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The effect of irrigation water quality on fiber characteristics of cotton

Sulama suyu kalitesinin pamuğun lif özelliklerine etkisi

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ABSTRACT

The effects of fresh water (EC_w=0.88 dS m^{-1}), saline water (EC_w=6.5 dS m^{-1}) and water deficit on different growth stage on fiber quality of cotton were investigated through a two-year field study. Fourteen different fiber quality characteristics were investigated. When canal water was used, the detrimental effect of water deficit on different growth stages (vegetative period VGP, flowering and boll formation FBF and opening boll OB) were apparent on ginning out turn, short conversion index, micronaire, length, count, trash area, count strength product and reflectance degree. With the use of saline water, no obvious effect of water deficit at different growth periods on fiber quality was observed. However, regardless of water deficit, spinning conversion index, strength, length, uniformity, elongation, count strength product, reflectance degree, and yellowness decreased, while micronaire, trash count, and short fiber index increased. The greatest effect of saline water stress was observed in elongation, which was reduced by about 33%. Two years data were combined and the relationship between mean soil salinity (EC_e) and each fiber quality was investigated. The highest regression coefficient (*r*= 76.18%, $p<0.01$) was obtained between EC_e and elongation. The regression coefficient of micronaire, elongation, strength, length, short fiber index, yellowness, spinning conversion index, count, uniformity, reflectance degree, count strength product and ginning out turn with EC_e were significant ($p<0.01$). In addition, the correlation coefficients between the fiber characteristics were lower in the second year, whereas they were higher in the first year of the study.

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ÖZ

Farklı su düzeylerinin ve farklı kalitedeki sulama sularının (kanal suyu ECw=0,88 dS m^{-1} ve tuzlu sulama suyu ECw=6,5 dS m^{-1}) pamuk bitkisinin farklı gelişme dönemlerine (vejetatif dönem VGP, Çiçeklenme ve elma oluşumu, FBF ve elma açımı OB) ve lif kalitesi üzerine etkilerinin belirlenmeye çalışıldığı bu araştırma, 2 yıl süresince tarla koşullarında yürütülmüştür. Araştırmada normal sulama suyunun (ECw=0,88 dS m^{-1}) çırçır randımanı, eğrilebilirlik indeksi, lif inceliği, lif uzunluğu, yabancı madde sayısı, yabancı madde değeri, iplik olabilirlik gücü ve parlaklık özelliklerinin farklı gelişme dönemlerindeki su kısıtlılığından olumsuz şekilde etkilendikleri belirlenmiştir. Tuzlu sulama suyunun kullanılması durumunda su kısıtlılığının farklı gelişme dönemlerinde lif özelliklerine etkisi kesin olarak ortaya konulamamıştır. Ancak su kısıtlılığına rağmen yabancı madde sayısı, lif inceliği, kısa lif indeksi artarken eğrilebilirlik indeksi, lif mukavemeti, lif uzunluğu, lif uniformitesi, lif esnekliği, iplik olabilirliği, parlaklık ve kısa lif indeksi artmıştır. Lif esnekliği tuz stresi nedeniyle lif özellikleri içerisinde en fazla azalan özellik olmuştur (%33). İki yıllık sonuçlar bir arada değerlendirildiğinde ortalama toprak tuzluluğu (ECe) ile lif özellikleri arasında farklı ilişkiler bulunmuştur. En yüksek regrasyon katsayısı ECe ve lif esnekliği arasında gerçekleşmiştir (*r*= %76,18 $p<0,01$). Lif inceliği, lif esnekliği, lif mukavemeti, lif uzunluğu, kısa lif indeksi, sarılık, eğrilebilirlik, yabancı madde, uniformite, beyazlık, iplik olabilirlik, ve çırçır randımanı ile ECe arasında regrasyon katsayısı yüksek ($p<0,01$) önemli ilişkiler bulunmuştur. Ayrıca lif özellikleri arasındaki korelasyon katsayıları ikinci yılda düşük, birinci yılda yüksek bulunmuştur.

