent mulch; M_0 = no mulch. S = south; WNW = west-northwest; WSW = west-southwest; W = west; NNW = north-northwest; SEE = south-southeast; SSW = south-southwest.

fully met. In I_{75} and I_{50}, IW was applied at 50 % and 75 % of full irrigation, respectively. Three different fertigation levels were applied: F_{100}, F_{75}, and F_{50}. At the F_1 level, the full amount of NPK fertilizer required by the artichoke was applied to the plant, while at the F_2 and F_3 levels, 50 % and 75 % of the full amount was applied, respectively. Therefore, fertigation levels F_{100}, F_{75}, and F_{50} were selected. Nitrogen (N) fertilizers were applied in three distinct stages. N fertilizer was applied as ammonium nitrate (33 %) during the first week of planting artichoke seedlings, at a rate of 0.4 t ha^{-1} for the F_1 treatment. During the second and third stages, ammonium nitrate fertilizer (33 %) was applied at a rate of 0.4 t ha^{-1} for the F_1 treatment during head formation and close to harvest. In F_2 and F_3, the same type of fertilizer was applied at rates of 30 and 0.2 t ha^{-1}, respectively, across three periods. Phosphorus (P) and potassium (K) fertilizers were applied immediately after planting for all treatments. In the F_1 treatment, P fertilizer was applied as P_2O_5 at a rate of 0.2 t ha^{-1}, while K fertilizer was applied as K_2O at the same rate of 0.2 t ha^{-1}. In the F_2 and F_3 treatments, P and K fertilizers were applied at rates of 0.15 t ha^{-1}. For the Bayrampaşa variety during the plant production period, it is advised to apply 11.2-22.4 kg of N as fosfat, and 0.4 t ha^{-1} of K as fosfat

Table 3 – Some properties of the area soil.

Soil depth	Soil type	Unit weight	Field capacity	Wilting point	pH	Total salt	$CaCO_3$	Organic matter
cm		g cm^{-3}	---------------- % ----------------			------------------------- % -------------------------		
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 – Some properties of irrigation water.

Water source	EC	Na^+	K^+	Ca^{2+}	Mg^{2+}	pH	Class	SAR
	dS m^{-1}	------------ me L^{-1} ------------						
Deep well	715	2.3	2.56	9.25	5.7	7.12	C_2S_1	0.85

EC = electrical conductivity; Na = sodium; K = potassium; Ca = calcium; Mg = magnesium; SAR = sodium adsorption ratio.

(Gürel and Bıyıklı, 2023). Three distinct mulching treatments were implemented as the third factor in the study. These treatments were polyethylene (PE) black mulch (M_1), PE transparent mulch (M_2), and no mulch (M_0) (Bogucka and Jankowski, 2020; Bogucka et al., 2021). Twenty-seven application topics were created for irrigation, fertigation, and mulching (Table 6).

In the Marmara Region, where the study was carried out, artichoke seedlings are planted in the ground in spring and fall. Due to higher artichoke unit pricing, the research revealed a preference for the spring season. March 01, 2019, and March 02, 2020, were the planting dates.

The components of the drip irrigation system used in the study were correctly selected. The plants in the plots were arranged at a height of 0.50 m above the row and a spacing of 1.00 m between the rows. Each plot had 35 plants, arranged in five rows of seven plants each. Within each plot, plants were harvested from plots containing of 15 plants. The study consisted of 27 treatments (plots) created by combining three factors. The study was conducted in three repetitions (blocks). Combination treatments of irrigation, fertilization, and mulching were conducted systematically using a drip irrigation system.

The distance from the fleshy part at the bottom to the top of the artichoke leaves, before they are peeled, is called the head length. The diameter of the fleshy part remaining at the bottom after the artichoke leaves are peeled is called the head diameter. The head length and diameter of the artichokes were measured with a caliper and a ruler, and the average of the measures was computed. The artichokes from the harvest plots were chopped into tiny pieces and baked at 65 °C to determine dry weight. (Öztürk Erdem et al., 2020). In addition to yielding parameters, water-soluble carbohydrate (WSC), protein, fat, pH, vitamin C (ascorbic acid) content, phenolic content, antioxidant capacity, iron (Fe), sodium (Na), zinc (Zn), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and copper (Cu) contents were found.

Determination of the water-soluble dry matter amount in artichoke (100 g^{-1})

The peeled artichoke leaves were chopped, mixed with water, and then strained through coarse filter paper. The water-soluble dry matter content, determined by refractomety at 20 °C with a digital refractometer (RA-500 model, KEM brand), was calculated as 100 g^{-1} (Allahdadi and Bahreininejad, 2019; Gürel and Bıyıklı, 2023).

pH values

The peeled artichoke leaves were crushed into a puree. The samples were pureed at focus temperature, and pH values were measured with a Sevencompact pH/Ion Mettler Toledo pH meter (Allahdadi and Bahreininejad, 2019; Gürel and Bıyıklı, 2023).

Water-soluble carbohydrate (%)

After drying of cut artichoke fruits in an oven at 65 °C for 48 h, the samples were weighed using a digital scale. Dried artichoke samples were milled to 1 mm for chemical analysis. WSC was quantified using near-infrared spectroscopy. The method has been elucidated by Jafari et al. (2003) and Allahdadi and Bahreininejad (2019).

Determination of protein (%)

Artichoke samples were analyzed for protein following the Kjeldahl method. In the Kjeldahl method, 50 g samples were processed through combustion, distillation, and titration stages, and the calculation was initiated. The artichoke's protein content (%) was calculated by multiplying its N content percentage by 6.25 (Allahdadi and Bahreininejad, 2019; Gürel and Bıyıklı, 2023).

Determination of fat composition by Soxhlet extraction device (%)

The oil content of artichoke samples was determined by Soxhlet extraction. The oil xtracted from artichoke samples was calculated by using the equation below (Hewavitharana et al., 2020).

Calculation:

% Fat = sample weight (g) – sample weight at the end of the test (g)

% Fat = (weight of the balloon (g) + weight of the oil remaining in the balloon (g) / weight of the sample (g) × 100

Determination of Vitamin C (ascorbic acid)

Vitamin C levels in artichoke samples were determined spectrophotometrically (Shimadzu IU-1800) according to El-Hadidy et al. (2022). The samples' vitamin C content was expressed as mg 100 g^{-1} (Deligios et al., 2019; Lombardo et al., 2022).

Determination of total phenolic content in artichoke heads

The phenolic content of the artichoke was determined by treating the samples with Folin-Ciocalteu reagent, saturated Na2CO3 solution, and gallic acid in ethyl alcohol, and measuring the absorbance at 725 nm using a spectrophotometer (Hewavitharana et al., 2020; Gürel and Bıyıklı, 2023).

Determination of antioxidant capacity

Antioxidants capacity was assessed using previously established methods. The antioxidant capacity values for artichoke samples were determined from the calibration curves using the equations derived, expressed as μmol Trolox equivalent (TE) g^{-1}. The R^2 values of the curves were 0.98 and 0.99 for the α-diphenyl-α-picrylhydrazyl (DPPH) free radical scavenging methods, respectively (Hewavitharana et al., 2020; Gürel and Bıyıklı, 2023).

Determination of the chemical analysis of fruit samples

The Kjeldahl technique and a Shimadzu UV-1208 spectrophotometer were used to measure the samples' total P concentration. An atomic absorption spectrophotometer was used to determine the fruit's concentrations of Ca, Na, K, Mg, Zn, Fe, and Cu (Varian AA240FS) (Wierzbowska et al., 2021).

Experimental design and statistical analysis

The study was designed to be carried out in three separate blocks or three times. In a three-factor trial, values must be compared. The MINITAB 17 program was used to do a three-way Analysis of Variance on the physical and chemical characteristics of artichokes. The relationship among the three factors — irrigation, fertigation, and mulching — was examined using post-hoc testing.

