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Effects of Different Continuous and Pulse Drip Irrigation Applications on Yield and Quality of Cotton (*Gossypium hirsutum* L.)

Batuhan Turkbay[1] and Safiye Pinar Tunali[2*]

[1]Aydın Adnan Menderes University, Graduate School of Natural and Applied Sciences, Department of Agricultural Structures and Irrigation, Aydın, Turkiye

[2]Aydın Adnan Menderes University, Faculty of Agriculture, Department of Biosystems Engineering, Aydın, Turkiye

[*]Corresponding author. E-mail: pinar.gulmez@adu.edu.tr

ABSTRACT

The depletion of water resources and the increasing effects of climate change necessitate the development of effective irrigation strategies for crops with substantial irrigation requirements, such as cotton. This study aimed to evaluate the effects of pulse drip irrigation on cotton yield, fiber quality, and water-use efficiency. The research was conducted at the Research and Application Farm of the Faculty of Agriculture, Adnan Menderes University, Aydın, during 2023 and 2024 growing season. In addition to continuous irrigation, three different pulse irrigation applications were evaluated. Soil moisture variation was used to determine irrigation times. According to the results, there was no statistically significant difference among irrigation applications in yield, quality, or water-use characteristics. However, pulse irrigation applications (especially K_2 and K_3) showed higher average values for yield and water-use parameters. Furthermore, it was determined that climatic differences between years had a greater effect on yield and quality than irrigation applications. In conclusion, it was determined that pulse irrigation applications can be implemented under suitable conditions without causing yield loss and have potential for water conservation.

Keywords: cotton (*Gossypium hirsutum* L.), pulse drip irrigation, fiber quality, water use efficiency.

INTRODUCTION

Water scarcity reduces both production and consumption, thereby negatively impacting economic growth (Desbureaux et al., 2019). In the last twenty years, one-fifth of the world's freshwater have been used. Agriculture accounts for 72% of global freshwater use (FAO, 2023). To maximize efficiency in agricultural irrigation, water must be delivered to the soil in the most economical and technically appropriate way. Pulse drip irrigation is a technique that delivers water to plants at specific intervals rather than continuously. The irrigation process is planned in short, interrupted bursts. The main goal of this practice is to ensure more balanced water penetration throughout the soil profile, reduce surface runoff and evaporation losses, and increase water-use efficiency. At the same time, by creating a controlled water constraint, it aims to stimulate water-sensitive processes in plant physiology, thus positively impacting productivity and quality (Abdelraouf et al., 2013).

Efficient water use in agricultural production is of great importance, especially for water-intensive crops like cotton. Cotton is a significant industrial crop, grown in approximately 75 countries worldwide, and serves as a fundamental raw material for the textile and food industries. Turkey ranks sixth worldwide in cotton production and consumption (Küçük and Issı, 2019). In cotton cultivation, irrigation should not be considered merely a factor in increasing productivity. The use of modern irrigation techniques is crucial for preventing water waste and minimizing environmental impacts (Ray and Majumder, 2024).

Numerous studies have shown that pulse drip irrigation practices save water and increase water-use efficiency across various plant species (Erdoğan, 2014; Rank and Vishnuu, 2021; Mohammadi et al., 2023; Abdelraouf et al., 2024). Furthermore, Zamaro et al. (2019) reported a significant

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increase in coriander yield, Carroll et al. (2024) in raspberry yield, and Abdelraouf et al. (2024) in lemon yield compared to continuous drip irrigation. Erdoğan (2014) also reported that pulse drip irrigation increases fertilizer use efficiency. Studies conducted across different regions have shown that pulse irrigation practices create a more favorable environment for plant roots (Rank and Vishnuu, 2021) and increase infiltration width, thereby enabling more efficient water storage (Zhu et al., 2024).

A review of the literature reveals that pulse drip irrigation offers a sustainable and effective solution to environmental challenges such as climate change and water scarcity. However, studies examining the combined effects of different pulse irrigation applications on cotton yield and quality are limited. This study focuses on increasing the sustainability of cotton production by achieving water savings through pulse irrigation practices without compromising yield or quality. In this context, some yield, water-use, and quality components obtained from pulse and continuous drip irrigation applications in cotton are compared. It is expected that the data from this study will contribute to the development of more environmentally friendly and economically effective irrigation programs in cotton farming.