1. Introduction

Agriculture is by far the biggest user of fresh water resources in the world. However, the constraints of inadequate availability of good quality irrigation water have been forcing farmers in many arid and semi arid region to use poor quality ground water and drain water for irrigation of crops. Long-term use of these waters results in the salt-build up in the root zone and, hence reductions of crop yield. Currently, various methods such as leaching, breeding and use of salt tolerant crop are employed to prevent yield reduction. Breeding and growing crop varieties capable of producing high yield under high levels of soil and /or water salinity can have a considerable relevance to agricultural production. Differences in salt tolerance of different crops have been extensively reported (Maas 1986). Barley, wheat and cotton are most prevailing plants showing resistant to soil and water salinity.

Cotton, genus *Gossypium*, is one of the oldest fibre crops. There are four species that are cultivated to a large extent (*G. Hirsutum, G. Barbadanse, G. Arboreum, and G. Harbeceum*). Upland cotton (G. *Hirsutum*) and Egyptian cotton (*G. Barbadense*) account for more than 99 per cent of the world supply of raw cotton. The lint percentage of *G. Hirsutum* is 35-45 % or even more (Ashraf and Ahmad 2000). This is particularly important as it is produced as much as $16.8x10^6$ t in 33 million ha in about 70 countries.

The constraint of inadequate availability of good quality irrigation water in many arid and semi arid region of the world have forced cotton farmers using poor quality of irrigation water. Cotton is capable of tolerating high levels of salinity in arid and semi arid regions (Bajwa et al. 1992). Studies showed that the threshold value was 7.7 dS m^{-1}, and 50 percent reduction in growth occurs at 17 dS m^{-1} of soil salinity for cotton (Maas 1986).

Cotton fiber quality is determined primarily by genetics, but can also be influenced by environmental factors such as soil type, insect pressure, weather, growing season length, and harvest and ginning management (Meredith 1984). Numerous studies have reported how fiber quality is affected by moisture deficits. The period from square initiation to first flower represents the most critical development period in terms of water supply affecting the fiber quality (Krieg 1997). Fiber quality is also dependent upon the production and retention of bolls and both can be decreased by water stress (Guinn and Mauney 1984). This stress affects lint quality in numerous ways, especially during the fiber elongation period, which result in a decrease in fiber length and fiber immaturity (Mc Williams 2004; Ritchie et al. 2004). Strength and elongation factors well correlate with soil water (Johnson et al. 2002). Adequate soil water, along with high ambient temperatures before and during boll development increases fiber maturity (Davidonis et al. 2004).

The results on the effect of salinity on fiber quality are controversial. Some studies showed that increased soil salinity led to an increase in both ginning out turn (Ashraf and Ahmad 2000) and micronaire values (Rhoades et al. 1988) but a decrease in fiber elongation (Ye et al. 1997) and strength (Rhoades et al. 1988). In terms of salinity level of irrigation water on fiber length, some studies showed no effect (Rhoades et al. 1988) while some reported increases with increasing salinity in irrigation water (Ray et al. 1989).

As discussed above, the literature is lacking information about the effect of saline environment in soil created by sustained saline water irrigations on fiber quality. This study therefore aimed at determining changes in fiber quality properties of cotton due to irrigation water with different salt contents applied during its growing periods.

2. Material and Method

The experiment was carried out in 1997 and 1998 at the Agricultural Experimental Station of Çukurova University (36° 59'N, 35° 18'E), on Mutlu series soil in the Çukurova region, characteristics of plain conditions with altitude of 20 m above sea level. The soils of the Çukurova region developed from alluvial deposits of river terraces and are classified as a Vertisol. They have relatively high clay content with the predominant clay minerals smectite and kaolinite is typical for the soils of the Çukurova region. Soil of the study area was clay-loam with the cation exchange capacity of 66.24 and 68.77 me100g^{-1} and the pH values of 7.15 to 7.58. The organic matter content is generally under 1.5%. Climatic data were obtained from a meteorological station located near experimental site. The Çukurova region has a typical Mediterranean climate with hot and dry summers and mild, rainy winters (Table 1). Twenty three percent of the 654.8 mm annual rainfall in 1997, and 24% of the 588.2 mm annual rainfall in 1998 were recorded throughout the growing season. The mean air temperature was 23.5 °C in 1997 and 25.2 °C in 1998. Irrigation water was analyzed for water quality (Table 2).