Results

The irrigation factor is more effective in influencing artichokes characteristics compared than fertilization and mulching. Soil moisture levels were assessed using the gravimetric method, and irrigation was applied one week after planting artichoke seedlings. The trial years facilitated the calculation of the minimum and maximum IW amounts, which ranged from 240.0 to 480.0 mm and 246.0 to 492.0 mm, respectively (Table 5). According to Table 5, the trial years' lowest and maximum ET readings were 228.5-530.0 and 340.8-552.0 mm, respectively. The relationship between ET and Ya during the research years and IW levels is depicted in Figure 2. Higher yields are correlated with more IW (Ya). Plant water consumption (PWC) and Ya values were shown to be linearly related. Additionally,

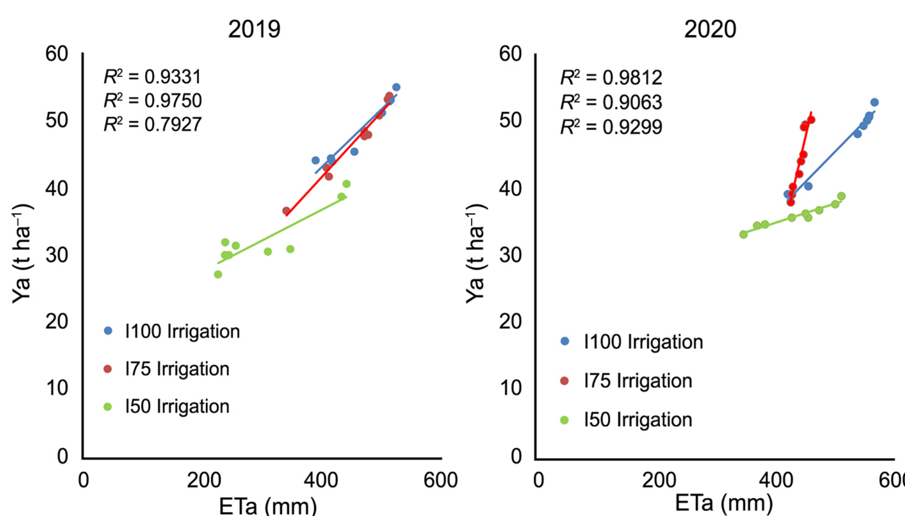

Figure 2 – The relationship between evapotranspiration (ETa) with yield (Ya) for 2019 and 2020 years. I = irrigation (%).

Table 5 – The relationship between the yield response factor (ky) value of artichokes and the amount of water during the study years.

Treatments	2019					2020				
	Ya	YRP	AW	ETa	ky	Ya	YRP	AW	ETa	ky
	t ha^{-1}	%	--------- mm ---------			t ha^{-1}	%	--------- mm ---------		
$I_{100}F_{100}M_1$	48.6	0.0	480.0	530.0	0.000	50.2	0.0	492.0	552.0	0.000
$I_{100}F1_{00}M_2$	46.7	3.9	480.0	520.4	0.463	48.2	4.0	492.0	543.6	0.382
$I_{100}F_{100}M_0$	44.8	7.8	480.0	505.9	0.582	47.5	5.4	492.0	540.1	0.401
$I_{100}F_{75}M_1$	46.5	4.3	480.0	518.1	0.520	48.0	4.4	492.0	542.8	0.380
$I_{100}F_{75}M_2$	47.0	3.3	480.0	518.0	0.688	46.7	7.0	492.0	534.2	0.463
$I_{100}F_{75}M_0$	39.0	19.8	480.0	458.8	0.680	45.5	9.4	492.0	524.7	0.528
$I_{100}F_{50}M_1$	37.5	22.8	480.0	421.5	0.896	37.7	24.9	492.0	445.3	0.776
$I_{100}F_{50}M_2$	38.0	21.8	480.0	419.3	0.958	36.4	27.5	492.0	418.5	0.880
$I_{100}F_{50}M_0$	37.7	22.4	480.0	393.4	1.149	36.5	27.3	492.0	412.0	0.929
$I_{75}F_{100}M_1$	47.3	2.7	360.0	518.2	0.000	47.6	5.2	369.0	450.0	0.000
$I_{75}F_{100}M_2$	46.8	3.7	360.0	515.4	0.511	46.9	6.6	369.0	440.5	1.436
$I_{75}F_{100}M_0$	41.5	14.6	360.0	482.3	0.565	46.5	7.4	369.0	438.2	1.135
$I_{75}F_{75}M_1$	44.4	8.6	360.0	500.8	0.548	42.4	15.5	369.0	437.5	0.254
$I_{75}F_{75}M_2$	41.3	15.0	360.0	476.0	0.642	41.4	17.5	369.0	433.4	0.283
$I_{75}F_{75}M_0$	42.1	13.4	360.0	475.5	0.750	39.5	21.3	369.0	430.6	0.253
$I_{75}F_{50}M_1$	35.3	27.4	360.0	415.8	0.779	37.6	25.1	369.0	420.2	0.315
$I_{75}F_{50}M_2$	36.6	24.7	360.0	411.7	0.909	36.5	27.3	369.0	418.9	0.296
$I_{75}F_{50}M_0$	30.2	37.9	360.0	343.9	0.930	35.3	29.7	369.0	416.8	0.286
$I_{50}F_{100}M_1$	34.2	29.6	240.0	445.6	0.000	36.2	27.9	246.0	498.5	0.000
$I_{50}F_{100}M_2$	32.3	33.5	240.0	437.2	0.339	35.0	30.3	246.0	488.6	0.599
$I_{50}F_{100}M_0$	24.5	49.6	240.0	350.5	0.752	34.1	32.1	246.0	462.8	1.235
$I_{50}F_{75}M_1$	24.0	50.6	240.0	312.7	1.010	33.0	34.3	246.0	445.1	1.212
$I_{50}F_{75}M_2$	23.6	51.4	240.0	246.9	0.952	33.6	33.1	246.0	440.7	1.614
$I_{50}F_{75}M_0$	25.5	47.5	240.0	240.5	1.081	33.0	34.3	246.0	418.7	1.811
$I_{50}F_{50}M_1$	25.0	48.6	240.0	258.3	1.563	32.0	36.3	246.0	375.5	2.127
$I_{50}F_{50}M_2$	23.6	51.4	240.0	240.1	1.488	31.8	36.7	246.0	362.6	2.243
$I_{50}F_{50}M_0$	20.7	57.4	240.0	228.5	1.234	30.5	39.2	246.0	340.8	2.009

Ya = yield; YRP = yield reduction percentage; AW = applied water; ETa = evapotranspiration; ky = yield response factor; I = irrigation (%); F = fertigation (%); M1 = black mulching material; M2 = transparent mulch; M0 = no mulch.

during the plant growth period, temperature and humidity affected ET values. The drip irrigation method was employed to assess optimal irrigation timing and factors influencing water Ya and production. The $I_{100}F_{100}M_1$ treatment exhibited the highest PWC values in both years of the study, whereas the lowest PWC value was recorded for the $I_{50}F_{50}M_0$ treatment (Table 5). In other words, the highest ET value was obtained from the subject where irrigation-fertilization was fully applied and M_1 was used. In contrast, the lowest ET value was obtained from the M_0 subject, which received 50 % irrigation and fertilization with no mulch.

Considering that the soils in which the experiment was carried out were alkaline in character (7.85-8.18) and the IW was in the C_2S_1 quality class, it was observed that as the irrigation level decreased, chemical fertilizers remained in the soil and damaged its texture and structure (Tables 3 and 4). Chemical fertilizers, because they contain chemicals, have caused the soil's clod structure to break down. This is very dangerous for soil health.

