THE EFFECT OF DIFFERENT IRRIGATION WATER AMOUNTS ON COTTON (*GOSSYPIUM HIRSUTUM* L.) YIELD AND QUALITY

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Abstract. In the study, it was aimed to figure out the relationship between irrigation and cotton plant yield (*Gossypium hirsutum* L.) under different conditions created by applying different irrigation water levels by using Subsurface Drip Irrigation System in the area of Harran University, representing the conditions of the Harran Plain in Şanlıurfa, Türkiye in 2019 and 2020. The irrigation issues; 125% (v/v), 100% (v/v), 75% (v/v), 50% (v/v), and 25% (v/v) were created according to the amount of evaporation obtained from Class A Pan for both years but, the issue of 150% (v/v) as over-irrigation issue was added in the study belonging to 2020 for understanding the statistical reliability of the optimum irrigation issue obtained. While amount of irrigation water used was 933.75-196.75 mm in 2019, it was 1138.5-189.75 mm in 2020. The other parameters of irrigation such as Class A-Pan coefficient (Kcp), plant water consumption (ET), soil water change in the effective root zone (ΔS, mm), water use efficiency (WUE), and irrigation water use efficiency (IWUE) were determined. The yield parameters such as seed cotton yield (kg ha^{-1}), ginning out turn (%), 100 grain weight (g), cotton boll weight (g), number of bolls per plant, plant height (cm) were obtained. Fiber quality parameters such as fiber index (%), fiber length (mm), fiber uniformity index (%), fiber strength (g tex^{-1}), fiber fineness (mic), fiber elongation at break (Elg) were studied. In conclusion, the Kcp value for both years was determined as 1.25. The results obtained in the study will support further studies in the field.
Keywords: *industrial plant, HVI 1001, limited irrigation, overirrigation, pressurized irrigation*

Introduction

Cotton (*Gossypium hirsutum* L.) is an industrial plant with variable possibilities of use in the world involving clothing, food, medicine, industry, etc. India, America, and China are the leaders in cotton cultivation. Türkiye is ranked 11th in the cotton planting list. South east Anatolia region takes the 1th place in terms of cotton cultivation area in Türkiye. Şanlıurfa is located in the South east Anatolian region in Türkiye and Şanlıurfa region singly accounts for 42% of Türkiye ‘s potential cotton production (Kaplan, 2020).

In the last 20 years, the use of pressurized irrigation methods has increased in Türkiye. Due to the effects of global climate changes and limited water resources, the tendency to pressurized irrigation method has increased. Pressurized irrigation methods include sprinkler, micro sprinkler irrigation, drip irrigation, subsurface drip irrigation and mechanized irrigation. Drip irrigation methods are important in terms of optimum use of water, irrigation labor and efficient use of energy (Demirok and Tuylu, 2019). Subsurface drip irrigation system, one of the pressurized irrigation systems, is the most efficient system with a rate of approximately 96%. Profitability can be increased through gains in yield and water use efficiency for cotton and other crops. Other advantages of subsurface drip irrigation are minimizing the amount of evaporation, optimizing water due to surface run off and deep infiltration losses of water, and achieving high productivity during the vegetation period of the plant. The biggest

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advantage of subsurface drip irrigation is minimizing evaporation losses during critical periods. This means obtaining high and quality products at lower costs by reducing weeds. Fertilizer is also given to the plants through this irrigation method (Al-taief and Alhadithi, 1988; Ayars, 2015; Jasim and Alroahdi, 2015; Akşam S at al., 2019; Pendergast, 2019; Çetin, 2020).

The present study aims to examine the possibilities of use subsurface drip irrigation method to cultivate cotton plant under the conditions of Harran Plain during two cultivation periods in 2019 and 2020. Some yield and fiber quality parameters and some irrigation parameters of cotton grown under some irrigation conditions created by different irrigation water levels applied were researched. All results obtained were statistically evaluated and Class A-Pan coefficient was determined. In summary in the study, the effects of the use of subsurface drip irrigation system on cotton cultivation to optimize irrigation conditions were statistically evaluated and the optimum irrigation condition for cotton cultivation under Harran Plain condition was figured out.

Materials and methods

The study was carried out in Eyyübiye Campus of Harran University, Şanlıurfa, Türkiye during two cultivation periods in 2019 and 2020. The coordinates of the experimental area are 37°07’18” North latitude and 38°49’07” East longitude. Cotton (*Gossypium hirsutum* L. cv. DP-396) was cultivated in the field representing Harran Plain, Şanlıurfa, Türkiye by using Subsurface Drip Irrigation System.