MATERIAL AND METHODS

Study Area

The research was conducted under field conditions in the experimental plot of the Biosystems Engineering Department at the Research and Application Farm affiliated with the Faculty of Agriculture, Aydın Adnan Menderes University, during the years 2023-2024. The experimental area is located at an average altitude of 56 meters above sea level, at 37°45'53" north latitude and 27°45'37" east longitude (Akça and Atatanır, 2020).

Climate Characteristics

Long-term climate data for the experimental area were obtained from the meteorological station established in 2014 and belonging to the Aydın Provincial Directorate of Meteorology. Figure 1 compares monthly data from 2014-2022 with data from 2023 and 2024. The climate data from the experimental area indicate that supplementary irrigation is necessary during periods when natural rainfall is insufficient to meet plant water needs. Efficient and planned use of water resources, especially during the summer months, is crucial to the performance of irrigation systems and the sustainability of agricultural production. This situation becomes even more critical in 2024.

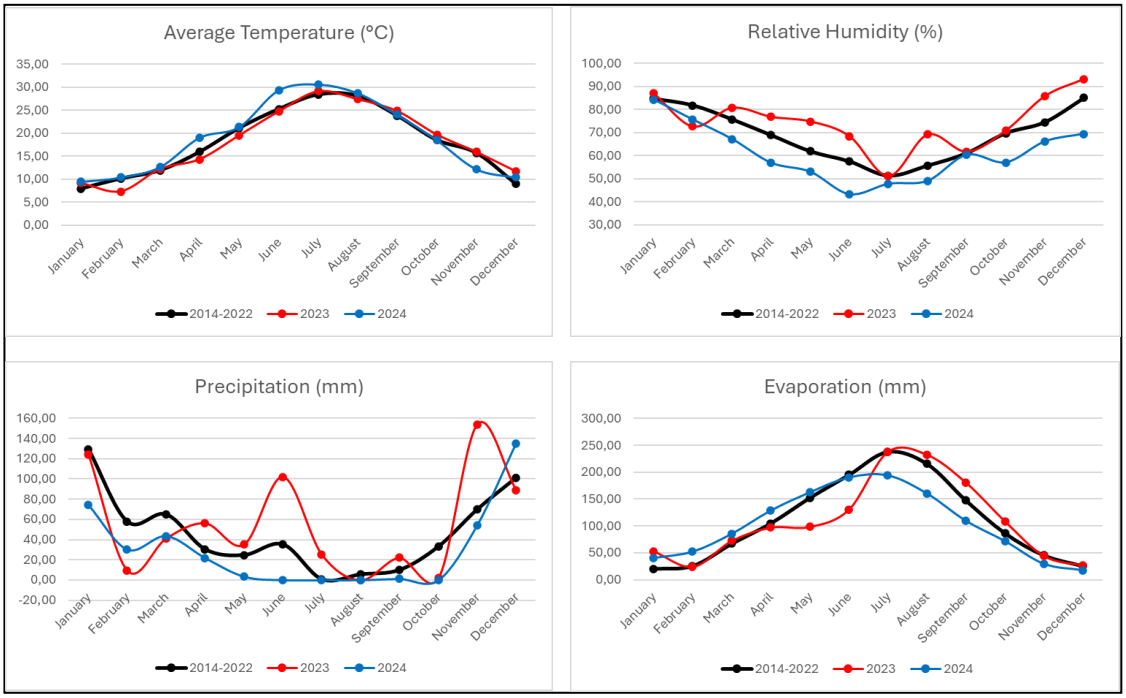


Figure 1. Some climate parameters of the research area

Soil Characteristics

The results of the physical and chemical analyses of the soils in the study area are given in Table 1 (Aksoy et al., 1998). The soils of the experimental area are located on a floodplain and have a flat slope (0-0.5%). The pH content of the series soils ranges from 8.39 to 8.97 and increases with depth in the soil profile (Mert, 2014).