Crop ky values for irrigation subjects I_{100}, I_{75}, and I_{50} were calculated as 0.74-0.70-1.05 and 0.59-0.53-1.61 for both trial years, respectively. As the IW amount decreased, the ky value increased. The proximity of the ky values in the I_{100} and I_{75} treatments permitted irrigation at the I_{75} level with minimal Ya reduction (Figure 3). In water management, crop ky values are essential because they show how plant Ya reacts to different IW levels.

The Ya values during the research years ranged from 48.6 to 50.2 t ha^{-1} and from 20.7 to 30.5 t ha^{-1}, respectively (Tables 7 and 8). In 2019, Ya values demonstrated significance at the 1 % level when assessed individually for irrigation, fertilization, and mulching factors, as well as in the context of their triple interactions. The findings indicated insignificance regarding blocks. In 2020, irrigation and fertigation were identified as significant factors at the 1 % level, whereas the interactions with mulching, irrigation, and fertilization were deemed insignificant. The maximum Ya in both years was obtained from $I_{100}F_{100}M_1$. Irrigation and fertilization were fully applied, and M_1 was used. Considering the Yas for mulching, the maximum Ya was obtained with M_1, followed by M_2 and M_0. Similarly, the lowest

Table 6 – Treatment topics.

Irrigation Treatments	Fertigation Treatments	Mulching Treatments	Treatment Topics
	%		
	F_1 (100)	M_1	$I_{100}F_{100}M_1$
	F_1 (100)	M_2	$I_{100}F_{100}M_2$
	F_1 (100)	M_0	$I_{100}F_{100}M_0$
	F_2 (75)	M_1	$I_{100}F_{75}M_1$
I_{100}	F_2 (75)	M_2	$I_{100}F_{75}M_2$
	F_2 (75)	M_3	$I_{100}F_{75}M_0$
	F_3 (50)	M_1	$I_{100}F_{50}M_1$
	F_3 (50)	M_2	$I_{100}F_{50}M_2$
	F_3 (50)	M_0	$I_{100}F_{50}M_0$
	F_1 (100)	M_1	$I_{75}F_{100}MI$
	F_1 (100)	M_2	$I_{75}F_{100}M_2$
	F_1 (100)	M_0	$I_{75}F_{100}M_0$
	F_2 (75)	M_1	$I_{75}F_{75}MI$
I_{75}	F_2 (75)	M_2	$I_{75}F_{75}M_2$
	F_2 (75)	M_0	$I_{75}F_{75}M_0$
	F_3 (50)	M_1	$I_{75}F_{50}MI$
	F_3 (50)	M_2	$I_{75}F_{50}M_2$
	F_3 (50)	M_0	$I_{75}F_{50}M_0$
	F_1 (100)	M_1	$I_{50}F_{100}MI$
	F_1 (100)	M_2	$I_{50}F_{100}M_2$
	F_1 (100)	M_0	$I_{50}F_{100}M_0$
	F_2 (75)	M_1	$I_{50}F_{75}MI$
I_{50}	F_2 (75)	M_2	$I_{50}F_{75}M_2$
	F_2 (75)	M_0	$I_{50}F_{75}M_0$
	F_3 (50)	M_1	$I_{50}F_{50}MI$
	F_3 (50)	M_2	$I_{50}F_{50}M_2$
	F_3 (50)	M_0	$I_{50}F_{50}M_0$

I = irrigation (%); F = fertigation (%); M_1 = black mulching material; M_2 = transparent mulch; M_0 = no mulch.

Ya was obtained from $I_{50}F_{50}M_0$ in both years. In this subject, irrigation, and fertigation were applied at 50 %, and M_0 was not used (Table 5). The highest values were recorded for the $I_{100}F_{100}M_1$ treatment in both years. In contrast, the lowest values were observed with the $I_{50}F_{50}M_0$ treatment for head length, diameter, main head weight, side head weight, and number of heads per plant (NHPP) (Tables 7 and 8). When evaluating 75 % and 100 % restricted irrigation treatments in terms of Ya loss and water savings, they provided significant advantages for the product. However, there were significant reductions in Ya between the 50 % and 100 % treatments. This also applies to the 66 % and 100 % treatments. Thus, the irrigation levels I_{100}, I_{75}, I_{50}, and I_{25} were selected. When evaluating 75 % and 100 % fertigation applications in terms of Ya loss, they are known to provide significant advantages to the product. However, there are significant reductions in Ya between 100 % and 50 % applications. This also applies to 66 % and 100 % applications. The study found that the triple interaction among mulching, fertigation, and irrigation, and their combined effect on Ya, were significant at the 1 % level in both years. The major and secondary head weights, head length, diameter, and NHPP were significant at the 1 % level for both irrigation and fertigation in both years. Furthermore, with relation to mulching in the first year, all values were significant at the 1 % level, except for the NHPP. As regards mulching in the second year, all variables were again significant at the 1 % level, except for secondary head weight and the NHPP. As the amount of IW rose, an inverse relationship between the dry matter content and water amount was observed. With

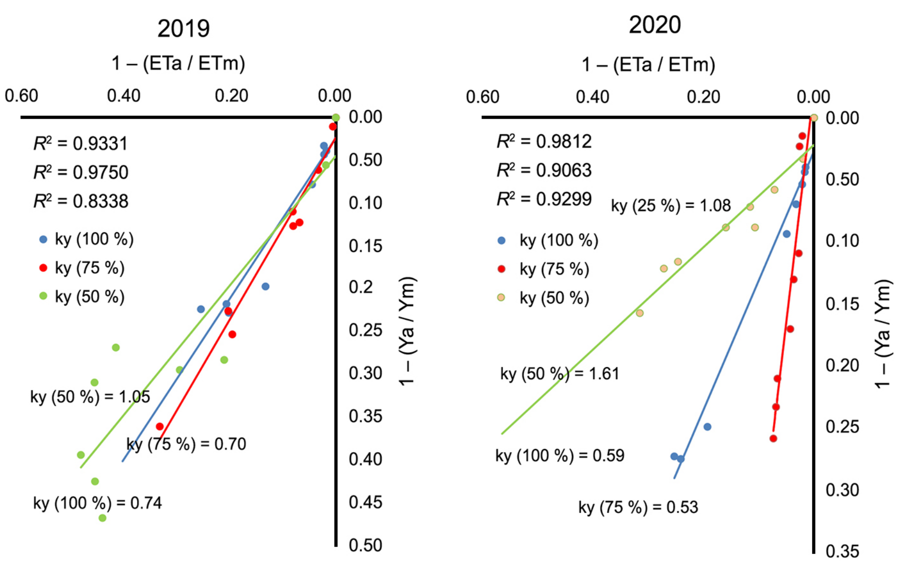

Figure 3 – The relationship between relative yield (Ya) decrease and relative evapotranspiration (ETa) deficit for the experimental years (2019 and 2020). ETm = maximum evapotranspiration; Ym = maximum yield; ky = yield response factor.

Table 7 – The effect of some production inputs on the yield (Ya) and quality values of artichokes in 2019.

