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Full Length Article

Evaluation of Breeding Potential of Cotton Germplasm of Pakistan Origin for Fibre Quality Traits under Heat Stress

Amjad Farooq[1], Amir Shakeel[1], Saghir Ahmad[2], Tariq Manzoor Khan[1] and Irfan Afzal[3]
[1]*Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad-38040, Pakistan*
[2]*Director Cotton, Cotton Research Institute, Multan-60800, Pakistan*
[3]*Department of Agronomy, University of Agriculture, Faisalabad-38040, Pakistan*
[*]For correspondence: amjad.cri@gmail.com

Abstract

Identification of genetic variability in cotton (*Gossypium hirsutum* L.) germplasm is the pre-requisite for improvement in fibre quality traits of cotton grown under varying temperature regimes. Fifty cotton cultivars were evaluated for fibre quality traits under heat stress. Heat stress (~38–39ºC) was applied at peak flowering time under field conditions by sowing during 15th April while cotton sown on 1st June with temperature of ~24–32ºC at peak flowering time was taken as control. Fibre fineness, fibre length, fibre maturity, fibre strength and ginning out turn were estimated at the peak flowering period of both treatments. Heat stress significantly affected fibre fineness, staple length, ginning out turn and fibre strength, but fibre maturity remained non-significant, of all cotton cultivars with varying degree. The estimates of genetic components (genotypic, phenotypic variance, coefficients of variances, heritability and genetic advances) conferred non-additive gene action for all the fibre traits. The non-additive gene action suggested heterosis breeding would be more rewarding than selection breeding against heat stress. Cluster analysis was used to dissect the variability among all cultivars and found maximum inter and intra-cluster variability during consecutive heat stress studies. Genetic diversity among cultivars suggested that the existence of great variation among cotton cultivars for fiber traits under heat stress could be used to tailor heat tolerant cultivars. In conclusion, cultivars Sitara-14, IR-NIBGE-8, CIM-602, VH-363, IR-NIBGE-9, Weal-AG-Shahkar and IUB-65 can be used for improving fibre traits of cotton through recombinant breeding against heat stress. © 2020 Friends Science Publishers

Keywords: Heat stress; Genetic variations; Fibre traits; Sowing dates; Cluster analysis; Cotton

Introduction

The environmental calamities including abiotic and biotic stresses are the major threats to agriculture and food security in Pakistan. High temperature is the most influential abiotic stress that affects cotton (*Gossypium hirsutum* L.) production (Karademir *et al*., 2012). The summer temperature in Pakistan approaches to 50ºC which limits seed cotton yield and fiber quality (Rahman, 2006; Khan *et al*., 2008; Ilhai *et al*., 2013), whilst the desired temperature ranges from 27–32ºC for boll development and maturation (Ekinci *et al*., 2017). Cotton plant gained more biomass and partitioned it to bolls and squares development at 30/20ºC day/night temperatures. Pettigrew (2008) reported that a slight increase in temperature, approximately 1ºC above mean temperature under field conditions may cause a significant decline in seeds per boll, and this was the primary reason for low yield under high temperature stress. High temperature at peak flowering time is often associated with poor seed cotton yield, while lower temperatures at some extent was considered favorable for better yield (Sarwar *et al*., 2012).

Fiber is more than 90% cellulose and its development depends upon the deposition of cellulose in the primary and secondary cell walls, while the rate of cellulose synthesis was significantly affected by temperature variations. The rate of cellulose synthesis increased above 18ºC and remained high between 28–37ºC and then decreased after 40ºC (Roberts *et al*. (1992). Therefore, the optimum temperature for rapid and metabolically efficient cellulose synthesis in cotton was near 28ºC in ovules culture and fiber elongation and weight gain in vitro or in field. Cotton fiber traits and lint yield were affected by the genetic variability of cultivars and environmental factors. Environmental variations such as very low temperatures during night decrease fibre initiation rate (Xie *et al*., 1993).