Table 1. Physical properties of the soil in the experimental area

Soil Depth (cm)	Soil Texture Distribution (%)			Texture Class	Bulk Density ($g.cm^{-3}$)	*Field Capacity		*Wilting Point		Available Water Capacity	
	Sand	Clay	Loam			(%)	(mm)	(%)	(mm)	(%)	(mm)
0-30	58.4	13.6	28.0	SL	1.35	23.1	93.5	10.1	40.9	13.0	52.6
30-60	56.4	13.6	30.0	SL	1.45	22.9	99.6	9.4	40.9	13.5	58.7
60-90	68.2	13.6	19.2	SL	1.52	18.4	83.9	7.3	33.2	11.1	50.7
90-120	49.7	17.5	32.0	SL	1.50	20.3	91.3	7.2	32.4	13.1	58.9

*: Dry Weight Percentage.

Plant Characteristics

The MAY 455 variety, an early-maturing cotton variety, was used in the experiment. It has a high yield potential and adaptability. The leaves are slightly hairy, and the plant has a conical growth habit. The bolls are close to the main stem. The percentage of five-lobed bolls is 60-70%. Due to its strong plant structure, it is suitable for mechanical harvesting.

The Spinning Consistency Index (SCI) is 140 or higher; the fiber fineness and maturity (Micronaire) values range from 4.4 to 4.7 mm, the upper half mean length (UHML) ranges from 29 to 32 mm, and the ginning outrun is in the range from 43 to 45% (May Tohum, 2024).

Water Source Characteristics

The components of the drip irrigation system in the experimental area are presented in Figure 2. The system includes a fertilizer tank, a screen filter, a main pipeline, a manifold pipeline, laterals, and fittings. Irrigation water was pumped from a well using a submersible pump and conveyed to the experimental area via 75 mm PE pipes. In all plots, one polyethylene (PE) lateral with an outer diameter of 16 mm was used per row. The emitters used in the laterals are spaced at 20 cm intervals, have an internally perforated design, and have a discharge rate of 2 L h^{-1}. To ensure controlled irrigation, 16 mm-diameter valves were installed at the inlet of each lateral line in each plot.



Figure 2. Drip irrigation system control unit

Experimental Design and Cultural Practices

The two-year experiment was conducted using a randomized block design with three replications. Four drip irrigation applications (continuous drip irrigation and 1-, 2-, and 3-pulsed drip irrigation) and three replications. Cotton was sown in the experimental plots at a row spacing of 0.7 m. The row length was 9 m, with 4 rows of plants. 3 m was left between plots and blocks to prevent lateral water movement and to facilitate tractor operations during cultural practices. To ensure emergence after sowing, dense planting was applied, and thinning was performed to 20 cm between plants in the row after true leaves formed. Standard agricultural practices (fertilization, weed and pest control) were applied to all plots. In addition, phenological observations of cotton were carried out in both years. For this purpose, the stages of initial emergence, square formation, flowering, boll formation, and fruit development of cotton were monitored in the plots. The total growing season, from the first emergence of cotton to harvest, lasted 191 days in 2023 and 186 days in 2024 (Figure 3).

