Impact of Climatic Behavior on Cotton Fibre Traits

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Abstract:

Temperature plays a critical and complicated role in the growth and development of cotton. Fibre development consists of fibre elongation, secondary wall synthesis and boll maturation. This 3 years' study was conducted from 2008 to 2010 at Central Cotton Research Institute, Multan to investigate the affect of environmental factors and flowering dates on fibre properties. Two Upland cotton (Gossypium hirsutum L.) cultivars used in this study were CIM-554 and CIM-557. For each cultivar, 200 white flowers (blooms at anthesis) were tagged after 7-days interval throughout the growing season. In every year, the tagging was initiated from 2nd week of August and continued up to 3rd week of September. The cotton bolls were picked at maturity and seed cotton was ginned at miniature saw ginning machine. Significant interactions among flowering date, year and variety were detected. Negative correlations of fibre properties with flowering dates were observed.

Keywords

Cotton cultivars, Boll maturation, Fibre length, Fibre Strength, Uniformity Index, flowering dates, Temperature.

1. INTRODUCTION

Cotton (Gossypium hirsutum L.) is a subtropical, semiarid origin and is accustomed to warm, dry conditions [1]. It's a soft, fluffy staple fibre plant of the genus Gossypium and belongs to family Malvaceae [2]. The plant is a shrub native to tropical and subtropical regions around the world including United States of America, Africa, India and Pakistan [3]. Crops have basic requirements of temperature to complete a specific phenophase or the whole life cycle. On the other hand, extremely high and low temperatures can have detrimental effects on crop growth, development and yield, particularly at critical phenophases. While cotton is morphologically indeterminate, like the rate of many developmental processes such as germination, floral initiation, and development of fruiting bodies is controlled by temperature [4].

Daily temperature also plays an important role in determining the earliest date of sowing; defining season length which can both influence yield potential and quality [5], [6], [7], and determining where cotton can be produced sustainably. Temperature fluctuations before anthesis and during fibre development have been implicated in changes in fibre quality [8]. Abiotic factors such as rainfall, temperature, and irrigation can alter seed and fibre development [9]. Under inadequate moisture conditions and increasing temperatures, fibre length decreases and fibre micronaire values increase [10]. The indeterminate growth habit of cotton twice determine that cotton bolls are initiated over a long period of time during the season, and fibre properties of bolls on the same plants can differ because of different environmental conditions during boll growth and development [11], [12]. Davidonis et al., [8] and Jenkins et al., [13], found that seasonal shifts in plant growth and metabolism are manifested in higher levels of fibre maturation in bolls from July flowers, as compared to fibres from August flowers.

To study the effect of environment on cotton properties two Upland cotton (Gossypium hirsutum L.) cultivars used in this study were CIM-554 and CIM-557. Crop management was in line with the local cultivation practices followed for upland cotton production in the region. For each cultivar, white flowers (blooms at anthesis) per plot were tagged after 7-days interval throughout the growing season. All tagged cotton bolls were picked at maturity and seed cotton was ginned on miniature saw ginning machine. The mean daily temperature, maximum daily temperature, minimum daily temperature, mean daily sunshine hours, total rainfall and thermal units during the boll maturation period (BMP, 0-50 days' post anthesis, the same as cotton fibre developmental period), for different flowering were collected.

1. MATERIALS & METHODS

Field studies were conducted for three consecutive growing seasons during 2008 through 2010 at the Central Cotton Research Institute (CCRI), Multan. Two Upland cotton (Gossypium hirsutum L.) cultivars used in this study were CIM-554 and CIM-557. Crop management was in line with the local cultivation practices followed for upland

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 12
August 2016

cotton production in the region. Date of sowing for both the cultivars was same in every year. The crop was kept in unstressed condition in terms of water and agronomic practices. For each cultivar, 200 white flowers (blooms at anthesis) per plot were tagged after 7-days interval throughout the growing season. In every year, the tagging was initiated from 2nd week of August and continued till 3rd week of September. All tagged cotton bolls were picked at maturity and seed cotton was ginned on miniature saw ginning machine. The lint samples were stored in the laboratory for determination of fibre properties.

The cotton lint samples were conditioned for 24 hours in standard atmospheric conditions (Temperature = 20˚C ± 2 and R.H. % = 65% ± 2) before testing. The fibre parameters was determined using High Volume Instrument (HVI 900A). The procedure of testing was adopted as given in ASTM Standards (2005).