Sowing date adjustment strategy had been used to alleviate heat stress at peak flowering period of cotton that could be mid to late summer (Reddy *et al*., 2002). Similarly, a very early sowing date is an important management factor that involved the escape of peak flowering from the onset of heat stress (Saleem *et al*., 2014). However, sub-optimal weather conditions in late sowing dates may change seed

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cotton yield and fiber quality (Gormus and Yucel, 2002; Dong *et al*., 2006, Zhao *et al*., 2012).

The genetic divergence in breeding material is the basis of a breeding program for crop improvement. The inheritance pattern of associated genes with desired characters helped the plant breeders to plan the breeding strategy for the improvement of those characters (Rathinavel *et al*., 2017; Sun *et al*., 2017). Genetic components including heritability, genetic advances were analyzed in diverse germplasm of cotton for the improvement of fibre traits. Heritability further indicated the improvement of traits on a phenotypic basis through selection or heterosis breeding (Magadum *et al*., 2012; Shakeel *et al*., 2012). Heritability accompanied by genetic advance suggested the better results and breeding procedure for further improvement (Ramanjinappa *et al*., 2011). Cluster analysis is used for assessment of genetic distance or remoteness in a set of genotypes. The most distant cultivars include in recombination breeding for strengthening the heterosis manifestation, segregation and variability in the next generations. Cluster analysis gives a clear picture of cultivars for single or complex traits which could be effectively used in cotton breeding programs (Spasova *et al*., 2016).

Current commercial cotton cultivars should be developed and registered for superior lint yield, fiber length and fiber strength under heat stress environments (Ulloa *et al*., 2006). Cotton cultivars that retain fruits at high temperatures would be more productive in current situations of cotton production and even more in a future warmer climate (Sawan, 2013).

The potential impact of the present study is to explore the genetic response of cotton germplasm against heat stress on fibre quality traits. The clustering of cultivars identified the diversity among cultivars and their selection for exploitation in a breeding program to improve the fibre quality traits of cotton under heat stress.

Materials and Methods

Experimental Material

Diverse germplasm of fifty cotton cultivars was collected from various private and public sector institutes of cotton (Table 1). Heat stress effects on fibre quality traits were assessed on these cultivars of cotton at Cotton Research Station, Faisalabad, Pakistan. The experiment was carried out during the year 2017 and 2018 in a randomized complete block design with split plot keeping sowing dates in main plots and cotton genotypes in sub plots. The experiment was replicated three times with net plot size of 3 m × 5m. Cotton was sown in 75 cm spaced rows with 30 cm plant to plant spacing. All inter-cultural, agronomical and other management practices were adopted according to general recommendations for early and late sown cotton at Faisalabad conditions of Pakistan. Fertilizers were applied to maintain crop nutrients including nitrogen, phosphorus and potash at 200, 60 and 100 kg ha^{-1} respectively. Whole phosphorus and potash, and 1/4th nitrogen were applied at bed preparation, whereas, remaining nitrogen further used in splits, 1/4th after 30 days, 1/4th at flowering and 1/4th at peak boll formation (Rahman *et al*., 2008). The experiment was sprayed adequately to control insect-pests when required (Khan and Damalas, 2015). Irrigations were applied by flooding to eliminate the effect of drought especially at the time to start flowering and bolls maturation period. Weather data for consecutive years of experiments was obtained from the observatory of Plant Physiology Section, Agronomic Research Institute, Faisalabad. Pakistan (Table 2).

Application of Treatments

The peak flowering period (75–80 days after sowing) was subjected to heat stressed and was compared with non-stressed (control) under field conditions. The 15th April sown helped in the synchronization of the peak flowering period of the crop with the highest temperature (~38–39ºC) in the month of July. Likewise, 1st June sown cotton was synchronized with optimum temperature (~24–32ºC) during the month of October. Two pickings were taken of both early and late sown cotton at peak maturity.