NaCl was used in the preparation of salt water. Salt water was created in pool about 600 m^3. NaCl was added into pool until reach the desired EC level. An EC-meter was used to determine electrical conductivity (EC). Sodium (Na^+) and potassium (K^+) were analyzed by a flamephotometer; carbonate (CO_3) and bicarbonate (HCO_3) by sulfuric acid titration; chloride (Cl^-) by silver nitrate titration; and calcium (Ca^{2+}) and magnesium (Mg^{2+}) by Versanat titration. Sulphate (SO_4) was calculated by subtracting the total cation amount of HCO_3, CO_3, and Cl^- from total amount of anions. pH was measured using a glass electrode pH-meter (USSL 1954). The cotton (*Gossypium hirsutum L.*) variety, Cukurova-1518 (standard cotton variety for the region), was planted by a row space of 70 cm and thinned 10-12 cm in rows. 160 kg ha^{-1} of nitrogen and 60 kg ha^{-1} of phosphorus were applied. The growth period of cotton was divided into three stages (Table 3).

Table 1. Climate data of the experimental area in 1997 and 1998.

Climatic Parameters	April	May	June	July	Aug.	Sept.
Long- term						
Average Temperature °C	17.1	21.4	25.2	27.7	28.1	25.4
Relative Humidity %	69	67	66	68	67	63
Wind Speed, m/s	2.3	2.3	2.4	2.6	2.4	2
Rainfall, mm	51.4	46.7	22.4	5.4	5.1	14.8
1997						
Average Temperature °C	14.1	22.3	25.1	28.6	26,7	24.4
Relative Humidity %	72.9	68.2	73.3	72.7	80,1	63.4
Wind Speed, m/s	1.7	1.2	1.1	1.6	1,2	0.8
Rainfall, mm	104.4	20.1	11.4	0.9	6,2	12.6
1998						
Average temperature °C	18	21.4	25.9	28.6	30.6	26.7
Relative Humidity %	68.7	70.5	74.9	77.9	73.1	69.1
Wind Speed, m/s	0.8	0.6	1.6	0.5	0.1	0.2
Rainfall, mm	56.2	30.3	0.2	9.7	0	43.2

We have used fresh water in the first year and saline water in the second year to determine response of saline and non-saline conditions. For irrigation, line-source sprinkler irrigation technique was used for four replications (Hanks et al. 1976*)*.

The system consisted of eight parallel laterals placed 12 m apart. The water amount in the plots was fluctuated based on the lateral position. Thus, the plots were applied with different amounts of water (D) for each period. Both of two laterals were

Table 2. Chemical composition of irrigation waters.

Years	pH	EC_w	Na^+	K^+	Ca^{+2}+Mg^{+2}	HCO_3	CO_3	Cl^-	SO_4	SAR
1997	7.83	0.88	3.90	0.21	5.82	2.20	-	5.78	1.95	2.33
1998	7.55	6.53	87.96	1.10	6.05	4.17	-	80.08	10.61	51.21

EC_w; electrical conductivity of irrigation water dS m^{-1}, anions and cations are me L^{-1}

Table 3. Irrigation treatments of the experiment.

Growth period	Irrigation treatment						
	A	B[a]	C	D	E	F	G
Germination	F	F	F	F	F	F	F
Vegetative period (VGP)	D	F	D	D	F	F	D
Flowering and boll formation (FBF)	D	F	F	D	D	F	F
Opening of boll (OB)	D	F	F	F	D	D	D

utilized to full irrigate (F). The first irrigation in the experiment was applied when 60% of the readily available water at the depth of 120 cm was depleted. The amount of water to be applied was determined according to irrigation level A_2, which was taken as reference, and was calculated as soil water deficit in the 60 cm depth (Figure 1). All irrigations were terminated when 10% more water than that in the treatment A_2 was applied. In this way, different leaching fractions were provided based on the mentioned treatment. To avoid undesired amount of irrigation in the treatments, the lateral test was performed.