Şanlıurfa, situated in south eastern Anatolia, Türkiye, has a climate feature that is hot and dry in summers and warm in winters. Some climate values obtained for 2019, 2020, and 1985-2020 long years average climate values in research area were presented in *Table 1* (Anonymous, 2021).

In the study area, the irrigated parcels were arranged in completely randomized experimental design with each irrigation treatments replicated three times. Each parcel was 6.72 m^2 and seeds of cotton were planted as 20 × 70 cm, and 5 sequenced. Two sequences were separated as border effect in the evaluation (*Fig. 1*). The soil in study area is heavy-textured and contains sand, silt, and clay (*Table 2*) (Özkaya, 2022). Lateral depth belonging to subsurface drip irrigation system was 40 cm (Lamm and Rogers, 2017; Enciso et al., 2005; Çetin and Kara, 2019). The depth was determined by considering plant root length in clay soils. After determining the lateral lines, cotton seeds were planted at a depth of 4 cm according to their lateral lines. The ground was compacted and covered with polyethylene material in order to prevent irrigation water from infiltrating deeply. In the study, irrigation interval was determined by considering farmer practices. In the region, furrow irrigation method is commonly used in cotton irrigation, and the first irrigation is performed in 30-40 days after germination. The second and subsequent irrigations vary from 12 to 15 days. In the study, planting and harvest dates in both years were May 1 and November 10, respectively. The soil moisture content was in field capacity. The first irrigation was applied after germination (35 days). The second and subsequent irrigations were applied at intervals of 8-12 days. C_1S_1 class of city water was used as irrigation water. No washing was performed because the electrical conductivity of the water was low (*Table 3*) (Özkaya, 2022). DAP fertilizer was applied as 16 kg da^{-1} (Nitrogen) and 8 kg da^{-1} Diphosphorus Pentoxide (P_20_5) to the soil during seed sowing. Depending on the vegetative development of the plant 20 kg da^{-1} urea fertilizer (46% N),

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25 ml foliar fertilizer (NH_2), 25 ml phosphorus (P) fertilizer, and 20 kg ha^{-1} ammonium nitrate (16.5% NH-N, 16.5% NO-N) fertilizer were used.

***Figure 1.** An appearance of cultivation area*

***Table 1.** Some climate parameters belonging to Şanlıurfa province in 2019 and 2020, and 1985-2020 long years average climate values (LYA) in research area*

Month	Years	Max. temp. (°C)	Min. temp. (°C)	Mean temp. (°C)	Humidity (%)	Wind speed (m sn^{-1})	Hours of sunshine (h)	Rain (mm)
May	2019	40.0	10.1	25.1	36.4	1.4	12.1	6.8
	2020	38.0	11.1	30.4	41.5	1.6	9.8	37.5
	LYA	37.2	11.3	24.9	41.2	1.6	8.2	24.0
June	2019	44.1	18.5	30.8	31.1	1.7	11.7	8.1
	2020	41.6	15.3	36.7	30.3	1.9	12.1	0.4
	LYA	42.5	17.3	31.1	30.8	1.9	11.6	3.6
July	2019	42.3	19.7	31.7	30.1	2.0	12.4	0.0
	2020	45.3	23.8	42.0	24.4	1.6	12.2	0.0
	LYA	43.5	21.6	40.6	27.7	1.9	11.9	0.0
August	2019	45.8	20.7	32.8	29.9	1.8	11.2	0.0
	2020	43.9	21.9	40.3	24.7	1.8	11.1	0.0
	LYA	44.0	21.2	34.2	31.2	1.7	11.0	0.0
September	2019	39.5	15.9	28.0	30.6	1.3	10.4	0.2
	2020	43.9	19.9	38.8	29.4	1.4	9.3	0.0
	LYA	41.3	17.3	30.4	30.6	1.5	7.9	22.6
October	2019	36.2	17.6	23.0	44.7	1.0	7.4	41.1
	2020	34.2	16.1	32.0	22.8	1.0	7.0	0.0
	LYA	34.0	12.6	23.9	37.0	1.1	7.7	22.6
November	2019	27.5	5.9	14.8	42.2	0.8	6.8	6.7
	2020	26.1	5.6	19.3	60.3	0.9	6.2	81.4
	LYA	26.0	4.5	14.7	54.7	0.9	6.3	44.3