Observations Recorded

All fibre traits were measured at peak maturity period by collecting samples of seed cotton from fully fresh opened bolls. Seed cotton was picked manually to avoid mixing of leaves trash and dried locules. Lint was separated by roller gin machine and ginning out turn (GOT) percentage was calculated as given:

GOT (%) = (Lint weight / seed cotton weight) × 100

Lint samples were sun dried and took into Fibre Technology laboratory of Cotton Research Station, Faisalabad. All samples were kept at 22–24ºC, 60–65% relative humidity and 7–8% moister contents as standard operating conditions for high volume instrument (HVI). Analysis of triplicate samples of all cultivars for fibre fineness, fibre length, fibre strength and fibre maturity was performed on High volume instruments (USTER® *HVI 1000*, USA).

Statistical Analysis

Analysis of variance was carried out to observe significant differences among cultivars and treatments (Steel *et al*., 1997). Genotypic and phenotypic variances were estimated using Lush (1940) formula i.e.

$$\text{Genotypic variance (Vg)} = \frac{GMS - EMS}{R} \quad (1)$$

Whereas,
GMS = Genotypic mean squares
EMS = Error mean squares
R = Number of replicates

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Table 1: List of fifty cotton cultivars evaluated for heat stress tolerance

Sr. No.	Genotypes	Institutes	Sr. No.	Genotypes	Institutes
1	FH-Noor	CRS, Faisalabad	26	CIM-622	CCRI, Multan
2	FH-458	CRS, Faisalabad	27	BS-80	Private Seed Company
3	FH-326	CRS, Faisalabad	28	RH-662	CRS, Rahim Yar Khan
4	VH-363	CRS, Vehari	29	CEMB-55	CEMB, Lahore
5	FH-466	CRS, Faisalabad	30	IR-NIBGE-9	NIBGE, Faisalabad
6	FH-Lalazar	CRS, Faisalabad	31	FH-152	CRS, Faisalabad
7	MNH-886	CRI, Multan	32	NIAB-878	NIAB, Faisalabad
8	FH-114	CRS, Faisalabad	33	MNH-1016	CRI, Multan
9	FH-118	CRS, Faisalabad	34	SILKY-3	CCRI, Multan
10	FH-312	CRS, Faisalabad	35	Zakriya-1	Private Seed Company
11	FH-342	CRS, Faisalabad	36	Tassco-1000	Private Seed Company
12	MNH-992	CRI, Multan	37	Tarzan-5	Private Seed Company
13	FH-142	CRS, Faisalabad	38	Sitara-15	Private Seed Company
14	Weal-AG-Gold	Private Seed Company	39	SLH-12	CRS, Sahiwal
15	Sitara-14	Private Seed Company	40	Tahafuz-5	Private Seed Company
16	FH-Kehkshan	CRS, Faisalabad	41	CIM-602	CCRI, Multan
17	Weal-AG-Shahkar	Private Seed Company	42	CYTO-179	CCRI, Multan
18	RH-648	CRS, Rahim Yar Khan	43	NS-181	Neelam Seed Company
19	NIAB-545	NIAB, Faisalabad	44	BH-201	CRS, Bahawalpur
20	Weal-AG-1606	Private Seed Company	45	NIAB-1011/48	NIAB, Faisalabad
21	FH-444	CRS, Faisalabad	46	MNH-988	CRI, Multan
22	IUB-65	Islamia Uni. Bahawalpur	47	Shaheen-1	Private Seed Company
23	BS-15	Private Seed Company	48	FH-91	CRS, Faisalabad
24	IR-NIBGE-8	NIBGE, Faisalabad	49	FH-242	CRS, Faisalabad
25	VH-Gulzar	CRS, Vehari	50	FH-442	CRS, Faisalabad