The first harvest was begun when approximately 60% of the cotton bolls opened; the second harvest was 5 weeks later. Fiber data were obtained from hand-harvested cotton in the middle (3*6m= 18 m^2) excluding the outer two rows in each plot to prevent side effects. Fiber properties for each sample were determined by High Volume Instruments (HVI): fiber length in millimeters measured as 2.5 (2.5% SL), fiber uniformity (Unf., %) determined as the ratio of the mean length to upper-half mean length expressed as a percentage, fiber strength as force (g/tex) necessary to break a fiber bundle, micronaire reading (mic.) as fineness of a fiber expressed in standard micronaire units (dtex), reflectance degree (%, Rd) and yellowness (+b) depicts the degree of cotton pigmentation, ginning out-turn (%, Gin.), spinning conversion index (SCI), short fiber index (%, SFI), fiber elongation (%, Elg.) as a measure of elasticity, trash count (count), trash area (area), count strength product (CSP), trash (%, T) values were determined.

Analysis of variance was performed using a general linear model procedure and differences amongst the treatments were determined with Duncan test, using SPSS for Windows (Version 11.5). The fiber characteristics were regressed with the amount of irrigation water and the soil salinity (Efe ve ark. 2000).

3. Results and Discussion

3.1. Effects of amount of irrigation water on fiber characteristics

The amount of irrigation water applied for each treatment and growth period were presented in Table 4, together with soil salinity (EC_e) values. Approximately 0.45 % less irrigation water was required in the second year, but the differences between the years were not significant ($p>0.05$). The treatments were irrigated with different volumes of irrigation water at different development stages. As expected, FBF stage was received more irrigation water than the other growth stages in treatment in the first year. The effects of growth stages (*G*) and amount of irrigation water (*I*) on fiber characteristics are statistically presented in Table 5. In 1997, the growth stages was significant on ginning out turn, spinning conversion index, micronaire, length, count, area, count strength product and reflectance degree. In 1998, however, it does not have significant effect on fiber characteristic except length and ginning out turn. Amount of irrigation water had significant

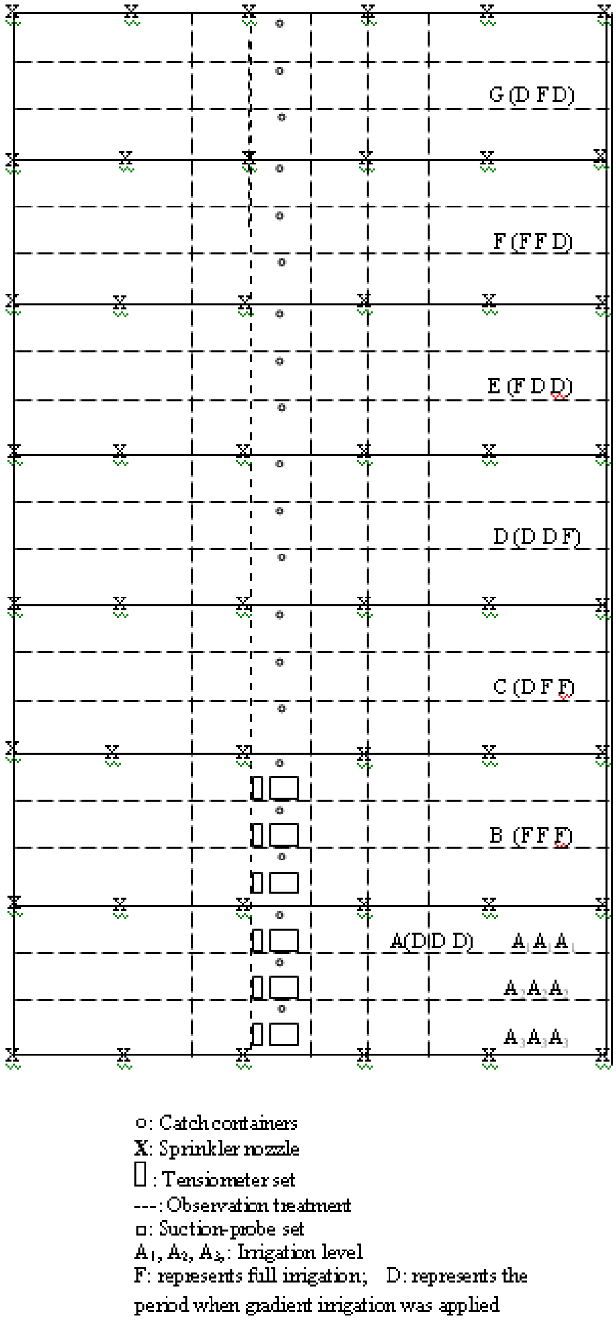

Figure 1. Diagram of the experimental field.