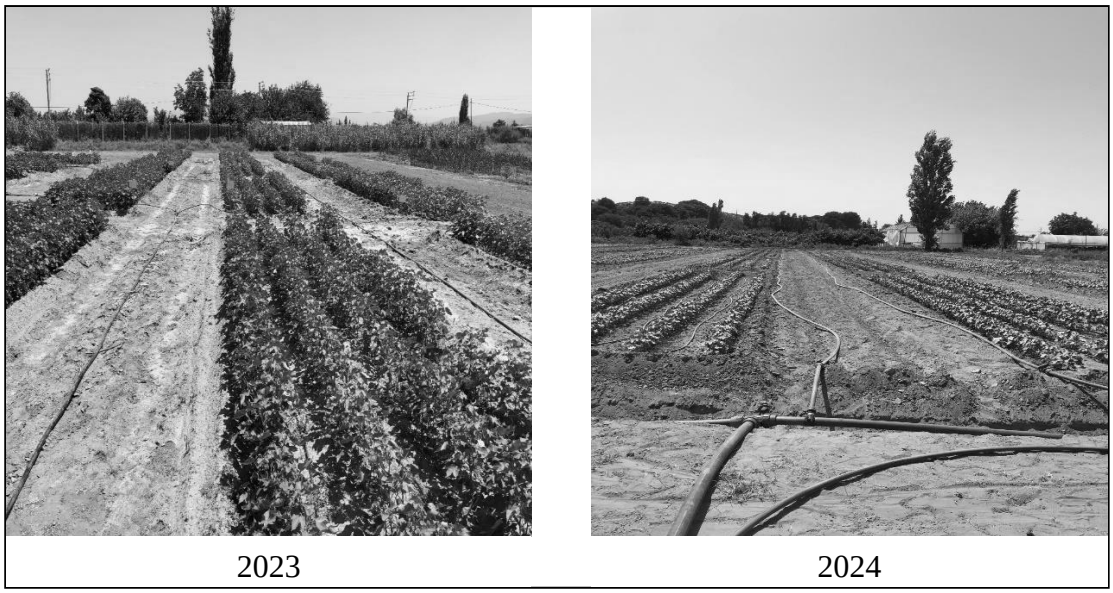


Figure 3. Experimental Area

Irrigation Applications

In pulse drip irrigation applications, the waiting times between irrigations were set at 1 hour per interval, based on the literature (Zamora et al., 2019; Zhu et al., 2024). The total irrigation time was kept constant across applications, but the method of water application varied with each irrigation (Table 2).

Table 2. Irrigation topics examined in the research

Treatments	Irrigation Applications	Waiting Times (h)
C	Continuous Irrigation (Control Plot)	-
P_1	Single Pulse Irrigation	1
P_2	Two-Pulse Irrigation	2
P_3	Three-Pulse Irrigation	3

The timing of the first irrigation in the experimental plots was determined based on local farmers' practices. Accordingly, in the first year of the experiment, the first irrigation was carried out in the second half of July. In the second year, due to low rainfall and high evaporation rates, the first irrigation was carried out in early July. A total of 7 irrigations were applied during the vegetation period in both years. Irrigation applications were carried out weekly, in accordance with

local farmers' practices and the requirements of other studies in the experimental area.

The amount of irrigation water was determined based on soil moisture content measured gravimetrically in the control plot (continuous-irrigation subject) 1 day before each irrigation. The soil profile water deficit was determined to reach field capacity, and the amount was applied equally to all plots. The gravimetric method was used to determine soil moisture content, which is a widely used method that allows for the direct and reliable determination of soil water content (FAO, 1998; Hillel, 1998). For this purpose, disturbed soil samples were collected from the middle of the plots at depths of 0-30, 30-60, and 60-90 cm, 1 day before each irrigation, using a soil probe. The fresh weights of the collected samples were determined, and their dry weights were measured after drying in an oven at 105°C for 24 hours; the soil moisture content was then calculated from these values.

The water balance equation method proposed by James (1988) was applied to determine seasonal plant water consumption for the study subjects.

$$ET = I + R + Cr - Dp + Rf \mp \Delta S \quad (1)$$

In the equation, ET: seasonal plant water consumption (mm), I: amount of irrigation water applied (mm), R: effective rainfall (mm), Cr: capillary rise (mm), Dp: deep infiltration (mm), Rf: surface runoff losses (mm), ΔS: soil profile moisture change (mm). Soil profile moisture change was calculated as the difference in moisture content between the beginning and end of the plant growth period. Since irrigation was done using the drip irrigation method, capillary rise, deep infiltration, and surface runoff losses were neglected (Sezen et al., 2011).

Water use efficiency was used to determine the most suitable irrigation program by comparing different irrigation practices. Water use efficiency values, also expressed as the water utilization rate, were calculated using Equations 2 and 3, which express the ratio of yields obtained for each irrigation treatment to seasonal plant water consumption and to the applied irrigation water (Howell and Hiler, 1975).

$$WUE = Y/ET \quad (2)$$

$$IWUE = Y/I \quad (3)$$

In the equations, WUE: water use efficiency (kg m^{-3}), IWUE: irrigation water use efficiency (kg m^{-3}), Y: yield (kg ha^{-1}), ET: seasonal plant water consumption (mm), and I: amount of irrigation water applied (mm).