Table 2: Seasonal mean temperature data during 2017 and 2018

Months	Mean Maximum Temp. (ºC)		Mean Minimum Temp. (ºC)	
	2017	2018	2017	2018
April	37.5	36.3	13.0	15.5
May	40.0	39.4	21.5	21.0
June	38.5	39.0	21.5	22.0
July	37.4	36.5	22.5	23.5
August	37.4	37.7	22.5	25.5
September	36.9	36.5	20.0	19.0
October	35.1	32.9	15.0	15.5
November	24.4	27.6	5.50	8.40

Environmental variance (Ve) = Error mean squares (EMS) (2)

Phenotypic variance (Vp) = Vg + Ve (3)

Genotypic, phenotypic and environmental coefficient of variation was calculated as:

$$GCV\ (\%) = \sqrt{(Vg/\bar{X})} \times 100 \quad (4)$$

$$PCV\ (\%) = \sqrt{(V_p/\bar{X})} \times 100 \quad (5)$$

$$ECV\ (\%) = \sqrt{(Ve/\bar{X})} \times 100 \quad (6)$$

Here GCV = Genotypic Coefficient of Variation, PCV = phenotypic coefficient of variation and ECV = Environmental Coefficient of Variance.

PCV and GCV values were categorized as low, moderate and high as given bellow:

0–10% = Low, 10–20% = Moderates and > 20 % = High

Heritability (broad sense) estimated as the ratio of genotypic variance (Vg) to the phenotypic variance (Vp) and expressed in percentage. Heritability broad sense (h_{bs}^2) was calculated by using the procedure of Falconer (1989).

$$h_{bs}^2 = Vg/Vp \quad (7)$$

The heritability percentage categorized as low, moderate and high as follows:

0–30% = Low, 30%–60% = Moderate and > 60% = High

Genetic Advance was estimated as formulae proposed by Johnson *et al*. (1955)

$$GA = I \times \sigma_p \times h_{bs}^2 \quad (8)$$

Whereas,

i = Efficacy of selection which is 2.06 at 5% selection intensity, σp = Phenotypic standard deviation, h_{bs}^2 = Heritability broad sense

$$\text{GA as per cent of mean (GAM)} = (GA/\bar{X}) \times 100 \quad (9)$$

Here GA = Genetic advance, and $\bar{X}$ = General mean of the trait

The GA as percent of mean was categorized as low, moderate and high as given bellow:

0–10% = Low; 10–20% = Moderate; > 20% = High

The cultivars grouping and classification was done by cluster analysis (Ward, 1963).

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Results

Descriptive Statistics of Fiber Traits

Analysis of variance revealed highly significant differences among the cultivars for fibre quality traits and their interaction (G×T) with treatments ($P \leq 0.01$). Heat stress significantly affected the cotton cultivars for fibre fineness, staple length, fibre strength and ginning out turn excluding fibre maturity (Table 3).

Fibre fineness ranged from 4.60–6.14 µg inch^{-1} and 4.02–5.38 µg inch^{-1} under control and heat stress conditions in 2017. Similar trends were found under control 4.05–5.35 µg inch^{-1} and heat stress 4.28–5.48 µg inch^{-1} in 2018 (Tables 4 and 5). The results of CIM-602 observed the best mean fibre fineness under control as well as under heat stress during 2017. Similarly, in following year VH-Gulzar under control and Weal-AG-Shahkar under heat stress were selected as the best among all cultivars (Table 6). Staple length range was 23.70–27.77 mm under control and 22.60–28.13 mm under heat stress of first-year experiment, whereas 24.55–30.51 mm and 25.71–29.84 mm was found under the control and heat stress in next year (Tables 4 and 5). The best staple length results of CIM-602 exposed in both treatments for first-year study. Whereas, in following year FH-342 and IUB-65 revealed higher mean staple length under control and heat stress respectively (Table 6). In the case of fibre maturity ranged between 81.6–90.6% under control and 85.0–90.3% under heat stress for first-year experiment, similarly, range 85.3–90.3% and 85.3–90.3% under control and heat stress observed in following year (Tables 4 and 5). Fibre maturity under control and heat stress was observed better in cultivars FH-342 and VH-363 respectively for first-year experiment. IR-NIBGE-9 and VH-363 had the highest mean fibre maturity under control and heat stress in the succeeding year (Table 6).