Table 4. The amount of applied water and the soil salinity at different growth stages of cotton.

Treatment	Growth Stages	1997		1998	
		I	EC_e	I	EC_e
A	VGP	79	1.09	96	0.86
	FBF	153	1.25	232	1.53
	BO	135	1.36	112	2.65
B	VGP	127	2.75	193	1.39
	FBF	245	0.76	305	1.82
	BO	228	1.02	151	2.97
C	VGP	75	1.28	114	1.26
	FBF	172	1.26	278	1.83
	BO	215	1.380	139	3.05
D	VGP	75	1.10	89	1.36
	FBF	185	1.02	232	1.80
	BO	115	1.18	136	2.43
E	VGP	132	1.17	147	1.32
	FBF	116	0.89	222	1.88
	BO	106	1.13	116	2.83
F	VGP	116	1.47	135	1.39
	FBF	221	0.99	202	1.89
	BO	187	0.93	123	3.00
G	VGP	67	1.51	113	1.22
	FBF	183	1.26	305	1.80
	BO	166	1.26	117	3.19

I; amount of irrigation water (mm), EC_e; mean of soil salinity (dS m^{-1}).

effects on spinning conversion index, micronaire, uniformite, short fiber index, trash, and count strength product in 1997 but not in 1998. Similarly, in 1998, interaction term (*G*I*) was not significant except for reflectance degree. However, in 1997, only spinning conversion index, strength and count strength product were significant in interactions terms (*G*I*).

Irrigation with different amounts of water at different growth stages affected some of the fiber characteristics. In the first year at FBF stage, micronaire increased with the increasing amount of water while short fiber index decreased with the decreased water. In the same year at BO stage, however, increased irrigation water increased only short fiber index. In the second year, the strength and the length characteristics of fiber were significantly positive affected ($p<0.05$) by amount of irrigation water at FBF stage.

Combined two-year data analysis revealed that elongation (p<0.05), micronaire (p<0.01), spinning conversion index ($p<0.05$) and count strength product (p<0.05) were significantly affected by the amount of water given at FBF stage while ginning out turn, reflectance degree, cnt (p<0.05) were significantly affected by the amount of water applied at OB stage. However, amount of irrigation water at VGP stage did not have any significant effect on the fiber characteristics of cotton. When the first year data on fiber characteristics were evaluated, water deficit in different growth stages improved some characteristic on one hand but deteriorated some others on the other hand (Table 6).

Except for A and C treatments, the length values were almost the same for all treatments. It did not have any significant difference in the length values after the full irrigation applied during the last two growth periods (FBF and BO). C treatment could indicate that these properties may have been influenced more severely by water deficit during VGP period. Similarly, the highest micronaire values (4.20) in A treatment where water deficit was applied during all growth periods was measured, but those in E treatment where full irrigation was applied during VGP were the lowest (3.67). As for yellowness values, the highest value obtained in E treatment (10.35) can be attributed to water deficit applied during FBF and OB periods while the lowest value obtained in C treatment (9.73) can account for the full irrigation in the same periods. In contrast, water deficit did not result in any changes in uniformity, short fiber index and elongation values.

Table 5. Variance analysis of fiber characteristics.

Year	Source of Variation	Df	Gin.	SCI	Mic.	Str.	Len.	Unf.	SFI	Elg.	T	Cnt	Area	CSP	Rd	+b
1997	*Replicate (R)*	3	*													
	Growth period(G)	6	***	**	***		**					*	*	**	*	
	RxG	18														
	Error	63														
	Irrigation Level(I)	3		*	*			*	*		**			**		
	*G*I*	18		***		**								*		
	Error	63														
1998	*Replicate (R)*	3	*			*										*
	G	6	***				*									
	RxG	18														
	Error	42														
	I	2														
	*G*I*	12													*	
	Error	42														
1997 -1998	*Year(Y)*	1	*	***	***	***	***	*	**	***		***		***	***	***
	Replicate (R)	3	***		*	*						*				
	G	6	***		***		***							**		
	*Y*G*	6														***
	Error	144														
	I	3		**	*	*	*		*					**		
	*Y*I*	2									*					
	*G*I*	18		**		**	*							**		
	*Y*G*I*	12		*		*										
	Error	144														

Gin.: Ginning out turn, SCI: Spinning conversion index, Mic.: Micronaire, Len.: Length, Unf.: Uniformity, SFI: Short fibre index, Elg.: Elongation, Cnt.: Trash count, CSP: Count strength product, Rd: Reflectance degree, +b: Yellowness, T: Trash. G: Water deficit on growth stages, I: amount of irrigation water, Y: Year. * , ** and ***are denote significant at the *p<0.05, p<0.01 and p<0.001 level* respectively

Table 6. Means of fiber characteristics in 1997 and 1998.