***Table 2.** Some soil properties of the study area*

Soil depth (cm)	Volume density (g cm^{-3})	Field capacity (%)	Wilting point (%)	Clay (%)	Silty (%)	Sand (%)	Texture
0-30	1.4	35.8	22.1	57	20	23	Clay
30-60	1.5	36.4	21.2	55	17	24	Clay
60-90	1.5	35.8	22.1	63	17	21	Clay

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Table 3. *Electrical conductivity of irrigation water used*

EC (mhoscm^{-1})	Color	Turbidity	Temperature (°C)	Sulphate (mg l^{-1})	Al (mg l^{-1})	Cl (mg l^{-1})	pH	Classification
0.445	0	0.6	16.4	23.5	0.074	39	7.77	C_1S_1

In the study, the plant water requirement was determined according to the Class A Pan method. (Tuylu and Tuylu, 2022; Demirok and Tuylu, 2017; Dağdelen and Özdemir, 2015; Şimşek and Gerçek, 2005; Kırnak, 2002). Class A Pan Coefficient (kcp) was obtained from the different irrigation applications in the preliminary tests (kcp = 1). $I_{1.00}$ issue determined as full-irrigation was the irrigation issue which amount of 100% (v/v) evaporation obtained from Class A Pan was used as irrigation water. $I_{0.75}$, $I_{0.50}$, and $I_{0.25}$ were created by proportionally reducing the amount of irrigation water used in $I_{1.00}$ issue (25, 50, 75%, respectively). They were planned as limited irrigation issues in the study. $I_{1.25}$ issue as over-irrigation issue was created proportionally increasing (25%) the amount of irrigation water used in $I_{1.00}$ issue. In the study, the irrigation issues were created as $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, and $I_{0.25}$ in 2019 and 2020. Moreover, the $I_{1.50}$ irrigation issue was added to the study in 2020 because of $I_{1.25}$ issue was figured out as optimum irrigation issue in 2019. $I_{1.50}$ issue as over-irrigation issue was created proportionally increasing (50%) the amount of irrigation water used in $I_{1.00}$ issue. In order to understand the statistical reliability of the optimum irrigation issue obtained, it was necessary to examine the $I_{1.50}$ issue as an over-irrigation issue. So the irrigation issues were examined as $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, and $I_{0.25}$ for during cultivation period in 2020.

In the study, some irrigation parameters and some yield and fiber quality parameters were examined to determine the optimum irrigation issue for cotton.

Irrigation parameters

Class A-Pan coefficient (Kcp), irrigation water amount (I), plant water consumption (ET), soil water change in the effective root zone in the irrigation interval, water use efficiency (WUE), and irrigation water use efficiency (IWUE) were examined as some irrigation parameters.

Class A Pan evaporation method was used to determine the amount of irrigation water under full-irrigation issue. The values in *Equation 1* is outlined below:

$$I = A \times Kcp \times Ep \times P \qquad \text{(Eq.1)}$$

where I: Amount of irrigation water to be applied (L), A: Pan container area (m^2), Kcp: Pan coefficient, Ep: Evaporation from Class A-Pan (mm), P: Percentage of wetted area.

Equation 2 was used to calculate the values related to the amount of water consumed by the plant (James, 1988). Deep infiltration and run off were not considered (Demirel and Genç, 2012; Carus, 2019). The values in *Equation 2* is outlined below:

$$ET = I + R - DP - RO \pm \Delta s \qquad \text{(Eq.2)}$$

where ET: Crop water consumption (mm), I: Irrigation water applied (mm), R: Precipitation (mm), DP: Deep infiltration (mm), RO: Run off (m), ΔS: Soil water in the effective root zone at irrigation range change (mm).

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Water use efficiency (WUE) (*Eq. 3*) and irrigation water use efficiency (IWUE) (*Eq. 4*) were obtained by proportioning the seed cotton yield values of the amount of irrigation water consumed by the plant (ET) and the amount of irrigation water applied (I) (Howell et al., 1994).

Equation 3 is outlined below:

$$WUE = Y\ ET^{-1} \quad \text{(Eq.3)}$$

where WUE = Water use efficiency (kg m^{-3}), Y = Yield (kg da^{-1}), ET = Seasonal crop water consumption (mm).

Equation 4 is outlined below:

$$IWUE = Y\ I^{-1} \quad \text{(Eq.4)}$$

where IWUE = Irrigation water utilization efficiency (kg m^{-3}), Y = Yield (kg da^{-1}), I = Seasonal irrigation water amount (mm).

Yield and fiber quality parameters

In the study, DP-396 cotton variety was selected as plant material. The adaptation of the variety to the region is very suitable and the standards of yield and quality values belonging to cotton variety are acceptable (Anonymous, 2019). The seeds were sown in May in both years.