2.1 WEATHER DATA

Weather data during the boll development periods through the years 2008 to 2010 were collected from weather station installed at Central Cotton Research Institute (CCRI), Multan. The mean daily temperature, maximum daily temperature, minimum daily temperature, mean daily sunshine hours, total rainfall and thermal units during the boll maturation period (BMP, 0-50 days' post anthesis, the same as cotton fibre developmental period), for different flowering dates are shown in Table 1. Thermal units were calculated using the following equation:

$$\text{Thermal units} = \sum [(\text{maximum temperature} + \text{minimum temperature})/2] - 15.5^{\circ}C$$

2.2 ANALYSIS OF DATA

The data thus obtained were statistically analyzed by using program Statistix 9.0.

3. RESULTS & DISCUSSIONS

3.1 FIBRE LENGTH

Cotton fibres are initiated from single cells on the outer epidermis of seeds at anthesis. The elongation of fibres begins about 2 days after anthesis and fibre length is determined during the first 25 days after anthesis [14]. Fibre length formation was determined by the rate and the duration of the fibre elongation process [15]. The analysis of variance of cotton fibre length and the findings from cotton genotypes and flowering date are presented in Table 2 and Fig-1 showed significant differences of interactions between the genotypes, flowering date and year were obtained for fibre length. Averaged across the years, fibre length of both varieties significantly increased from D1 to D3 flowering then decreased. This is probably due to mean thermal units across years from D1 to D3 flowering ranging from 727 to 693 and mean daily temperature gradually decreased. Averaged across the flowering dates, highest maximum length achieved from Y1 due to the maximum rainfall 35.9 mm in Y1. In agreement with several research studies, Zhao et al., [16] showed that the flowering dates also significantly affected the formation of fibre length, strength, maturity and micronaire. The flowering date was delayed, fibre length and strength first increased and then decreased, fibre maturity and micronaire decreased. This is due to the gradually decreased MDTBMP (Mean daily temperature of boll maturation period) as the flowering dates shifts. Quisenberry and Kohel [17] reported that variations in fibre length and the elongation period were also associated with relative heat-unit accumulations. Regression analyses showed that genotypes that produced longer fibres were more responsive to heat-unit accumulation levels than the genotypes that produced shorter fibre.

Table 1. Total rainfall, mean, maximum and minimum daily temperatures, thermal units and daily sunshinehours during boll maturation period for the years 2008 to 2010 at CCRI, Multan, Pakistan.

	2008	2009	2010	Mean
Total Rain Fall (mm)				
D_1	37.4	14.0	34.2	**28.5**
D_2	82.4	14.5	16.5	**37.8**
D_3	27.6	7.5	16.5	**17.2**
D_4	27.6	7.5	16.5	**17.2**
D_5	20.2	7.5	16.5	**14.7**
D_6	20.2	7.5	0	**9.2**
Mean	**35.9**	**9.8**	**16.7**	
Mean daily Temperature (°C)				
D_1	29.5	30.6	30.1	**30.1**
D_2	29.4	29.6	30.3	**29.7**
D_3	29.0	29.4	29.4	**29.2**
D_4	28.4	28.5	29.0	**28.6**
D_5	27.9	27.5	27.9	**27.8**
D_6	27.4	26.6	26.9	**26.9**
Mean	**28.6**	**28.7**	**28.9**	
Maximum daily Temperature (°C)				
D_1	33.6	35.5	34.5	**34.5**
D_2	33.8	34.2	35.5	**34.5**
D_3	33.8	35.1	34.6	**34.5**
D_4	33.4	34.8	34.5	**34.2**
D_5	33.3	34.4	33.6	**33.8**
D_6	33.0	33.7	33.1	**33.3**
Mean	**33.5**	**34.6**	**34.3**	
Minimum daily Temperature (°C)				
D_1	25.4	25.7	25.7	**25.6**
D_2	24.9	24.9	25.1	**25.0**
D_3	24.1	23.6	24.1	**23.9**
D_4	23.3	22.2	23.5	**23.0**
D_5	22.5	20.6	22.1	**21.7**
D_6	21.7	19.4	20.6	**20.6**
Mean	**23.7**	**22.7**	**23.5**	
	2008	**2009**	**2010**	**Mean**
D_1	699	753	730	**727**
D_2	692	726	717	**712**
D_3	693	693	692	**693**
D_4	644	648	675	**656**
D_5	620	598	617	**612**
D_6	592	551	567	**570**
Mean	**657**	**662**	**666**	
Mean daily sunshine hours				
D_1	8.6	9.1	8.3	**8.7**
D_2	8.1	8.9	8.6	**8.5**
D_3	8.7	9.1	8.7	**8.8**
D_4	8.3	9.2	8.8	**8.8**
D_5	8.3	9.3	8.8	**8.8**
D_6	8.0	8.7	8.8	**8.5**
Mean	**8.3**	**9.1**	**8.7**	