Irrigation Treatments	Fertigation Treatments	Mulching Treatments	Ya	Head Length	Head Diameter	Principal Head Weight	Secondary Head Weight	NHPP	Dry Matter
			t ha^{-1}	------------- cm -------------		---------------- g ----------------			%
	F1 (100 %)	M_1	48.6 a	12.5 a	13.3 a	512.4 a	482.8 a	5.0 a	12.8 a
	F1 (100 %)	M_2	46.7 ab	12.2 ab	13.2 ab	500.0 a	471.1 b	4.9 a	13.1 a
	F1 (100 %)	M_0	44.8 abc	12.0 abc	13.2 ab	462.8 c	436.1 c	4.8 a	13.4 a
	F2 (75 %)	M_1	46.5 ab	12.2 ab	13.0 abc	469.3 bc	437.9 c	4.8 a	13.3 a
I100	F2 (75 %)	M_2	47.0 ab	12.1 ab	12.9 abcd	481.4 b	435.5 c	4.7 a	13.4 a
	F2 (75 %)	M_0	39.0 cdefg	12.0 abc	13.0 abc	462.8 c	430.7 c	4.8 a	13.5 a
	F3 (50 %)	M_1	34.1 fgh	11.7 abcd	12.8 abcd	379.3 ij	357.4 i	4.7 a	13.7 a
	F3 (50 %)	M_2	38.0 cdefg	11.0 bcdef	12.3 abcde	362.2 kl	341.3 j	4.5 a	13.5 a
	F3 (50 %)	M_0	37.7 cdefg	10.5 defg	12.2 abcde	320.4 n	301.9 l	4.5 a	13.6 a
	F1 (100 %)	M_1	47.3 ab	11.7 abcd	13.0 abc	444.2 d	418.6 d	4.8 a	13.6 a
	F1 (100 %)	M_2	46.5 ab	11.4 abcde	13.0 abc	425.6 ef	401.1 e	4.6 a	13.5 a
	F1 (100 %)	M_0	41.5 abcd	11.2 abcde	12.9 abcd	400.9 gh	377.6 g	4.6 a	13.6 a
	F2 (75 %)	M_1	44.4 abc	11.5 abcde	12.2 abcde	415.6 f	403.8 e	4.7 a	13.6 a
I75	F2 (75 %)	M_2	41.3 bcde	11.1 abcde	11.8 bcdef	434.9 de	400.5 e	4.6 a	13.5 a
	F2 (75 %)	M_0	41.1 bcdef	10.5 defg	11.5 defgh	413.2 fg	389.4 f	4.5 a	13.7 a
	F3 (50 %)	M_1	35.3 defgh	10.2 efg	11.6 cdefg	321.9 n	303.4 l	4.6 a	13.5 a
	F3 (50 %)	M_2	36.6 defgh	9.7 fgh	11.0 efghi	325.0 n	306.2 l	4.5 a	13.6 a
	F3 (50 %)	M_0	30.2 hij	9.2 ghi	10.7 fghi	295.6 p	278.5 n	4.4 a	13.6 a
	F1 (100 %)	M_1	34.2 efgh	10.6 cdefg	12.6 abcd	390.1 hi	368.7 h	4.4 a	13.7 a
	F1 (100 %)	M_2	32.3 ghi	10.6 cdefg	12.2 abcde	359.1 l	339.4 j	4.3 a	13.5 a
	F1 (100 %)	M_0	24.5 jk	10.1 efg	11.9 abcde	356.0 l	365.3 hi	4.4 a	13.5 a
	F2 (75 %)	M_1	24.1 jk	10.2 efg	11.5 defgh	375.3 j	335.0 j	4.3 a	13.6 a
I50	F2 (75 %)	M_2	23.6 jk	9.2 ghi	11.6 cdefg	372.2 jk	320.4 k	4.1 a	13.7 a
	F2 (75 %)	M_0	25.5 ijk	9.2 ghi	11.5 defgh	339.0 m	298.5 l	4.1 a	13.9 a
	F3 (50 %)	M_1	24.3 jk	8.4 hi	10.4 ghi	315.8 n	289.7 m	4.2 a	14.0 a
	F3 (50 %)	M_2	23.5 jk	8.3 hi	10.2 hi	306.5 o	288.8 m	4.0 a	13.9 a
	F3 (50 %)	M_0	20.7 k	8.0 i	10.0 i	300.3 op	283.9 mn	3.9 a	14.0 a
I			**	**	**	**	**	**	**
F			**	**	**	**	**	**	**
M			**	**	**	**	**	ns	ns
Blocks			ns	ns	ns	ns	ns	ns	ns
I × F			**	**	**	**	**	ns	ns
I × M			ns	ns	ns	**	**	ns	ns
F × M			**	ns	ns	**	**	ns	ns
I × F × M			**	ns	ns	**	**	ns	ns

*Correlation is significant at the $p < 0.05$ level. **Correlation is significant at the $p < 0.01$. NHPP = number of heads per plant; I = irrigation (%); F = fertigation (%); M = mulching; M_1 = black mulching material; M_2 = transparent mulch; M_0 = no mulch; ns = non-significant.

the least fertilizer and irrigation, $I_{50}F_{50}M_1$ and $I_{50}F_{50}M_0$ had the highest dry matter Ya. Conversely, $I_{50}F_{75}M_2$ showed the highest dry matter Ya in the second year (see to Tables 7 and 8). In both trial years, the irrigation dry matter content values were significant at the 1 % level. In the first year, fertigation was significant at the 1 % level, and in the second year, it was significant at the 5 % level. Other physical parameters were classified into distinct statistical groups, even though the dry matter ratios and the NHPP for both years were within the same statistical class.

Irrigation and fertigation were significant at the 1 % level, in an analysis of artichoke quality indicators, including pH, lipid, protein, ascorbic acid, total phenolic compounds, and antioxidant capacity in both years. In the first year, the assessment of pH, ascorbic acid, total phenolic compounds, and antioxidant capacity values showed that mulching was significant at the 1 % level. Additionally, in the second year, ascorbic acid and antioxidant capacity values also demonstrated significance at the 1 % level when assessed in relation to mulching. In the first trial year, the total sugar and water-soluble carbohydrate values were classified within a single statistical category. Similarly, in the second year, the water-soluble carbohydrate, pH, protein, and total phenolic content values also fell within a single statistical category. Additional quality parameters of artichokes were categorized into various statistical classes. The evaluation of total sugar, soluble carbohydrates, fat, and protein contents in artichokes during the first year revealed no significant interaction among irrigation, fertigation, and mulching factors. In

Table 8 – The effect of some production inputs on the yield (Ya) and quality values of artichokes in 2020.