Yield and some yield parameters as seed cotton yield (kg ha^{-1}), ginning out turn (%), 100 seed weight (g), boll seed cotton weight (g), number of bolls per plant, plant height (cm) were researched. The fiber quality parameters such as fiber index (%), fiber length (mm), fiber uniformity index (%), fiber strength (g tex^{-1}), fiber fineness (mic), fiber elongation at break (Elg) were examined by HVI 1001 (High Volume Instrument) (Sayeed et al., 2022).

SPSS 26.0 computer program was used to determine the statistical analysis of the data obtained. One Way ANOVA was performed as variance analysis. The Duncan method was used for the difference and grouping between the interaction method and irrigation water amounts.

Results

According to the irrigation issues belonging to the study in 2019 ($I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$) and in 2020 ($I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$), irrigation parameters values determined such as the amounts of irrigation water (I), plant water consumption (ET), soil moisture change (Δs, mm), water use efficiency (WUE), irrigation water use efficiency (IWUE) were presented in *Table 4*.

According to the irrigation amounts ($I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$) in 2019, it was determined that the mean seed yield amounts were 5870.73 kg ha^{-1}, 3813.50 kg ha^{-1}, 2863.46 kg ha^{-1}, 2052.06 kg ha^{-1}, and 1330.96 kg ha^{-1}, respectively. According to the irrigation amounts ($I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$) in 2020, it was figured out that the seed cotton yield values were 4637.4 kg ha^{-1}, 5559.1 kg ha^{-1}, 4711.9 kg ha^{-1}, 3356.6 kg ha^{-1}, 2465.0 kg ha^{-1}, and 1608.1 kg ha^{-1}, respectively. According to the statistical analyses performed, it was figured out that the effect of irrigation water amounts on seed cotton yield was at very significant level for both years (2019-2020)

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($p < 0.01$). According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, the values of ginning out turn were 43.0%, 43.00%, 42.33%, 40.66%, 38.33% in 2019 and 41.16%, 42.66%, 42.00%, 40.33%, 40.00%, 39.33% and 2020, respectively. The values of ginning out turn were statistically evaluated and it was figured out that the effect of irrigation water on the ginning out turn was significant ($p < 0.05$). According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, the values of 100 seeds weight (g) were determined as 8.12 g, 7.43 g, 7.47 g, 8.72 g, 7.70 g in 2019 and 8.85 g, 8.20 g, 8.06 g, 7.63 g, 7.91, 7.61 g in 2020, respectively. The results of analysis of variance between irrigation water amounts and 100 seed weight (g) statistically figured out at significant level ($p < 0.05$).

Table 4. *Irrigation parameters determined in the study in 2019 and 2020*

Years	Irrigation amounts	I (mm)	ET (mm)	Δs	WUE	IWUE
2019	$I_{1.25}$	933.7	1040.0	44.0	0.56	0.63
	$I_{1.00}$	747.0	858.5	48.6	0.44	0.51
	$I_{0.75}$	560.25	680.3	57.15	0.42	0.51
	$I_{0.50}$	373.25	488.3	51.9	0.42	0.55
	$I_{0.25}$	186.75	296.6	47.0	0.45	0.71
2020	$I_{1.50}$	1138.5	1305.8	48.0	0.36	0.41
	$I_{1.25}$	948.75	1110.5	42.5	0.50	0.59
	$I_{1.00}$	759.0	924.3	46.0	0.51	0.62
	$I_{0.75}$	569.25	733.7	45.15	0.46	0.59
	$I_{0.50}$	379.5	542.9	44.1	0.45	0.65
	$I_{0.25}$	189.75	346.9	37.9	0.46	0.84

According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, it was obtained that the values of boll seed weight (g) were 4.28 g, 4.09 g, 4.06 g, 4.04 g, 3.60 g in 2019 and 4.01 g, 4.38 g, 4.06 g, 3.82 g, 3.76 g, 3.85 gin 2020, respectively. It was found that there were differences at significant level ($p < 0.05$) between the weight of cotton with boll seed and the irrigation water amounts. While irrigation amounts × block interaction values were determined as not significant ($p > 0.05$), the block values were determined as significant ($p < 0.05$). According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, it was figured out that the bolls of per plant were 20.66, 14.34, 10.66, 7.61, 5.53 in 2019 and 13.52, 17.53, 13.29, 12.32, 10.07, 6.97 in 2020, respectively. The statistical results of the study showed that there were significant differences between the number of bolls per plant and the amount of irrigation water ($p < 0.05$). According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, it was figured out that the values of plant height (cm) were 93.88 cm, 83.58 cm, 74.62 cm, 57.76 cm, 48.18 cm in 2019 and 85.46 cm, 94.14 cm, 78.14 cm, 65.06 cm, 54.41 cm, 52.34 cm in 2020, respectively. According to the analysis of variance, it was determined that there was significantly interaction ($p < 0.05$) between irrigation water amounts and plant height (cm). In all issues in 2019 and 2020, it was found that the block and irrigation water amounts × block interaction values were not significant ($p > 0.05$) (*Tables 5* and *6*).