Where D_1=2nd week of August, D_2=3rd week of August, D_3=4th week of August, D_4=1st week of September, D_5=2nd week of September, D_6=3rd week of September.

In year 2010 the fibre length showed different pattern from years 2008 & 2009. Fibre length increased with delaying date of flowering from 2nd week of August to 2nd week of September in both genotypes was probably attributed to mean daily sunshine hours increasing and continuous rainfall in boll maturation period from 2nd week of August to 2nd week of September and the thermal units ranged from 730 to 617. This is in agreement with Reddy et al., [18] who reported that under adequate moisture conditions and increasing temperatures, fibre length decreased. Fibre length of 3rd week of September in 2010 showed lower length in both genotypes because no rainfall and insufficient thermal units in the period of boll maturation. In year 2008 thermal units of first three dates of flowering in boll maturation period remained in between 699 to 693 and total rainfall 147.7 mm, the both varieties

International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 12
August 2016

showed higher lengths in this period. Previous studies have documented the impacts of flowering date on fibre properties. Liakatas et al., [16] proved that mean temperature reduction improved yield component

ts, but fibre length, uniformity, strength and micronaire were increased by high, particularly high daytime temperatures. Singh & Bhan, [3] stated that in India, moisture conservation practices (mulching) increased fibre length and yield.

Correlation analysis (Table-5) showed the negative correlation between fibre length and flowering date, also in fibre length and year.

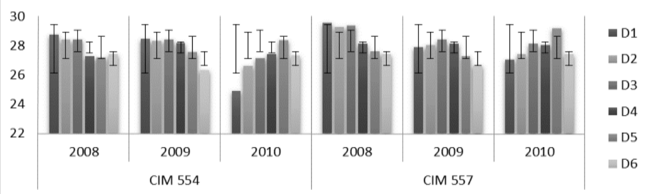
Where D1=2nd week of August, D2=3rd week of August, D3=4th week of August, D4=1st week of September, D5=2nd week of September, D6=3rd week of September, V1=CIM 554, V2=CIM 557, Y1=2008, Y2=2009, Y3=2010.

Table 2. LSD all pair wise comparisons test of fibre length for flowering date*variety*year

Flowering Date	V_1				V_2			
	Y_1	Y_2	Y_3	Mean	Y_1	Y_2	Y_3	Mean
D_1	28.76 e[+]	28.48 f	24.91w	**27.38 E[*]**	29.57 a	27.91 k	27.03 t	**28.17 C**
D_2	28.42 f	28.32 g	26.63u	**27.79 B**	29.26 c	28.04 j	27.44 n	**28.25 B**
D_3	28.42 f	28.42 f	27.14s	**27.99 A**	29.39 b	28.42 f	28.15 hi	**28.65 A**
D_4	27.30 pq	28.18 h	27.44n	**27.64 D**	28.15 hi	28.11 i	28.04 j	**28.10 D**
D_5	27.20 r	27.57 m	28.35g	**27.71 C**	27.63 q	27.30 pq	29.16 d	**27.91 E**
D_6	27.41 no	26.33 v	27.34op	**27.02 F**	27.41 no	26.66 u	27.42 l	**27.27 F**
Mean	**27.92 A[$]**	**27.88 B**	**26.97 C**		**28.51 A**	**27.74 c**	**27.93 B**	

[+]Values with different letters in each column are statistically significant at p<0.05
[*]Means with different letters in each column are statistically significant at p<0.05
[$]Means with different letters are statistically significant at p<0.05 among years
Where D_1=2[nd] week of August, D_2=3[rd] week of August, D_3=4[th] week of August, D_4=1[st] week of September, D_5=2[nd] week of September, D_6=3[rd] week of September, V_1=CIM 554, V_2=CIM 557, Y_1=2008, Y_2=2009, Y_3=2010.