Year	Trt.	Gin	SCI	Mic.	Str.	Len.	Unf.	SFI	Elg.	T	Cnt	Area	CSP	Rd	+b
1997	A	0.382bc	125.38a	4.20d	27.36ab	27.68a	82.76	7.56	5.56	2.88ab	32.13ab	1.13ab	2038a	71.88abc	9.79ab
	B	0.384c	131.13ab	3.98bcd	27.12ab	28.61c	83.27	6.46	5.94	3.00ab	34.31ab	1.46ab	2087abc	71.99abc	10.21cd
	C	0.385c	125.75a	4.01bcd	26.81a	27.79ab	82.75	7.51	5.58	3.38b	39.38b	1.68b	2055ab	71.71ab	9.73a
	D	0.378bc	132.63ab	4.09cd	28.30b	28.12abc	83.35	6.61	5.65	3.00ab	35.94ab	1.56ab	2075abc	71.46ab	9.85abc
	E	0.368a	135.18b	3.67a	28.32b	28.59c	82.91	6.93	5.69	2.94ab	41.13b	1.40ab	2104bc	70.91a	10.35d
	F	0.375ab	134.57b	3.77ab	27.71ab	28.58c	83.22	6.51	5.94	3.00ab	27.00a	1.23ab	2117c	72.28ab	10.12abc
	G	0.375ab	128.75ab	3.83abc	26.80a	28.37bc	82.64	7.36	6.03	2.82a	28.00a	1.06a	2103bc	73.09c	10.06abcd
1998	A	0.379bc	115.92	4.77	26.08ab	26.98a	83.13b	7.48	3.52	2.92	46.33	1.28	1958	70.85	9.12a
	B	0.379bc	116.17	4.85	27.10ab	27.62abc	82.50ab	7.92	3.75	2.92	51.67	1.36	1961	70.46	9.19a
	C	0.386c	113.25	4.79	25.94a	27.97bc	82.35ab	7.95	3.93	2.92	37.58	1.36	1953	70.51	9.74b
	D	0.371ab	115.00	4.73	26.33ab	27.33ab	82.55ab	8.01	3.47	3.42	49.00	1.73	1965	70.83	9.07a
	E	0.367a	115.50	4.66	26.69ab	27.59abc	82.09a	8.39	3.99	2.92	47.42	1.28	1984	71.33	9.17a
	F	0.364a	118.67	4.52	26.80ab	27.99bc	82.27ab	8.00	4.08	3.00	45.75	1.28	2018	71.30	9.07a
	G	0.368ab	121.58	4.48	27.53b	28.16c	82.41ab	7.75	4.21	3.58	50.58	1.82	2016	71.05	9.43ab

Trt: Treatment, Gin.: Ginning out turn, SCI: Spinning conversion index, Mic.: Micronaire, Len.: Length, Unf.: Uniformity, SFI: Short fiber index, Elg.: Elongation, Cnt.: Trash count, CSP: Count strength product, Rd: Reflectance degree, +b: Yellowness, T: Trash

In the second year, water deficit on growth stage had no effect on fiber quality criteria except for ginning out turn and differences were detected for ginning out turn, spinning conversion index, micronaire, strength, length, uniformity, short fiber index, elongation, count strength product and reflectance degree ($p<0.05$). As discussed below, high soil salinity was the main cause for this phenomenon.

3.2 Effects of soil salinity on fiber characteristics

The salt concentration of the irrigation water in the second year was 7 times greater than that in the first year, leading to a higher salt accumulation of cotton root zone ($p<0.001$) (Table 4). Soil salinity values varied between 0.76-1.51 dS m^{-1} in the first year and between 0.86-3.19 dS m^{-1} in the second year. It should be noted that soil salinity in A, B, C, D, E, F and G treatments in the second year had 3.58, 4.64, 4.36, 4.68, 5.23, 5.24 and 4.10 times higher, respectively, when compared those of first years treatments.