Table 5. *Cotton yield parameters and Duncan groups of the study in 2019*

Irrigation issues	Cotton seed yield (kg ha^{-1})	Ginning outturn (%)	100 Seed weight (g)	Boll seed cotton weight (g)	Number of bolls (per plant)	Plant height (cm)
$I_{1.25}$	5 870.7d	43.00b	8.12ab	4.28c	20.66b	93.88c
$I_{1.00}$	3 813.5d	43.00b	7.43a	4.09bc	14.34b	83.58c
$I_{0.75}$	2 863.4c	42.33b	7.47a	4.06bc	10.66b	74.62bc
$I_{0.50}$	2 052.0b	40.66b	8.72b	4.04ab	7.61a	57.76ab
$I_{0.25}$	1 330.9a	38.33a	7.70a	3.60a	5.53a	48.18a
Irrigation water amount	**	**	**	**	**	**
Block	N.S.	N.S.	N.S	*	N.S.	N.S.
Irrigation water amount × block	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

**p < 0.01: very significant; *p < 0.05: significant; N.S.: p > 0.05: not significant

Table 6. *Cotton yield parameters and Duncan groups of the study in 2020*

Irrigation issues	Cotton seed yield (kg ha^{-1})	Ginning outturn (%)	100 Seed weight (g)	Boll seed cotton weight (g)	Number of bolls (per plant)	Plant height (cm)
$I_{1.50}$	4 637.4c	41.16ab	8.85b	4.01ab	13.52c	85.46c
$I_{1.25}$	5 559.1c	42.66b	8.20ab	4.38b	17.53d	94.14c
$I_{1.00}$	4 711.9c	42.00ab	8.06ab	4.06a	13.29c	78.14bc
$I_{0.75}$	3 356.6ab	40.33ab	7.63a	3.82a	12.32ab	65.06ab
$I_{0.50}$	2 465.0a	40.00ab	7.91a	3.76a	10.07b	54.41a
$I_{0.25}$	1 608.1a	39.33a	7.61a	3.85a	6.97a	52.34a
Irrigation water amount	**	*	**	**	**	**
Block	N.S.	N.S.	N.S	N.S.	N.S.	N.S
Irrigation water amount × block	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

**p < 0.01: very significant; *p < 0.05: significant; N.S.: p > 0.05: not significant

The results belonging to the fiber measurements were obtained with the HVI 1001 were evaluated. The amount of irrigation water, blocks, and the amount of irrigation water × block interaction were statistically examined (*Tables 7* and *8*).

According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, it was determined that the fiber index is were 6.12 g, 5.60 g, 5.48 g, 5.97 g, 4.78 g in 2019 and 5.36 g, 5.15 g, 6.10 g, 5.83 g, 5.27 g, 4.93 g in 2020, respectively. It was concluded that there was no significant interaction between the fiber index (g) and irrigation water amount, block, and irrigation water amount × block in both years ($p > 0.05$). According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, it was determined that the fiber length (mm) was 26.01 mm, 26.39 mm, 25.88 mm, 25.67 mm, 26.28 mm in 2019 and 28.90 mm, 28.76 mm, 28.72 mm, 29.10 mm, 28.51 mm, 28.59 mm in 2020, respectively. There was no significant interaction between the fiber length (mm) and irrigation water amount, block and irrigation water amount × block values ($p > 0.05$). According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, it was determined that the fiber uniformity index (%) was 81.84%, 82.71%, 83.12%, 81.21%, 82.66% in 2019 and 84.73%, 84.53%, 86.26%, 86.30%, 85.30%, 85.43% in 2020, respectively. When the relationships between the fiber uniformity index (%) and irrigation water amount, block, irrigation amount × block interaction were evaluated there were no significant level statistically ($p > 0.05$). According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, it was determined that the fiber strength (g tex^{-1}) values were 30.01 g tex^{-1}, 29.51 g tex^{-1}, 28.20 g tex^{-1}, 27.69 g tex^{-1}, 26.80 g tex^{-1} in 2019 and