Fig 1. Fiber Length



3.2 FIBRE STRENGTH

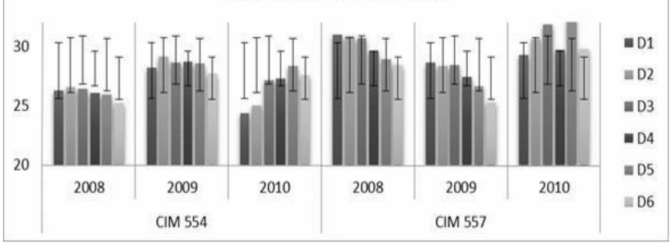
Cotton fiber strength is closely related to secondary cell wall synthesis [9]. Secondary wall formation occurs from 15 to 45 days after anthesis, and determines fiber fineness, strength and maturity [14]. The analysis of the variance of fiber strength and the findings from cotton genotypes and flowering date are presented in Table-3 and Fig-2 showed significant differences of interactions between the genotypes, flowering date and year were obtained for fiber strength. Averaged across the years, fibre strength increased with delaying flowering dates of V1 and in V2 first strength increasing to D3 then showed decreasing pattern. Among the genotypes CIM-557 showed maximum strength of 32.31 g/tex in year 2010 and CIM-554 showed minimum strength of 24.32 g/tex in the same year. The strength pattern of three year study described that the variety CIM-557 showed greater strength than CIM-554. In agreement with several research studies, Dever and Gannaway[7] reported that fiber strength is influenced more by genotype than by environment. Jones and Wells [18] reported that fiber strength was slightly greater in bolls from the first 4 to 6 week of flowering, compared with fibers from bolls produced by flowers opening during the last 2 week of the flowering period. But in year 2010 strength increased in both genotypes with delaying flowering time. Bradow and Davidson [9] resulted that increased strength was correlated with a decrease in precipitation. Minimum temperature did not affect fiber strength.

Table 3. LSD all pair wise comparisons test of Strength for flowering date*variety*year

Flowering Date	V_1				V_2			
	Y_1	Y_2	Y_3	Mean	Y_1	Y_2	Y_3	Mean
D_1	26.27 u[+]	28.19 o	24.32 y	**26.26 F[*]**	30.97 c	28.64 kl	29.28 h	**29.63 C**
D_2	26.57 s	29.10 i	25.02 x	**26.90 D**	30.83 d	28.37 n	30.60 e	**29.93 B**
D_3	26.41 t	28.64 kl	27.15 r	**27.40 B**	30.66 e	28.40 n	31.81 b	**30.29 A**
D_4	26.07 v	28.67 k	27.25 r	**27.33 C**	29.65 g	27.42 q	29.68 fg	**28.92 E**
D_5	25.94 v	28.54 lm	28.37 n	**27.61 A**	28.94 j	26.64 s	32.31 a	**29.30 D**
D_6	25.23 w	27.69 p	27.56 p	**26.82 E**	28.44 mn	25.26 w	29.79 f	**27.83 F**
Mean	**26.08 C[$]**	**28.47 A**	**26.61B**		**29.91B**	**27.45 C**	**30.58 A**	

[+]Values with different letters in each column are statistically significant at p<0.05
[*]Means with different letters in each column are statistically significant at p<0.05
[$]Means with different letters are statistically significant at p<0.05 among years
Where D_1=2[nd] week of August, D_2=3[rd] week of August, D_3=4[th] week of August, D_4=1[st] week of September, D_5=2[nd] week of September, D_6=3[rd] week of September, V_1=CIM 554, V_2=CIM 557, Y_1=2008, Y_2=2009, Y_3=2010.

Fig 2. Fiber Strength



All environmental variables were interrelated, and a close general association between fiber strength and environment was interpreted as indicating that fiber strength is more responsive to the growth environment. In year 2010 the rainfall decreased with compare to 2008, mean daily sunshine hours remain constant and mean daily temperature was remain in 26.8˚C to 30.1˚C in the boll maturation period. Reddy et al., [10], which indicated that fibers were longer when bolls grew at less than optimal temperatures (25 °C) for boll growth, maturity and micronaire increased linearly with the increase in temperature up to 26 °C but decreased at 32 °C.