Fertilization Treatments	Irrigation Treatments	Mulching Treatments	Ya	Head Length	Head Diameter	Principal Head Weight	Secondary Head Weight	NHPP	Dry Matter
			t ha^{-1}	-------------- cm	--------------	----------------- g	-----------------		%
I100	F1 (100 %)	M_1	50.2 a	12.2 a	13.4 a	518.2 a	490.7 a	5.2 a	12.7 a
	F1 (100 %)	M_2	48.2 ab	12.1 ab	13.2 a	512.5 a	483.5 ab	5.1 a	12.8 a
	F1 (100 %)	M_0	47.5 ab	11.9 abc	13.0 ab	508.3 a	480.3 abc	5.1 a	12.9 a
	F2 (75 %)	M_1	48.0 ab	12.1 ab	12.8 abcd	478.7 bc	453.6 abcd	5.3 a	13.3 a
	F2 (75 %)	M_2	46.7 abc	12.0 abc	12.9 abc	495.6 ab	460.9 abcd	5.3 a	13.4 a
	F2 (75 %)	M_0	45.5 abc	11.7 abc	12.9 abc	475.8 bcd	450.8 abcd	5.2 a	13.2 a
	F3 (50 %)	M_1	37.7 defg	11.8 abc	12.8 abcd	405.2 e	383.7 abcde	5.1 a	13.3 a
	F3 (50 %)	M_2	36.4 defg	11.8 abc	12.2 abcd	392.5 ef	371.7 abcde	5.0 a	13.4 a
	F3 (50 %)	M_0	36.5 defg	11.7 abc	12.3 abcd	375.4 fg	355.6 abcde	5.0 a	13.3 a
I75	F1 (100 %)	M_1	47.6 ab	11.7 abc	13.3 a	467.4 cd	442.6 abcd	5.1 a	12.7 a
	F1 (100 %)	M_2	46.9 ab	12.0 abc	13.2 a	462.2 cd	440.3 abcde	5.0 a	13.1 a
	F1 (100 %)	M_0	46.5 abc	11.9 abc	12.3 abcd	453.3 d	429.2 abcde	5.2 a	13.2 a
	F2 (75 %)	M_1	42.4 bcd	11.6 abc	12.4 abcd	466.0 cd	435.7 abcde	5.2 a	13.4 a
	F2 (75 %)	M_2	41.4 bcde	11.8 abc	11.8 bcde	453.5 d	429.5 abcde	5.1 a	13.5 a
	F2 (75 %)	M_0	39.5 cdef	11.1 abc	11.4 efgh	452.8 d	430.0 abcde	5.0 a	13.5 a
	F3 (50 %)	M_1	37.6 defg	10.8 abc	11.6 cdef	365.7 ghi	346.3 bcdef	4.9 a	13.3 a
	F3 (50 %)	M_2	36.5 defg	10.5 c	11.2 fgh	351.6 hi	333.0 def	4.8 a	13.4 a
	F3 (50 %)	M_0	35.3 defg	10.9 abc	11.4 efgh	345.6 ij	321.8 def	4.7 a	13.2 a
I50	F1 (100 %)	M_1	36.2 defg	11.9 abc	12.7 abcd	374.2 fgh	354.3 abcde	4.7 a	13.7 a
	F1 (100 %)	M_2	35.0 efg	10.6 bc	12.5 abcd	358.7 ghi	339.6 cdef	4.8 a	13.4 a
	F1 (100 %)	M_0	34.1 fg	11.7 abc	12.4 abcd	346.1 i	366.5 def	4.8 a	13.8 a
	F2 (75 %)	M_1	34.0 fg	11.6 abc	12.5 abcd	377.8 fg	362.7 abcde	4.9 a	13.7 a
	F2 (75 %)	M_2	33.6 fg	10.5 c	11.5 defg	380.6 fg	360.5 abcde	4.7 a	13.9 a
	F2 (75 %)	M_0	33.2 fg	10.7 abc	11.2 fgh	375.7 fg	367.1 abcde	4.6 a	13.8 a
	F3 (50 %)	M_1	33.0 fg	10.5 c	11.0 gh	319.4 k	299.4 ef	4.5 a	13.4 a
	F3 (50 %)	M_2	32.8 fg	10.7 abc	11.0 gh	322.5 jk	284.1 f	4.4 a	13.5 a
	F3 (50 %)	M_0	30.5 g	10.6 bc	10.3 h	302.7 k	277.8 f	4.4 a	13.6 a
I			**	**	**	**	**	**	**
F			**	**	**	**	**	**	*
M			**	**	**	**	ns	ns	ns
Blocks			ns	ns	*	ns	ns	ns	ns
I × F			**	*	**	**	ns	ns	ns
I × M			ns	*	ns	ns	ns	ns	ns
F × M			ns	ns	ns	**	ns	ns	ns
I × F × M			ns	*	*	**	ns	ns	ns

*Correlation is significant at the $p < 0.05$ level. **Correlation is significant at the $p < 0.01$. Ya = yield; NHPP = number of heads per plant; I = irrigation (%); F = fertigation (%); M = mulching; M_1 = black mulching material; M_2 = transparent mulch; M_0 = no mulch; ns = non-significant.

the second year, an evaluation of all quality parameters, excluding total sugar, related to the triple interaction of irrigation, fertigation, and mulching factors revealed no significant correlation (Tables 9 and 10).

In terms of irrigation and fertigation, the analysis of the Na, P, K, Ca, Zn, Fe, and Mg content of artichokes showed a significant association of 1 % in both years. Zn, K, P, and Na concentrations were evaluated in connection to mulching, and the results showed a strong association for both years at the 1 % level. The quality criteria in the first year were not noteworthy, according to the examination of the irrigation, fertigation, and mulching variables as regards their triple interaction. Except K and Fe, all quality measures showed negligible correlations in the second year. Zn values were classified into a single statistical class in the first year, whereas values for other nutritional components were distributed across several statistical classes. All nutrient element levels were categorized into separate statistical groups in the second year (Tables 11 and 12).

Discussion

In a three-year study on artichoke, it was reported that the total amount of water applied at 7, 14, and 21-day intervals was 599, 616, and 616 mm for I_7 treatment, 391,398, and 398 mm for I_{14} treatment, and 248, 255, and 255 mm for I_{14} treatment (Salata et al., 2022). In another study on artichokes, the total IW amount was calculated at 3,150 m^3 ha^{-1} due to differences in quality and IW application. Furthermore, it was found that

Table 9 – The effect of some production inputs on the yield and quality values of artichokes in 2019.

Irrigation Treatments	Fertigation Treatments	Mulching Treatments	Total Sugar	WSC	pH	Fat	Protein	Ascorbic Acid	Total Fenolic Compound	Antioxidant Capacity
			-------- g 100 g^{-1} --------			------------------- g 100 g^{-1} -------------------			mg g^{-1}	mg 100g^{-1}
I100	F1 (100 %)	M_1	82.2 a	8.6 a	3.6 bcde	0.80 cde	6.2 a	13.8 a	23.1 a	171.3 a
	F1 (100 %)	M_2	80.3 a	8.6 a	3.6 bcde	0.80 cde	6.2 a	12.7 b	22.9 ab	168.3 ab
	F1 (100 %)	M_0	79.5 a	8.6 a	3.5 defg	0.81 cde	6.0 abcd	9.6 fg	22.6 ab	169.4 ab
	F2 (75 %)	M_1	80.4 a	8.4 a	3.7 abc	0.80 cde	5.9 abcde	12.7 b	22.7 ab	165.8 abc
	F2 (75 %)	M_2	81.6 a	8.6 a	3.5 defg	0.80 cde	5.8 abcde	9.8 ef	22.5 abc	167.2 abc
	F2 (75 %)	M_0	78.8 a	8.4 a	3.7 abc	0.80 efgh	5.7 abcde	9.1 gh	22.1 abc	153.9 efgh
	F3 (50 %)	M_1	77.8 a	8.7 a	3.8 ab	0.80 cde	5.5 bcde	8.6 hij	21.6 abcd	150.7 ghij
	F3 (50 %)	M_2	79.5 a	8.6 a	3.8 ab	0.80 cde	5.5 bcde	8.9 hi	21.3 abcd	152.9 efgi
	F3 (50 %)	M_0	80.9 a	8.6 a	3.9 a	0.73 e	5.4 de	8.4 ij	20.7 ab	151.5 ghij
I75	F1 (100 %)	M_1	81.5 a	8.7 a	3.5 defg	0.90 abcd	6.2 a	10.7 cd	22.4 abc	164.2 abcd
	F1 (100 %)	M_2	80.9 a	8.7 a	3.5 defg	0.90 abcd	6.2 a	10.9 c	22.5 abc	160.1 cdef
	F1 (100 %)	M_0	81.0 a	8.7 a	3.5 defg	0.90 abcd	6.0 abcd	9.1 gh	22.5 abc	161.7 bcde
	F2 (75 %)	M_1	77.5 a	8.6 a	3.5 defg	0.80 cde	6.2 a	9.8 ef	21.8 abcd	157.5 defg
	F2 (75 %)	M_2	79.9 a	8.6 a	3.7 abc	0.80 cde	6.1 ab	9.7 ef	21.8 abcde	155.2 efgh
	F2 (75 %)	M_0	80.9 a	8.6 a	3.7 abc	0.77 de	6.1 ab	9.7 ef	21.4 abcd	154.5 efgh
	F3 (50 %)	M_1	79.5 a	8.6 a	3.7 abc	0.80 cde	5.5 bcde	8.8 hij	20.2 def	150.1 ghij
	F3 (50 %)	M_2	80.5 a	8.7 a	3.8 ab	0.80 cde	5.4 de	8.7 hij	19.2 efg	148.4 hijk
	F3 (50 %)	M_0	76.4 a	8.7 a	3.8 ab	0.80 cde	5.4 de	8.3 j	18.51 fgh	146.2 ijkl
I50	F1 (100 %)	M_1	84.3 a	8.7 a	3.1 j	0.93 abc	6.3 a	13.7 a	22.2 abc	156.1 efg
	F1 (100 %)	M_2	83.9 a	8.8 a	3.2 fghi	0.96 ab	6.3 a	13.7 a	22.1 abc	154.0 efgh
	F1 (100 %)	M_0	85.0 a	8.8 a	3.3 efgh	1.03 a	6.3 a	12.9 b	21.6 abcd	150.2 ghij
	F2 (75 %)	M_1	82.5 a	8.9 a	3.3 efgh	0.83 bcde	6.2 a	10.6 cd	21.2 bcd	147.6 hijk
	F2 (75 %)	M_2	80.9 a	8.8 a	3.4 efgh	0.80 cde	6.3 a	13.6 a	21.3 abcd	144.1 jklm
	F2 (75 %)	M_0	82.6 a	8.9 a	3.5 defgh	0.83 bcde	6.3 a	10.3 de	21.bcd	141.6 klmn
	F3 (50 %)	M_1	85.4 a	8.8 a	3.6 cdef	0.80 cde	5.4 de	8.9 hi	17.9 ghi	139.1 mn
	F3 (50 %)	M_2	84.0 a	8.7 a	3.7 abc	0.80 cde	5.5 bcde	9.0 ghi	17.1 hi	137.1 n
	F3 (50 %)	M_0	84.9 a	8.9 a	3.7 abc	0.80 cde	5.5 bcde	8.6 hij	16.4 i	135.8 n
I			**	**	**	**	**	**	**	**
F			ns	ns	**	**	**	**	**	**
M			ns	ns	**	ns	ns	**	**	**
Blocks			ns	ns	*	ns	ns	ns	ns	*
I × F			ns	ns	**	**	**	**	*	*
I × M			ns	ns	**	ns	ns	**	*	*
F × M			ns	ns	ns	ns	ns	**	**	**
I × F × M				ns	**	ns	ns	**	**	**