Other Parameters Examined in Cotton

At harvest, plants in the two central rows of each plot were manually harvested and weighed to determine the plot lint yield (kg ha^{-1}). A 300 g sample was taken from each plot, and fiber quality parameters were analyzed using the HVI (High Volume Instrument) system in an authorized laboratory. In addition, parameters such as boll weight, seed cotton yield per plant, ginning outturn, and 100-seed weight were determined according to standard methods (Figure 4).

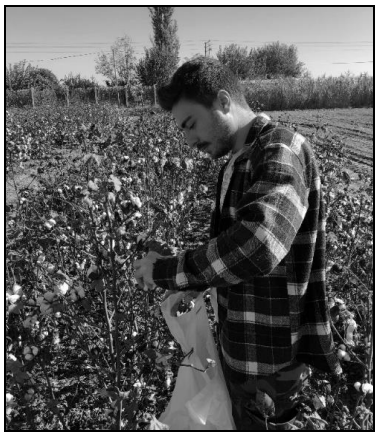


Figure 4. Cotton harvesting

Statistical Analyses

To reveal differences in irrigation applications within the scope of this study, data for all parameters were analyzed using analysis of variance (ANOVA). Duncan's multiple-range test ($p < 0.05$) was used to evaluate statistical differences. The IBM SPSS Statistics 21 program was used for all statistical analyses (IBM Corp., Armonk, NY, USA).

RESULTS AND DISCUSSION

This study investigated the effects of different irrigation applications on cotton yield, water-use efficiency, and some quality parameters. The results showed that irrigation applications did not have a statistically significant effect on most of the parameters examined. However, the year factor was found to be a determining factor for many parameters.

The Effect of Irrigation Applications on Some Yield Components

The results of the analysis of variance (ANOVA) and Duncan's multiple-range test for some yield components obtained from the study are presented in Table 3.

Table 3. Effect of year and irrigation applications on selected cotton yield components

Year (Y)	Irrigation Applications (IA)	Boll Weight (g)	Seed Cotton Yield per Plant (g)	100-Seed Weight (g)	Ginning Outturn (%)
2023	C	6,29^{b}	47,70	12,01^{ab}	42,07
	P_1	6,89^{a}	53,53	11,29^{b}	41,77
	P_2	7,26^{a}	48,73	12,22^{a}	41,33
	P_3	7,08^{a}	48,17	11,93^{ab}	41,60
2024	C	3,67^{b}	24,77	8,11^{e}	42,47
	P_1	4,69^{a}	37,17	8,69^{d}	42,57
	P_2	4,61^{a}	38,17	9,18^{c}	41,92
	P_3	4,69^{a}	26,43	9,16^{c}	41,93
ANOVA (P)	Y	0,000**	0,015*	0,000**	0,055^{ns}
	IA	0,006**	0,698^{ns}	0,008**	0,257^{ns}
	Y x IA	0,794^{ns}	0,900^{ns}	0,043*	0,913^{ns}

Groups that differ at the 5% level according to the Duncan test are indicated by different letters.
^{ns}: Difference is insignificant;
*: Significant at the 5% probability level;
**: Significant at the 1% probability level.

Table 3 clearly shows statistically significant differences between years for all parameters except ginning outturn. These results indicate that environmental conditions specific to 2024, such as rainfall distribution, temperature, evaporation, and relative humidity, negatively affect cotton yield, leading to a significant decrease, especially under continuous irrigation. According to 2023 boll weight data, pulse irrigation at the optimal level positively affects boll development and seed yield in cotton plants. In particular, the high value in the P_2 application suggests it may help eliminate negative effects on yield when the plant is exposed to mild water stress. In addition, pulse and continuous irrigation applications have a statistically significant effect on boll weight. In 100-seed weight values, year and irrigation applications were highly significant. The table indicates that when the year and irrigation application factors are considered together, certain applications may be more effective in certain years. Therefore, the interaction between environmental conditions and irrigation applications should not be ignored. The literature reports that cotton ginning outturns vary depending on regional conditions and application methods. Özkara and Şahin (1993) reported a yield of 43-44%, while Dağdelen et al. (2009b) reported 44.4-45.4% in the Aydın region. These findings indicate that fiber and seed separation efficiency can vary across growing conditions and cotton varieties. The yield values obtained from the experiment ranged

from 41.33% to 42.07% and remained within commercially acceptable limits.