3.3 FIBRE UNIFORMITY INDEX

The analysis of variance of fibre uniformity index and the findings from cotton genotypes and flowering date are presented in Table-4 and Fig-3 showed significant differences of interactions between the genotypes, flowering date and year were obtained. Averaged across the years, fibre Uniformity of V1 significantly increased from D1 to D3 flowering then decreased and in V2 fibre uniformity remain same from D1 to D4 then decreased. In agreement with Liakates et al., [19] found that yield and fibre characters responded to variation of daily mean and amplitude of temperature. Fibre length and uniformity were

International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 12
August 2016

greater at intermediate temperature regimes, generally favoured by high day and relatively low night temperatures.

Table 4. LSD all pair wise comparison ns test of Length Uniformity Index for flowering date*variety*year

Flowering Date	V₁				V₂			
	Y_1	Y_2	Y_3	Mean	Y_1	Y_2	Y_3	Mean
D_1	83.80 f*	84.58 d	79.55 z	**82.64 B†**	85.11 a	82.41 n	82.48 lmn	**83.33 A**
D_2	82.82 ij	83.06 gh	81.06 u	**82.31 C**	84.68 c	82.51 lm	82.79 j	**83.33 A**
D_3	83.12 g	83.18 g	82.89 i	**83.04 A**	83.87 f	82.31 o	83.80 f	**83.33 A**
D_4	81.47 s	82.55 l	82.99 h	**82.34 C**	82.65 k	82.45 mn	84.91 b	**83.34 A**
D_5	81.34 t	81.57 r	81.37 t	**81.43 D**	81.74 q	80.83 v	84.21 e	**82.26 B**
D_6	80.39 x	80.69 w	81.78 q	**80.95 E**	82.21 p	80.02 y	82.99 h	**81.74 C**
Mean	**82.15 B§**	**82.59 A**	**81.61 C**		**83.38 B**	**81.76 C**	**83.53 A**	

*Values with different letters in each column are statistically significant at $p<0.05$
†Means with different letters in each column are statistically significant at $p<0.05$
§Means with different letters are statistically significant at $p<0.05$ among years
Where D_1=2nd week of August, D_2=3rd week of August, D_3=4th week of August, D_4=1st week of September, D_5=2nd week of September, D_6=3rd week of September, V_1=CIM 554, V_2=CIM 557, Y_1=2008, Y_2=2009, Y_3=2010

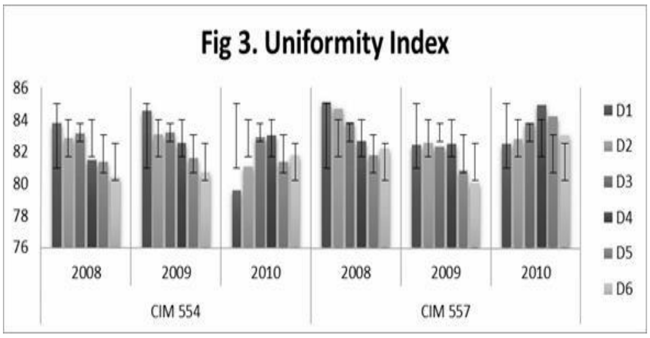


Fig 3. Uniformity Index

Table-5 showed a negative correlation between fibre uniformity index and flowering dates.

As flowering dates delayed the uniformity decreased because of bolls obtained from late flowering acquire less thermal units' accumulations.

Table 5 showed a negative correlation between fibre uniformity index and flowering dates.

Table5. Correlations (Pearson)

	Flowering Date	Length	Strength	Length Uniformity Index	Variety
Length	-0.2207				
Strength	-0.0927	0.6328			
Length Uniformity Index	-0.3681	0.7958	0.6727		
Variety	0.0000	0.2517	0.5816	0.2525	
Year	0.0000	-0.3346	0.1255	-0.0530	0.0000

3. CONCLUSIONS

From the results obtained in the present study, it could be generally concluded that flowering date × year × variety, significantly ($p \leq 0.05$) affected fibre properties. Fibre properties showed significant differences with flowering date. Total rainfall, thermal units, mean daily temperature and daily mean sunshine hours affecting cotton fibre properties during flowering period. In early flowering dates, fibre properties comparatively high from late flowering dates because of high mean daily temperature and greater thermal units. Correlations analysis also showed negative correlation between fibre properties and flowering dates. The result of this study also showed that 'CIM-557' cotton strain has more responsive to thermal units because fibre properties of 'CIM-557' are better than 'CIM-554'.

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