When compared to the first year values, ginning out turn by 1.16% ($p<0.05$), spinning conversion index by 10.65% ($p<0.01$), strength by 2.98% ($p<0.01$), length by 2.06% ($p<0.01$), uniformity by 0.61% ($p<0.01$), elongation by 32.98% ($p<0.01$), count strength product by 4.95% ($p<0.01$) reflectance degree by 1.39% ($p<0.01$) and yellowness by 7.49% ($p<0.01$) decreased in the second year (Table 7). In contrast, micronaire by 20.08 % ($p<0.01$), short fiber index 13.15% ($p<0.01$), count by 35.87 % ($p<0.01$) increased in the same year. Area and trash remained unchanged ($p>0.05$). As shown, most of the fiber quality criteria deteriorated due to high soil salinity in the second year. Amongst them, three fiber characteristics (micronaire values, elongation and spinning conversion index) have to be emphasized. The micronaire values increased up to 4.85 dtex indicating fibers becoming thicker. The elongation values decreased to 3.47% and the fiber became shorter. The spinning conversion index values which showed changes due to water deficit applied in the first year remained same in the second year, probably due to the high soil salinity.

One of the most important problems due to salinity is the reduction of the fiber quality of cotton. Bernstein (1960) reported that increased soil salinity increased the lint percentage but decreased the seed index, fiber length and strength, and the fiber fineness was little affected. Increasing salinity in irrigation water (5.42 to 20.31 dS m^{-1}) made the fibers became coarser but fiber length was not affected (Ray et al. 1989). Other studies revealed that increased soil salinity (140 and 210 mol m^{-3}) increased the ginning out turn (Ashraf and Ahmad 2000) and micronaire (Rhoades et al. 1988) values while decreased fiber elongation and strength (Rhoades et al. 1988). Salinity level of irrigation water had no effect on fiber length (Rhoades et al. 1988); however the opposite was reported that fiber length reduced with the increasing salinity in irrigation water (Ray et al. 1989). The relationship between investigated fiber characteristics were determined by correlation coefficient for each year (Table 8).

The results showed that spinning conversion index highly correlated with micronaire, strength, length, uniformity, short fiber index and count strength product. Likewise, strength highly correlated with length, uniformity, short fiber index, trash, trash count, area, count strength product and reflectance degree. In general, the correlation coefficients between fiber characteristics were high in the second year, especially between elongation and spinning conversion index, length and short fiber index, count strength product and trash, count strength product and count, count strength product and area, reflectance degree and micronaire, and yellowness and strength.

4. Conclusion

Good fiber quality is a key factor in cotton production and is a desirable trait for its export market (Choudhary et al. 2001). From the results of this study, it is possible to reach two main conclusions. First, the effects of water deficiency at the growth stage of cotton on fiber quality in the first year were more predominate during FBF stage but less at BO stage. From the point of better total fiber quality, in the regions where water is scarce, it should definitely be avoided from water deficiency at the FBF stage.

Table 7. Linear regression lines of changes in fiber characteristics of soil salinity (n = 28 for 1997 and n= 21 for 1998, y= ax+b).

Response	1997 (ECw=0.88 dS m^{-1})			1998 (ECw=6.5 dS m^{-1})			1997-1998		
Variable	a	b	r^2, %	a	b	r^2, %	a	b	r^2, %
Gin.	0.039	0.361	12.35	-0.011	0.394	6.78	-0.003	0.380	7.59*
SCI	-58.971	155.65	21.98*	2.823	111.15	1.43	-9.086	134.24	48.66**
Mic.	0.336	3.758	0.46	-0.361	5.381	11.57	0.493	3.711	59.48**
Str.	-9.263	31.409	26.61**	1.047	24.62	5.1	-0.531	27.673	11.8**
Len	-3.534	29.751	16.31*	1.519	24.736	33.31**	-0.338	28.355	16.23**
Unf.	-3.288	84.378	8.13	-1.325	85.017	20.95*	-0.385	83.169	15.37**
SFI	5.844	4.512	11.16	0.822	6.344	5.62	0.644	6.712	19.88**
Elg.	-3.415	7.200	22.68**	0.780	2.347	13.68	-1.205	6.219	76.18**
T	-0.545	3.227	0.75	-0.075	3.236	0.16	0.057	2.975	1.13
Cnt	4.817	32.466	0.10	1.4556	44.101	0.09	8.018	31.254	26.34**
Area	-0.880	1.726	1.85	0.1394	1.176	0.54	0.062	1.325	1.24
CSP	-325.16	2221.3	17.23*	56.788	1870	9.42	-65.714	2108.6	51.79**
Rd	2.722	70.743	4.15	-0.300	71.481	0.6	-0.641	72.161	24.19**
+b	-0.975	10.42	4.79	0.511	8.2713	13.43	-0.468	10.183	56.12**