100-seed weight is a significant yield component in cotton and is sensitive to genetic and environmental factors, as well as agricultural practices. In Turkey, 100-seed weight ranges from 8.0 to 13.0 g across different cotton varieties (Aydemir, 1982). In the Aydın region, this value has been reported to range from 9.80 to 11.24 g (Sezgin, 2001). In this study, the values obtained in the 2023 trials were close to the upper limits reported in the literature, indicating that high genetic potential was revealed under optimal growing conditions. In particular, the 12.22 g recorded in the P_2 application is a positive indicator in terms of yield. The 2024 values, however, were lower than the previous year and the literature, and were affected by environmental factors such as water stress and temperature fluctuations.

The Effect of Irrigation Practices on Soil Moisture Changes

In both years of the study, soil moisture deficits were measured one day before each irrigation event to determine the amount of water to be applied to the plots. The amounts of irrigation water applied and the corresponding moisture deficit values are presented in Figure 5. These applications aim to determine the extent to which soil and moisture loss can retain water. Soil moisture deficit measurements were taken before each irrigation and directly reflect the effects of the irrigation applications.

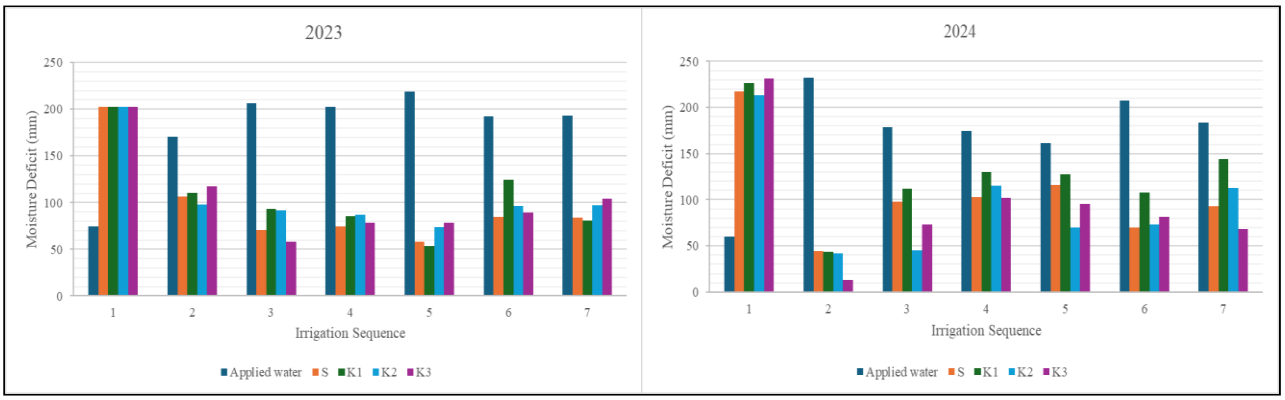


Figure 5. Moisture Deficit Values at Each Irrigation Event

The results show that applying the same amount of water with different application methods significantly affects soil water balance. Pulse drip irrigation applications have reduced the moisture deficit, resulting in more efficient water retention in the soil. Analyses by year and irrigation frequency generally show that applying the same amount of irrigation water using different methods, especially with pulse drip irrigation (P_3), reduces the moisture deficit, increases water retention, and minimizes potential water losses. The P_3 application achieved the lowest moisture deficit levels in both 2023 and 2024, making it the most efficient method for soil-water interaction. Continuous drip irrigation, especially in situations where the soil cannot absorb sufficient water, has revealed the possibility of water loss through deep infiltration or surface runoff. In this context, pulse drip irrigation can provide significant advantages for sustainable agriculture, especially in water-scarce regions.

The fact that the amount of water given to all plots was kept constant in both years indicates that the differences obtained are solely due to the application method. These findings reveal that intermittent drip irrigation enables the soil to use water more efficiently, especially by limiting surface-to-deep infiltration. Furthermore, the fact that moisture deficit values reached their minimum levels in the P_3 application suggests that this method may be the most effective strategy. In conclusion, pulse drip

irrigation appears to have significant potential to reduce soil moisture loss and improve water efficiency. It is recommended that such applications be widespread, especially in agricultural areas with limited water resources.