*Correlation is significant at the $p < 0.05$ level. **Correlation is significant at the $p < 0.01$ level. WSC = water-soluble carbohydrate; I = irrigation (%); F = fertigation (%); M = mulching; M_1 = black mulching material; M_2 = transparent mulch; M_0 = no mulch; ns = non-significant.

the seasonal water volumes applied during two growth cycles were 3,300 and 3,000 m^3 ha^{-1}, respectively (Gagliardi et al., 2019). Additionally, the seasonally applied water volumes during the two growing cycles were 3,300 and 3,000 m^3 ha^{-1}, respectively. Minimum and maximum ET values in the trial years ranged from 228.5 to 530.0 and from 340.8 to 552.0 mm, respectively. The trial years' results aligned with the PWC amount and IW figures from prior years (Gagliardi et al., 2019; Salata et al., 2022).

For both trial years, the ky factor values for irrigation subjects I_{100}, I_{75}, and I_{50} were determined to be 0.59, 0.53, and 1.61 and 0.74, 0.70, and 1.05, respectively. The ky factor values for the different irrigation levels during the experimental years are displayed in Figure 3. The seasonal water-yield relationship factor value and the ky values determined in this study coincide with those reported in a prior study carried out in the Marmara Region of Turkey (Ruttanaprasert et al., 2016). According to earlier research in Turkey, the ky value ranged from 1 to 1.50 throughout the growing season. Figure 3 shows that the average ky was 0.91 in the second year and 0.83 in the first. Because of the enormous rainfall observed in both years, the figures are less than one.

In the research years, the Ya values ranged from 20.7 to 30.5 t ha^{-1} and 48.6 to 50.2 t ha^{-1}, respectively. No significant losses were observed in the subjects' artichoke head length, head diameter, and NHPP across both research years. The reason for this is that there is sufficient natural rainfall during the artichoke1s growing period and that evaporation is low, especially

Table 10 – The effect of some production inputs on the yield and quality values of artichokes in 2020.

Irrigation Treatments	Fertigation Treatments	Mulching Treatments	Total Sugar	WSC	pH	Fat	Protein	Ascorbic Acid	Total Fenolic Compound	Antioxidant Capacity
			---------- g 100 g^{-1} ----------			---------- g 100 g^{-1} ----------		mg 100 g^{-1}	mg g^{-1}	mg 100 g^{-1}
I100	F1 (100 %)	M_1	78.3 abccd	8.2 a	3.8 ab	0.77 efgh	6.3 a	12.7 ab	21.2 a	182.4 a
	F1 (100 %)	M_2	75.5 abcde	8.2 a	3.9 a	0.78 efg	6.3 ab	12.8 a	21.3 a	180.4 ab
	F1 (100 %)	M_0	73.5 bcdef	8.2 a	3.8 ab	0.75 efg	6.3 a	12.6 abc	21.3 a	179.5 abcd
	F2 (75 %)	M_1	69.9 def	8.1 a	3.7 ab	0.76 efg	6.3 a	12.5 abcd	21.4 a	180.2 abc
	F2 (75 %)	M_2	68.2 ef	8.1 a	3.8 ab	0.75 efg	6.3 a	11.8 abcde	21.0 a	177.3 abcd
	F2 (75 %)	M_0	68.4 ef	8.1 a	3.8 ab	0.73 g	6.2 a	11.9 abcde	21.0 a	173.4 bcdef
	F3 (50 %)	M_1	67.5 f	8.2 a	3.8 ab	0.73 g	6.0 a	11.5 defgh	21.2 a	170.1 defgh
	F3 (50 %)	M_2	69.9 def	8.2 a	3.8 ab	0.74 fg	6.0 a	11.5 defgh	21.2 a	168.1 fghij
	F3 (50 %)	M_0	70.8 cdef	8.2 a	3.8 ab	0.73 g	5.9 a	11.3 efghi	20.9 a	165.8 ghijk
I75	F1 (100 %)	M_1	77.9 abcde	8.2 a	3.8 ab	0.78 efg	6.2 a	12.3 abcde	20.8 a	177.9 abcd
	F1 (100 %)	M_2	80.93 ab	8.2 a	3.7 ab	0.76 efg	6.2 a	12.2 abcde	20.7 a	175.5 abcde
	F1 (100 %)	M_0	80.9 ab	8.2 a	3.8 ab	0.75 efg	6.2 a	12.0 abcde	20.7 a	171.3 bcdef
	F2 (75 %)	M_1	78.3 abcd	8.2 a	3.8 ab	0.77 efgh	6.3 a	12.0 abcde	20.8 a	172.5 bcdef
	F2 (75 %)	M_2	80.4 abc	8.3 a	3.8 ab	0.79 efg	6.2 a	11.8 abcde	20.6 a	170.8 defgh
	F2 (75 %)	M_0	81.0 ab	8.1 a	3.8 ab	0.80 defg	6.0 a	11.7 bcdef	20.5 a	167.6 fghij
	F3 (50 %)	M_1	81.8 ab	8.3 a	3.8 ab	0.80 defg	6.0 a	11.7 bcdef	20.4 ab	162.4 hijkl
	F3 (50 %)	M_2	80.2 abc	8.2 a	3.7 ab	0.81 cdefg	5.9 a	11.5 defgh	20.1 ab	160.0 jklm
	F3 (50 %)	M_0	75.5 abcde	8.3 a	3.7ab	0.81 cdefg	5.9 a	11.3 efghi	19.9 ab	157.4 klmn
I50	F1 (100 %)	M_1	82.2 ab	8.2 a	3.6 ab	0.82 cdefg	6.2 a	11.9 abcde	20.2 ab	169.3 efghi
	F1 (100 %)	M_2	80.8 ab	8.2 a	3.6 ab	0.83 bcdef	6.1 a	11.8 abcde	20.1 ab	165.1 ghijk
	F1 (100 %)	M_0	81.9 ab	8.1 a	3.5 b	0.86 abcde	5.9 a	11.7 bcdef	20.1 ab	161.8 ijkl
	F2 (75 %)	M_1	77.3 abcde	8.1 a	3.6 ab	0.87 abcde	5.8 a	11.6 cdefg	19.8 ab	157.4 klmn
	F2 (75 %)	M_2	76.4 abcde	8.2 a	3.6 ab	0.92 abcd	5.7 a	11.4 efghi	19.6 ab	155.7 lmn
	F2 (75 %)	M_0	77.6 abcde	8.2 a	3.5 b	0.93 abc	5.7 a	11.2 fghi	19.4 ab	152.4 mn
	F3 (50 %)	M_1	83.5 a	8.3 a	3.6 ab	0.94 ab	5.7 a	11.2 fghi	19.3 ab	149.6 n
	F3 (50 %)	M_2	81.1 ab	8.3 a	3.6 ab	0.95 ab	5.6 a	11.1 ghi	18.5 ab	145.2 o
	F3 (50 %)	M_0	80.9 ab	8.3 a	3.7 ab	0.97 a	5.5 a	10.8 i	17.2 b	140.8 p
I			**	ns	**	**	**	**	**	**
F			**	ns	ns	**	**	**	**	**
M			ns	ns	ns	ns	ns	**	ns	**
Blocks			ns	ns	ns	*	ns	ns	*	*
I × F			**	ns	ns	**	ns	*	*	**
I × M			ns	ns	ns	*	ns	ns	ns	ns
F × M			ns	ns	ns	ns	ns	ns	ns	ns
I × F × M			*	ns	ns	ns	ns	ns	ns	ns