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31.86 g tex^{-1}, 31.96 g tex^{-1}, 31.76 g tex^{-1}, 31.63 g tex^{-1}, 30.86 g tex^{-1}, 29.96 g tex^{-1} in 2020, respectively. It was concluded that there were no significance between the fiber strength (g tex^{-1}) and irrigation water amount, block, irrigation water amount × block interaction ($p > 0.05$). According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, it was determined that the fiber fineness (mic) values were 4.31, 4.28, 4.25, 4.26, 4.22 in 2019 and 5.11, 5.52, 4.87, 5.47, 5.28, 5.36 in 2020, respectively. It was concluded that there were no significant interaction values between the fiber fineness (mic) and irrigation water amount, block, irrigation water amount × block ($p > 0.05$). According to the irrigation issues $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ and $I_{1.50}$, $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$, it was determined that the fiber breaking elongation (elg) was 7.06, 7.93, 7.36, 7.23, 7.16 in 2019 and 7.33, 7.40, 7.33, 7.10, 7.13, 7.06 in 2020, respectively. While irrigation water amount and block variance analysis values were found at significant level in 2019 ($p < 0.05$), it was figured out that only the irrigation water amount variance analysis values were at significant level in 2020 ($p < 0.05$).

Table 7. *Variance analysis results of fiber quality parameters and Duncan groups in 2019*

Irrigation issues	Fiber index (g)	Fiber length (mm)	Fiber uniformity index (%)	Fiber strength (g tex^{-1})	Fiber fineness (mic)	Fiber elongation (elg)
$I_{1.25}$	6.12	26.01	81.84	30.01	4.31	7.06
$I_{1.00}$	5.60	26.39	82.71	29.51	4.28	7.93
$I_{0.75}$	5.48	25.88	83.12	28.20	4.25	7.36
$I_{0.50}$	5.97	25.67	81.21	27.69	4.26	7.23
$I_{0.25}$	4.78	26.28	82.66	26.80	4.22	7.16
Irrigation water amount	N.S.	N.S.	N.S.	N.S.	N.S.	*
Block	N.S.	N.S.	N.S	N.S.	N.S.	*
Irrigation water amount × block	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

**$p < 0.01$: very significant; *$p < 0.05$: significant; N.S.: $p > 0.05$: not significant

Table 8. *Variance analysis results of fiber quality parameters and Duncan groups in 2020*

Irrigation issues	Fiber index (g)	Fiber length (mm)	Fiber uniformity index (%)	Fiber strength (g tex^{-1})	Fiber fineness (mic)	Fiber elongation (elg)
$I_{1.50}$	5.36	28.90	84.73	31.86	5.11	7.33
$I_{1.25}$	6.10	28.76	84.53	31.96	5.52	7.40
$I_{1.00}$	5.83	28.72	86.26	31.76	4.87	7.33
$I_{0.75}$	5.15	29.10	86.30	31.63	5.47	7.10
$I_{0.50}$	5.27	28.51	85.30	30.86	5.28	7.13
$I_{0.25}$	4.93	28.59	85.43	29.96	5.36	7.06
Irrigation water amount	N.S.	N.S.	N.S.	N.S.	N.S.	*
Block	N.S.	N.S.	N.S	N.S.	N.S.	N.S.
Irrigation amount × block	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

**$p < 0.01$: very significant; *$p < 0.05$: significant; N.S.: $p > 0.05$: not significant

Discussion

In the present study, the irrigation, yield, and quality parameter values obtained were similar when they were compared previous studies.

In the study, while WUE was 0.56 kg m^{-3}, 0.44 kg m^{-3}, 0.42 kg m^{-3}, 0.42 kg m^{-3}, and 0.45 kg m^{-3} in 2019, it was 0.36 kg m^{-3}, 0.50 kg m^{-3}, 0.51 kg m^{-3}, 0.46 kg m^{-3}, 0.45 kg m^{-3}, and 0.46 kg m^{-3} in2020. In Pendergast et al. (2013), cotton plant

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(*Gossypium hirsutum* L.) was cultivated in Australia and it was stated that the water use efficiency was 0.17-0.40 kg m^{-3}.

It was observed that while the cotton seed yield in 2019 and 2020 increased depending on the proportional increase of irrigation water amount under $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, $I_{0.25}$ issues, it decreased under $I_{1.50}$ issue in 2020. In a previous study, the cotton seed yield of the cotton plant cultivated by subsurface drip irrigation method was determined as 3 323-6 182 kg ha^{-1} ($p < 0.01$) (Dağdelen and Özdemir, 2016). In that study, the relationship between cotton and subsurface drip irrigation method was examined.