Gin.: Ginning out turn, SCI: Spinning conversion index, Mic.: Micronaire, Len.: Length, Unf.: Uniformity, SFI: Short fiber index, Elg.: Elongation, Cnt.: Trash count, CSP: Count strength product, Rd: Reflectance degree, +b: Yellowness, T: Trash

Table 8. Correlation coefficients of fiber characteristics in 1997 and 1998.

1997 1998	Gin	SCI	Mic.	Str.	Len.	Unf.	SFI	Elg.	T	Cnt	Area	CSP	Rd
SCI	-0.237**												
Mic.	0.213* **0.223***	-0.462** **-0.506****											
Str.	-0.312** **-0.208***	0.688** **0.712****											
Len.	-0.181*	0.626** **0.582****	-0.297** **-0.214***	0.309** **0.399****									
Unf.		0.784** **0.674****		0.316** **0.230***	0.412** **0.256****								
SFI		-0.839** **-0.766****		-0.353** **-0.317****	-0.610** **-0.511****	-0.973** **-0.961****							
Elg		**0.357****	-0.335** **-0.576****		**0.272****		**-0.181***						
T		0.177*		0.300** **0.200***				-0.275** **-0.314****					
Cnt.				0.306** **0.453****				-0.356** **-0.439****	0.419** **0.526****				
Area				0.237** **0.246***				-0.267** **-0.366****	0.710** **0.887****	0.504** **0.658****			
CSP	-0.176* **-0.209***	0.795** **0.822****	-0.697** **-0.723****	0.281** **0.391****	0.713** **0.612****	0.523** **0.387****	-0.635** **-0.521****	0.340** **0.643****	**-0.195***	**-0.229***	**-0.233***		
Rd	0.189*		**-0.183***	-0.441** **-0.212***				0.337** **0.539****	-0.348** **-0.478****	-0.434** **-0.650****	-0.444** **-0.618****	0.355** **0.508****	
+b				**0.215***									-0.238** **-0.208***

*, ** significant at 0.05 and 0.01 probability level, respectively. First and second values shows correlation coefficients of fiber characteristics of 1997 and 1998 respectively. Gin.: Ginning out turn, SCI: Spinning conversion index, Mic.: Micronaire, Len.: Length, Unf.: Uniformity, SFI: Short fibre index, Elg.: Elongation, Cnt.: Trash count, CSP: Count strength product, Rd: Reflectance degree, +b: Yellowness, T: Trash

Second, in the second year, water deficiency applied at any growth stage had no effect on fiber quality. It was the increased soil salinity not the water deficiency that decreased all the fiber characteristics. Spinning conversion index, strength, length, uniformity, elongation, count strength product, reflectance degree and yellowness decreased while micronaire, count and short fiber index increased. Fiber elongation was the most severely affected fiber characteristics from salinity. In this year, the range between the maximum and the minimum values fiber characteristics became narrow due to high salinity level in soil.

It has become clear that it was the increased soil salinity at the root zone of the cotton not the water deficiency that primarily decreased the fiber quality characteristics. Therefore, to provide a good quality fiber, precautions (leaching, drip irrigation etc.) should be taken when irrigation with water with high salt content is unavoidable, or, crops resistance to salinity should be grown.

The effect of use of different irrigation water with different salt content at different growth stages are lacking in the literature. Therefore, more studies are needed to reveal the response of cotton to different level of salinity (soil and irrigation water) at different growth stages.

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