Fibre strength was ranged between 12.30–25.30 g tex^{-1} under the control and 19.79–31.82 g tex^{-1} under heat stress for the first-year of study. Moreover 18.40–39.33 g tex^{-1} and 24.30–37.50 g tex^{-1} range was observed under control and heat stress, respectively in the following year (Tables 4 and 5). Maximum fibre strength was observed in Weal-AG-1606 and Sitara-14 under control and heat stress respectively for first-year study, while cultivars MNH-886 and Sitara-14 revealed maximum mean fibre strength under control and heat stress conditions during next year study (Table 6). The range of ginning out turn under control was 33.93–41.43% and under heat stress was 34.94–42.86% during 2017. The range 36.67–42.67% and 34.58–42.37% under control and heat stress respectively determined in 2018 (Tables 4 and 5). Weal-AG-1606 and IR-NIBGE-8 explained maximum ginning out turn under control and heat stress respectively in 2017. The results of mean ginning out turn during 2018 expressed NIAB-878 and IR-NIBGE-9 were superior under control and heat stress respectively (Table 6).

Genetic Components

The genetic components including genotypic, phenotypic variance and their coefficients of variances for all the fibre traits were found almost equal at each treatment level in consecutive years of study. Similarly, high heritability (broad sense) accompanied by low genetic advance was observed in all fibre traits except fibre maturity with low heritability and low genetic advance (Tables 4 and 5). Genetic components revealed that fibre traits were under the control of non-additive gene action.

Cluster Analysis

Cluster analysis for fifty cotton cultivars was performed in consecutive years under control and heat stress conditions to study divergence among the cultivars for fibre quality traits. Among clusters, cluster I and IV under control treatment, while cluster I & II showed maximum inter and intra-cluster variability during heat stress in 2017 (Fig. 1A and B). Cluster III & IV revealed maximum variability under control, whereas cluster II & III showed maximum inter and intra-cluster variability during heat stress in 2018 (Fig. 2A and B). Sitara-14 and IR-NIBGE-8 revealed maximum variation and found in cluster I follow CIM-602 in cluster II and VH-363 in cluster III under heat stress during 2017 (Fig. 1B). IR-NIBGE-9 and Weal-AG-Shahkar in cluster I, VH-363 in cluster II and Sitara-14, IUB-65 found in cluster III during heat stress in 2018 (Fig. 2B).

Discussion

Mean maximum temperature along with mean minimum temperature during peak flowering period of both treatments significantly differentiate the cultivars for fibre quality traits of cotton.

The overall descriptive statistical results during both years of study for all fibre traits showed that the heat tolerance in cultivars was present either fluctuation in mean maximum and minimum temperature occur in early and late sown cotton (Farooq *et al*. (2015a).

Fibre fineness the best under heat stress which might be due to least deposition of cellulose in primary and secondary cell wall of fibre which usually decrease above 40ºC (Roberts *et al*. (1992). Furthermore, the early sowing of cotton cultivars was recommended for high fibre fineness (Ban *et al*., 2015; Luo *et al*., 2016; Usman *et al*., 2016). The cultivars CIM-602 and Weal-AG-Shahkar showed the best results under heat stress for fibre fineness (Table 6). In early sown cotton heat stress may cause pre-mature boll opening that can deteriorate staple length (Abbas and Ahmad, 2018; Mauget *et al*., 2019); similar decline in staple length was observed in present study (Tables 4 and 5).