In both years in the study, the ginning out turn values increased depending on the proportional increase of irrigation water amount under $I_{1.25}$, $I_{1.00}$, $I_{0.75}$, $I_{0.50}$, and $I_{0.25}$ issues. It decreased under $I_{1.50}$ issue in 2020. In Dağdelen and Özdemir (2016), it was stated that the ginning efficiency values according to irrigation issues ($I_{0.25}$, $I_{0.50}$, $I_{0.75}$, $I_{1.00}$) were determined as 38.80%, 40.00%, 40.68%, 41.53% ($p < 0.01$). In another study carried out, subsurface drip irrigation method was used in cotton plant cultivation, and it was stated that the ginning out turn was determined as 40.5-42.0% in the first year and 43.5-47.4% in the second year ($p < 0.01$) (Çetin et al., 2019).

In the study, while 100 seed weight (g) values were 8.12-7.70 g in 2019 and 8.85-7.61 g in 2020, they were determined as 11.34-9.96 g in Dağdelen and Özdemir (2016). In another study performed in Suruç Plain conditions in Türkiye, it was stated that 100 seed weight of DP-396 cotton variety was determined as 8.95 g ($p < 0.01$) (Kakaç, 2018). In the study performed by Singh (2022), subsurface drip irrigation method was used in cotton cultivation and cotton seed weight value was determined as 4.04-3.64 g.

In the present study, boll seed cotton weight (g) values were obtained as 4.28-3.60 g in 2019 and 4.01-3.85 g in 2020. In Dağdelen and Özdemir (2016), it was stated that according to the irrigation issues examined ($I_{0.25}$, $I_{0.50}$, $I_{0.75}$, $I_{1.00}$), they were determined as4.4-4.7 g ($p < 0.01$).

In the study it was figured out that the number of bolls per plant were 20.66-5.53 in 2019 and 13.52-6.97 in 2020. In Çetin et al. (2019), it was stated that the number of bolls per plant was determined as 12.6-16.4 ($p < 0.01$). In the study carried out in Kerman region of Iran, subsurface drip irrigation system was used and 3 different irrigation issues (I_{100}, I_{80}, I_{60}) were examined in cotton cultivation. It was stated that the number of bolls per plant were determined as 19.08, 16.41, and 13.66, respectively (Zounemat-Kermani, 2018).

In the present study, it was figured out that the values of plant height (cm) were 93.88-48.18 cm in 2019 and 85.46-52.34 cm in 2020. In Witt et al. (2020), cotton plants were cultivated by subsurface drip irrigation system, and plant heights were determined as 67.3-80.9 cm in the first year of that study and 57.3-81.0 cm in the second year of that study ($p < 0.01$).

When the results belonging to the fiber index (g) and irrigation water amount, block, and irrigation water amount × block interaction values of both years in the study compared some previous studies, there were differences from each other. For example; while there were no significant level ($p > 0.05$) between the fiber index (g) and irrigation water amount, block, and irrigation water amount × block interaction values in the study, in Yıldız and Haliloğlu (2017), it was stated that the fiber index value of DP-396 cotton variety cultivated under drip irrigation condition was 5.87 g ($p < 0.01$). Similarly, in Yuka (2014), it was stated that the average fiber index value of DP-396 cotton variety cultivated under furrow irrigation condition was 6.97 g ($p < 0.01$).

In the study, there was no significant interaction between the fiber length (mm) and irrigation water amount, block and irrigation water amount × block values ($p > 0.05$) in both years. But, in Attia et al. (2015), it was found that the fiber length (mm) value of the cotton plant cultivated under subsurface drip irrigation condition was 26.2-29.7 ($p < 0.05$). There were no significant levels statistically ($p > 0.05$) when the relationships between the fiber uniformity index (%) and irrigation water amount, block, irrigation amount × block interaction was evaluated for both years in the present study. Similarly, in Kakaç (2018), the interaction of DP-396 cotton variety cultivated under drip irrigation condition was examined and it was stated that the fiber uniformity index value was 82.53% ($p > 0.05$).