The Effect of Irrigation Applications on Water Yield Relationships

The results of the analysis of variance (ANOVA) and Duncan's multiple-range test for water yield relationships obtained from the study are presented in Table 4.

Table 4. Effect of different irrigation applications on cotton yield and water -use efficiency

Year (Y)	Irrigation Applications (IA)	Seed Cotton Yield (kg ha^{-1})	Irrigation Water Applied (mm)	Effective Rainfall (mm)	Seasonal Crop Evapotranspiration (mm)	WUE (kg m^{-3})	IWUE (kg m^{-3})
2023	C	4262,4	687,03	127,40	893,85	0,480	0,620
	P_1	4439,7			897,03	0,500	0,650
	P_2	4345,2			880,26	0,490	0,630
	P_3	4445,0			873,07	0,510	0,650
2024	C	3273,3	732,34	0,00	866,22	0,380	0,440
	P_1	3252,6			860,27	0,380	0,440
	P_2	3786,0			852,62	0,440	0,520
	P_3	3786,2			864,78	0,440	0,520
ANOVA (P)	Y	0,001**	-	-	-	0,003**	0,000**
	IA	0,603^{ns}	-	-	-	0,433^{ns}	0,581^{ns}
	Y x IA	0,702^{ns}	-	-	-	0,736^{ns}	0,728^{ns}

Groups that differ at the 5% level according to the Duncan test are indicated by different letters.
^{ns}: Difference is insignificant;
*: Significant at the 5% probability level;
**: Significant at the 1% probability level.

Table 4 shows that the average amount of irrigation water was 709.69 mm. This clearly demonstrates the critical role of irrigation in cotton development. The average seasonal crop evapotranspiration value of 835.89 mm also supports this. Furthermore, the average irrigation water use efficiency of 0.56 kg m^{-3} indicates a moderate yield per unit of irrigation water. The low variation in WUE and IWUE values indicates that the experiment was stable with respect to water use efficiency. Effective rainfall values reveal that rainfall in the experimental area was both irregular and generally low.

The seasonal crop evapotranspiration values in the table indicate that the cotton plant requires a significant amount of water during its growth period and uses most of the water applied. Overall, irrigation applications provided sufficient water under the experimental conditions, but the water-to-yield conversion rate varied across applications. This situation reveals that irrigation should be carefully planned not only in terms of quantity but also in scheduling and application methods.

WUE and IWUE exhibit wide ranges in the literature. In the study conducted by Dağdelen et al. (2009a), WUE and IWUE values were reported as 0.76-0.98 and 0.81-1.46 kg m^{-3}, respectively, while Dağdelen et al. (2009b) reported them as 0.735-1.134 and 0.917-2.234 kg m^{-3}. The values obtained from the experiment are lower than those reported in the literature. Bakeer et al. (2009) and El-Mogy et al. (2012) reported that WUE and IWUE were higher under pulse drip irrigation than continuous drip irrigation. These results support the idea that irrigation application methods and water management are decisive factors in water-use efficiency. Dağdelen et al. (2009a) reported that the fact that IWUE values are greater than WUE values is due to the use of water stored in the soil.

Effect of Irrigation Applications on Fiber Quality

The results of the analysis of variance (ANOVA) and Duncan's multiple-range test for some fiber quality parameters obtained from the study are presented in Table 5.