*Correlation is significant at the $p < 0.05$ level. **Correlation is significant at the $p < 0.01$ level. WSC = water-soluble carbohydrate; I = irrigation (%); F = fertigation (%); M = mulching; M_1 = black mulching material; M_2 = transparent mulch; M_0 = no mulch; ns = non-significant.

since temperatures in the second year were lower than in previous years. The research findings align with earlier studies regarding the quality parameters of artichoke (Öztürk et al., 2020; Tartoura et al., 2021; Lombardo et al., 2022). The results of the present study are consistent with earlier investigations into quality parameters of artichoke (Öztürk et al., 2020; Tartoura et al., 2021; Ismail et al., 2022; Dima et al., 2023).

When the study's results on the Na, P, K, Ca, Zn, Fe, and Mg content of artichokes were analyzed, it was found that the $I_{100}F_{100}$ treatment — in which fertilization and irrigation were fully implemented — had the highest values. As with the other parameters, the maximum values were obtained from M_1, followed by M_2. The lowest value was obtained from the subject M_0. The findings of our current study align with previous research on the impact of three factors on the Ya and some parameters of artichokes (Jiménez-Moreno et al., 2019: Siadat-Jamian et al., 2019; Wierzbowska et al., 2021; Zeipina et al., 2022; Salata et al., 2022; Ismail et al., 2022; Dima et al., 2023; Tortosa-Diaz et al., 2025).

In Turkey, no studies have examined the effect of the triple-factor interaction among irrigation-fertilization-mulching on the artichoke. Therefore, it was conducted as an original study. In the study, when $I_{100}F_{100}$ treatments were compared with $I_{75}F_{75}$ treatments, a slight decrease was observed in Ya and quality values. Artichoke plants showed different responses to irrigation levels across phenological periods. In this case, it was possible to apply limited irrigation in specific phenological periods of artichoke. In conditions of water scarcity, it is possible to contribute to sustainable agriculture, especially by

Table 11 – Some parameters of artichokes in 2019.

Irrigation Treatments	Fertigation Treatments	Mulching Treatments	Na	P	K	Ca	Zn	Fe	Mg
			----------	----------	----------	mg	----------	----------	----------
I100	F1 (100 %)	M_1	98.3 a	90.5 a	385.5 a	50.3 a	0.65 a	1.52 a	70.6 a
	F1 (100 %)	M_2	97.4 a	90.3 a	381.4 ab	50.3 a	0.64 a	1.50 ab	70.1 ab
	F1 (100 %)	M_0	96.3 a	88.4 abc	373.6 bcdef	49.5 ab	0.64 a	1.50 ab	70.6 a
	F2 (75 %)	M_1	95.2 a	89.1 ab	375.5 bc	50.6 a	0.64 a	1.49 abc	69.4 ab
	F2 (75 %)	M_2	96.5 a	90.9 a	374.3 bcd	47.2 abcd	0.63 a	1.48 abc	69.5 ab
	F2 (75 %)	M_0	94.9 a	85.2 abcd	371.4 cdefg	48.3 abc	0.62 a	1.49 abc	69.8 ab
	F3 (50 %)	M_1	94.8 a	82.4 abcd	370.8 cdefg	45.2 abcdef	0.63 a	1.48 abc	68.5 ab
	F3 (50 %)	M_2	92.5 abc	80.9 abcd	365.6 efghi	41.1 defgh	0.62 a	1.48 abc	67.1 abc
	F3 (50 %)	M_0	93.7 abc	77.7 abcd	363.7 ghijk	42.2 cdefgh	0.62 a	1.47 abc	66.4 abcd
I75	F1 (100 %)	M_1	95.5 a	86.8 abc	374.6 bc	47.8 abcd	0.63 a	1.48 abc	68.3 ab
	F1 (100 %)	M_2	94.7 a	85.1 abcd	370.4 cdefg	47.6 abcd	0.64 a	1.46 abcd	68.4 ab
	F1 (100 %)	M_0	95.4 a	81.2 abcd	372.5 cdef	47.7 abcd	0.64 a	1.47 abc	67.8 abc
	F2 (75 %)	M_1	94.3 ab	80.3 abcd	365.8 defgh	46.8 abcde	0.63 a	1.47 abc	65.5 abcd
	F2 (75 %)	M_2	91.3 abcd	79.4 abcd	365.7 defghi	45.6 abcde	0.62 a	1.45 abcd	63.1 abcd
	F2 (75 %)	M_0	92.5 abc	80.3 abcd	362.6 hijk	44.2 abcdef	0.63 a	1.46 abcd	62.5 abcde
	F3 (50 %)	M_1	90.9 abcd	75.7 bcde	357.1 jklm	42.8 bcdef	0.64 a	1.44 abcd	60.2 bcdef
	F3 (50 %)	M_2	89.7 abcd	72.5 defg	355.1 lm	40.8 efghij	0.63 a	1.43 abcd	57.1 defgh
	F3 (50 %)	M_0	85.6 bcde	70.7 efgh	357.1 klm	41.7 cdefg	0.62 a	1.41 abcd	56.1 efgh
I50	F1 (100 %)	M_1	89.5 abcd	77.7 abcd	367.9 cdefg	43.8 abcde	0.62 a	1.44 abcd	61.3 abcde
	F1 (100 %)	M_2	85.2 cde	73.0 defg	365.8 defgh	41.7 cdefg	0.61 a	1.43 abcd	60.5 bcdef
	F1 (100 %)	M_0	82.7 de	70.2 efgh	365.1 efghi	40.1 fghij	0.60 a	1.41 abcd	58.1 cdefg
	F2 (75 %)	M_1	77.8 ef	66.5 fgh	363.6 efghi	38.21 ghij	0.60 a	1.40 bcde	55.3 fgh
	F2 (75 %)	M_2	73.5 fg	63.6 gh	365.28 hi	36.8 hijk	0.61 a	1.38 cdef	54.2 fgh
	F2 (75 %)	M_0	70.1 fgh	61.8 h	360.1 ijkl	35.2 ijk	0.59 ab	1.39 bcde	52.5 gh
	F3 (50 %)	M_1	65.6 ghi	60.4 hi	353.4 lm	31.3 jkl	0.55 abc	1.35 def	51.73 gh
	F3 (50 %)	M_2	62.8 hi	58.f hi	350.3 n	30.6 kl	0.49 bc	1.32 ef	49.9 h
	F3 (50 %)	M_0	60.1 i	55.4 i	351.7 m	27.2 l	0.45 c	1.29 f	48.9 h
I			**	**	**	**	**	**	**
F			**	**	**	**	**	**	**
M			**	**	**	*	**	*	*
Blocks			ns	**	*	ns	ns	ns	ns
I x F			**	ns	*	**	ns	**	**
I x M			*	ns	**	ns	ns	ns	ns
F x M			ns	ns	*	ns	ns	ns	ns
I x F x M			ns	ns	ns	ns	ns	ns	ns