While it was figured out that there were no significance between the fiber strength (g tex^{-1}) and irrigation water amount, block, irrigation water amount × block interaction ($p > 0.05$) in the study, in the study belonging to Yıldız and Haliloğlu (2017), it was stated that the fiber strength value of the DP-396 cotton variety cultivated under drip irrigation condition was determined as 31.00 g tex^{-1} ($p < 0.05$). There were no significant interaction values between the fiber fineness (mic) and irrigation water amount, block, irrigation water amount × block ($p > 0.05$) for both years in the study. Similarly, in Witt (2020), it was stated that the fiber fineness value of cotton plant cultivated under subsurface drip irrigation condition was 4.9-5.1 mic in the first year and it was 4.7-5.0 mic in the second year of that study ($p > 0.05$).

In the present study, while irrigation water amount and block variance analysis values were found at significant level in 2019 ($p < 0.05$), it was figured out that only the irrigation amount variance analysis values were at significant level in 2020 ($p < 0.05$). In a previous study belonging to Attia (2015), it was stated that the fiber elongation value of the cotton plant cultivated under subsurface drip irrigation condition was determined as 9.5-10.1 Elg and there was no significance between the fiber elongation value and irrigation water amount, block, irrigation water amount × block ($p > 0.05$).

Conclusion

According to the results belonging to both years in the study, it was figured out that there was an interaction between irrigation water amount and cotton yield parameters. On the other hand, it was determined that there was no statistical interaction between irrigation water amount and fiber quality parameters. However, it was concluded that there was statistical difference between the cotton yield parameters and fiber fineness (mic) of the block and irrigation × block interaction.

The values of irrigation parameters in 2019 were calculated that irrigation water amount (I) was 933.75-186.75 mm, evapotranspiration (ET) was 1040.0-296.6 mm, water use efficiency (WUE) was 0.56-0.42 kg m^{-3}, irrigation water use efficiency (IWUE) was 0.71-0.51 kg m^{-3}, respectively. According to the amount of irrigation water, efficiency values found out that seed cotton yield was 5870.73-1330.96 kg ha^{-1}, ginning outturn was 43%-38.33%, 100 seed weight was 8.72-7.43 g, boll seed weight was 4.28-3.60 g, boll number per plant was 20.66-5.53, plant height was 93.88-48.18 cm, respectively. According to the results obtained as fiber quality parameters, it was determined that fiber index was 6.12-4.78 g, fiber length was 26.39-25.67 mm, fiber uniformity index (%) was 83.12-81.21, fiber strength was 30.01-26.80 g tex^{-1}, fiber fineness (mic) was 4.31-4.22, and fiber elongation at break (Elg) was 7.93-7.06, respectively. In 2020, the values of irrigation parameters were calculated that irrigation

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water amount (I) was 1138.5-189.75 mm, plant water consumption (ET) was 1305.8-346.9 mm, water usage efficiency (WUE) was 0.51-0.36 kg m^{-3}, irrigation water usage efficiency (IWUE) was 0.84-0.41 kg m^{-3}. Yield parameters were determined that seed cotton yield was 5559.1-1608.1 kg ha^{-1}, ginning outturn was 42.66%-39.33%, 100 seed weight was 8.85-7.61 g, boll seed weight was 3.76-4.38 g, boll number per plant was 17.53-6.97, plant height was 94.14-52.34 cm, respectively. The fiber quality parameters were found that index fiber was 6.10-4.93 g, fiber length was 29.10-28.51 mm, fiber uniformity index was 86.30%-84.53%, fiber strength was 31.96-29.96 g tex^{-1}, fiber fineness (mic) was 5.52-4.87, fiber elongation (Elg) was 7.40, respectively. In the study, the Kcp value was obtained as 1.25 for both years. The Kcp was recommended for optimum irrigation to cultivate cotton under subsurface drip irrigation condition in Harran Plain. The farmers and the researchers related to cotton cultivation should create the irrigation conditions accordingly in Harran Plain.

In conclusion, in the study, it was suggested that Kc = 1.25 should be use for cotton cultivation in Harran Plain. On the other hand, under the possible conditions such as agricultural drought, hydrological drought in future, Kc = 1, Kc = 0.75, and Kc = 0.50 values may be acceptable as restriction factor in limited-irrigation schedules by accepting the decrease in yield. If yield reduction cannot be accepted, it should be recommended to decrease the size of the irrigation areas and Kc = 1.25 should be use.

Author contributions. In the study, irrigation applications and cultivation were performed by Y. E. Özkaya under G. İ. Tuylu's supervision. The evaluation of the study was performed by G. İ. Tuylu, and the editing of the manuscript was performed by Y. E. Özkaya and G. İ. Tuylu.

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Conflicts of interest. The authors declare no conflict of interest.

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