Table 5. Effect of different irrigation applications on fiber quality parameters

Year (Y)	Irrigation Applications (IA)	Fiber Length (UHML, mm)	Fiber Strength (Str, g tex^{-1})	Fiber Fineness (MIC)	Uniformity Index (UI, %)	Fiber Elongation (Elg, %)
2023	C	30,100	35,170	5,330	85,600	8,070
	P_1	30,730	32,730	5,310	85,800	7,930
	P_2	30,910	32,170	5,290	86,500	8,030
	P_3	30,100	30,370	5,450	84,800	7,870
2024	C	27,820	30,630	4,770	83,470	8,300
	P_1	28,260	32,870	4,680	84,500	8,070
	P_2	28,090	31,000	4,750	84,300	7,930
	P_3	28,070	31,430	4,600	84,070	8,400
ANOVA (P)	Y	$0,000^{**}$	$0,206^{ns}$	$0,000^{**}$	$0,021^{*}$	$0,273^{ns}$
	IA	$0,755^{ns}$	$0,312^{ns}$	$0,955^{ns}$	$0,632^{ns}$	$0,813^{ns}$
	Y x IA	$0,933^{ns}$	$0,149^{ns}$	$0,454^{ns}$	$0,804^{ns}$	$0,649^{ns}$

Groups that differ at the 5% level according to the Duncan test are indicated by different letters.
^{ns}: Difference is insignificant;
*: Significant at the 5% probability level;
**: Significant at the 1% probability level.

The results in Table 5 show that environmental conditions across years influence fiber quality parameters, but different irrigation practices do not result in significant changes. Comparing the analysis results from 2023 and 2024, it is evident that cotton fibers were generally longer and stronger in 2023, while in 2024, they were finer but slightly shorter. Increasing fiber fineness improves the softness and luster of textile products, while decreasing fiber length may reduce yarn durability. Although the data for both years are similar in terms of uniformity and strength, small performance fluctuations were observed in the 2024 fibers. The average fiber length (29.26 mm) generally indicates that the cotton fibers obtained from the experiment are at a good level. The average Fiber Homogeneity (UI - Uniformity Index) of 84.88% also indicates high homogeneity. However, the average fiber fineness of 5.02 indicates that the fibers are coarse. The higher average elasticity throughout 2024 suggests that environmental conditions, agricultural practices, or genetic material characteristics of that year had a positive impact on the fiber structure. Consequently, 2024 cotton exhibits greater fiber elasticity than 2023 cotton, reducing the risk of breakage and improving processability in yarn production.

In terms of fiber quality parameters, irrigation methods and years showed different effects. Fiber fineness and fiber length varied by year; the effect of irrigation application remained limited. Özkan and Güleryüz (1995) reported fiber fineness of 4.49 µm for furrow irrigation and 4.63 µm for drip irrigation; Dağdelen et al. (2009b) reported a range of 5.11-5.48 µm. In this study, the fibers from 2023 corresponded to the "long" class with UHML of 30.10-30.91 mm, and those from 2024 to the "medium" class with UHML of 27.82-28.26 mm (Altun, 2020). This difference demonstrates the decisive role of environmental conditions and cultivation techniques in fiber length. The uniformity index reflects the length homogeneity of cotton fibers. While the 2023 cotton samples showed higher, more stable UI values, homogeneity decreased in 2024. This situation may negatively affect spinning performance. Fiber strength values were high in both years and were classified as "strong-very strong" (Yaşar, 2020).

Overall, this study reveals that cotton yield and fiber quality parameters are more strongly affected by annual environmental conditions. In contrast, irrigation methods have a limited effect on certain parameters, particularly lint weight and 100-seed weight. Furthermore, environmental stresses and

application techniques are critical for fiber development and spindle performance.

CONCLUSIONS

This study evaluated the effects of continuous and pulse drip irrigation applications on cotton yield, fiber quality, and water-use characteristics, with the aim of improving irrigation efficiency and reducing unnecessary water losses.

The most important finding of this study is that pulse drip irrigation applications do not differ statistically from continuous drip irrigation applications.

This reveals that pulse drip irrigation can improve cotton yield and quality. In terms of irrigation water conservation and sustainable production, further optimization of intermittent irrigation strategies and their testing across different climate zones will make significant contributions to future water management. Similar studies predict that, instead of basing irrigation applications on control, considering the moisture variations of each intermittent irrigation application will significantly reduce plant water consumption.

The results indicate that irrigation methods have a limited impact on yield, whereas environmental conditions (especially climatic factors) are more decisive in determining yield and quality. Therefore, it is recommended that climate data be considered year-round in production planning and irrigation scheduling.

Although there are no significant differences between the treatments, it is suggested that the applications with the highest yields and quality (e.g., P_2 or P_3) be retested in larger trials.

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