*Correlation is significant at the $p < 0.05$ level. **Correlation is significant at the $p < 0.01$ level. Na = sodium; P = phosphorous; K = potassium; Ca = calcium; Zn = zinc; Fe = iron; Mg = magnesium; I = irrigation (%); F = fertigation (%); M = mulching; M_1 = black mulching material; M_2 = transparent mulch; M_0 = no mulch; ns = non-significant.

conserving water (Siadat-Jamian et al., 2019; Dima et al., 2023; Tortosa-Diaz et al., 2025).

For this purpose, M_1 should be preferred over M_0 and M_2 material in terms of irrigation and fertilization for $I_{75}F_{75}$ treatments. M_1 is preferred over other mulch materials because it absorbs more sunlight, thereby maintaining soil temperature, controlling weeds, and increasing water retention capacity, thereby encouraging early crop ripening (Zangoueinejad et al., 2018). The results of the study showed that mulching increased artichoke Ya and quality, similar to those found in previous studies (Romero-Muñoz et al., 2024).

Conflict of Interest

The author declares that there is no conflict of interest.

Data Availability Statement

The author does not have permission to share data.

Declaration of use of AI Technologies

AI technologies or supported applications and programs were not used in creating the text or in the calculations.

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Table 12 – Some parameters of artichokes in 2020.

Irrigation Treatments	Fertigation Treatments	Mulching Treatments	Na	P	K	Ca	Zn	Fe	Mg
			------------	------------	------------	mg	------------	------------	------------
I100	F1 (100 %)	M_1	94.1 ab	94.8 a	397.4 a	54.7 a	0.71 a	1.62 a	76.0 ab
	F1 (100 %)	M_2	93.8 ab	94.1 a	395.2 ab	54.1 ab	0.70 ab	1.60 ab	76.2 a
	F1 (100 %)	M_0	94.8 a	93.8 a	393.6 ab	53.8 a	0.69 ab	1.61 ab	75.2 ab
	F2 (75 %)	M_1	93.4 ab	92.1 ab	390.1 abc	53.2 ab	0.70 ab	1.58 abc	73.9 abc
	F2 (75 %)	M_2	93.2 ab	90.2 abc	386.7 abcd	50.4 abc	0.67 ab	1.60 ab	72.3 abc
	F2 (75 %)	M_0	92.1 abc	90.6 abc	385.9 bcde	46.9 bcde	0.68 ab	1.59 abc	70.6 abcde
	F3 (50 %)	M_1	92.4 abc	89.2 abcd	380.4 cdefg	45.3 cdef	0.69 ab	1.61 ab	68.7 abcde
	F3 (50 %)	M_2	91.9 abc	86.4 bcdef	376.2 defghi	42.4 defgh	0.66 abc	1.58 abc	67.8 abcde
	F3 (50 %)	M_0	91.4 abc	85.1 cdefg	375.4 efghi	41.9 defgh	0.65 abcd	1.57 abc	68.7 abcde
I75	F1 (100 %)	M_1	92.6 abc	90.8 abc	382.1 cdef	48.4 abcd	0.69 ab	1.55 bcd	75.4 ab
	F1 (100 %)	M_2	92.3 abc	90.8 abc	380.5 cdefg	48.3 abcd	0.70 ab	1.57 abc	73.2 abc
	F1 (100 %)	M_0	91.2 abc	88.8 abcd	377.2 defgh	47.7 abcde	0.70 ab	1.58 abc	72.4 abc
	F2 (75 %)	M_1	90.9 abc	85.5 cdefg	378.4 defgh	45.3 cdef	0.68 ab	1.55 bcd	74.5 ab
	F2 (75 %)	M_2	90.1 abc	86.3 bcdef	375.2 efghi	41.90 defg	0.65 abcd	1.56 abcd	73.8 abc
	F2 (75 %)	M_0	88.2 abcd	82.7 efg	371.1 fghijk	40.1 efghi	0.66 abc	1.53 cde	72.91 abc
	F3 (50 %)	M_1	86.3 abcd	80.6 fgh	370.4 ghijk	36.2 hi	0.63 abcd	1.50 def	70.1 abed
	F3 (50 %)	M_2	85.7 abcde	81.1 fgh	367.8 hijkl	37.3 ghi	0.64 abcd	1.45 fgh	67.2 abcde
	F3 (50 %)	M_0	85.2 abcde	80.4 fgh	368.8 hijk	37.2 ghi	0.63 abcd	1.44 fgh	62.5 defg
I50	F1 (100 %)	M_1	87.0 abcd	83.6 defg	373.2 fghij	44.5 cdefg	0.65 abcd	1.50 def	65.8 cdef
	F1 (100 %)	M_2	85.3 abcde	80.6 fgh	372.9 fghij	44.9 cdefg	0.63 abcd	1.50 def	66.8 bcde
	F1 (100 %)	M_0	82.5 abcde	81.9 fg	367.7 hijkl	43.9 cdefg	0.64 abcd	1.45 fgh	65.7 cdef
	F2 (75 %)	M_1	82.9 abcde	79.3 ghi	365.3 ijkl	42.1 defgh	0.62 abcd	1.47 efg	62.6 defg
	F2 (75 %)	M_2	81.4 bcdef	75.0 hij	363.2 jkl	40.3 efghi	0.63 abcd	1.41 ghi	60.1 efg
	F2 (75 %)	M_0	80.2 cdefg	73.1 ijk	360.3 kl	38.6 fghi	0.60 bcd	1.44 fgh	60.2 efg
	F3 (50 %)	M_1	77.1 def	71.2 jk	356.6 l	37.2 ghi	0.60 bcd	1.40 hi	55.6 g
	F3 (50 %)	M_2	73.1 ef	70.6 jk	342.8 m	35.i	0.56 cd	1.36 ij	57.4 fg
	F3 (50 %)	M_0	70.9 f	67.8 k	340.3 m	37.8 fghi	0.55 d	1.33 j	55.6 g
I			**	**	**	**	**	**	**
F			**	**	**	**	**	**	**
M			*	**	**	**	*	**	*
Blocks			ns	ns	ns	ns	ns	ns	ns
I × F			**	**	**	*	ns	**	*
I × M			ns	ns	ns	ns	ns	**	ns
F × M			ns	ns	ns	**	ns	**	ns
I × F × M			ns	ns	*	ns	ns	**	ns

*Correlation is significant at the $p < 0.05$ level. **Correlation is significant at the $p < 0.01$ level. Na = sodium; P = phosphorous; K = potassium; Ca = calcium; Zn = zinc; Fe = iron; Mg = magnesium; I = irrigation (%); F = fertigation (%); M = mulching; M_1 = black mulching material; M_2 = transparent mulch; M_0 = no mulch; ns = non-significant.

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