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Table 3: Analysis of variance for fibre quality traits of fifty cotton cultivars that affected by heat stress over the years of 2017 and 2018

Source of Variation	Df	Fibre fineness (µg inch^{-1})		Staple length (mm)		Fibre maturity (%)		Fibre strength (g tex^{-1})		Ginning out turn (%)	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Replication	2	0.32	0.12	22.02	2.10	33.69	163.72	8.99	1.323	9.375	2.048
Treatments	1	44.07**	3.02*	16.99$^{n.s}$	11.85**	47.20$^{n.s}$	3.85$^{n.s}$	3435.98**	58.609$^{n.s}$	50.062$^{n.s}$	230.563**
Error (a)	2	0.07	0.19	4.44	0.24	16.01	5.58	8.56	26.040	13.959	1.830
Genotypes	49	0.37**	0.31**	4.79**	5.38**	9.80**	4.56**	20.50**	30.001**	11.286**	22.315**
Treatments× Genotypes	49	0.23**	0.25**	2.08**	3.68**	8.19**	4.54**	19.32**	37.595**	6.439**	2.231**
Error (b)	196	0.04	0.03	0.70	0.23	4.84	2.32	0.20	2.8192	1.139	0.575
Total	299										

Table 4: Genetic components estimates for fibre traits under control (1st June) and heat stress (15th April) during 2017

Source of variation	Fibre fineness (µg inch^{-1})		Staple length (mm)		Fibre maturity (%)		Fibre strength (g tex^{-1})		Ginning out turn (%)	
	Control	Heat stress	Control	Heat stress	Control	Heat stress	Control	Heat stress	Control	Heat stress
Genotypic mean square	0.29	0.31	3.39	3.48	13.31	4.68	18.37	21.45	6.59	11.14
Error mean square	0.04	0.05	0.77	0.64	5.31	4.36	0.24	0.16	0.94	1.35
Grand mean	5.60	4.84	25.79	25.32	87.80	88.59	18.04	24.81	39.21	40.02
Maximum	6.14	5.38	27.77	28.11	90.67	90.33	25.30	31.82	41.43	42.86
Minimum	4.60	4.02	23.70	22.59	81.67	85.00	12.30	19.79	33.93	34.94
Standard deviation	0.35	0.37	1.28	1.26	2.82	2.12	2.51	2.69	1.68	2.15
Environmental variance	0.04	0.05	0.77	0.64	5.31	4.36	0.24	0.16	0.94	1.35
Genotypic variance	0.08	0.09	0.87	0.95	2.67	0.10	6.05	7.09	1.88	3.26
Phenotypic variance	0.12	0.14	1.64	1.58	7.98	4.47	6.28	7.26	2.82	4.61
Environmental co-efficient of variance	3.38	4.51	3.39	3.15	2.63	2.36	2.69	1.62	2.46	2.89
Genotypic co-efficient of variance	5.19	6.17	3.62	3.85	1.86	0.36	13.63	10.74	3.50	4.51
Phenotypic co-efficient of variance	6.19	7.64	4.96	4.97	3.22	2.38	13.89	10.86	4.28	5.36
Heritability (Broad sense)	70.23	65.26	53.29	59.93	33.40	2.31	96.26	97.78	66.84	70.82
Genetic advance i= 1.76	0.43	0.42	1.19	1.32	1.65	0.09	4.22	4.61	1.96	2.66
Genetic advance %	7.61	8.73	4.63	5.21	1.88	0.09	23.39	18.58	5.01	6.65

*= Significant at 5%, **= Significant at 1%, df = Degree of freedom

Table 5: Genetic components estimates for fibre traits under control (1st June) and heat stress (15th April) during 2018

Source of variation	Fibre fineness (µg inch^{-1})		Staple length (mm)		Fibre maturity (%)		Fibre strength (g tex^{-1})		Ginning out turn (%)	
	Control	Heat stress	Control	Heat stress	Control	Heat stress	Control	Heat stress	Control	Heat stress
Genotypic mean square	0.30	0.26	6.30	2.76	4.11	4.99	47.96	19.64	8.11	16.44
Error mean square	0.02	0.03	0.19	0.27	2.48	2.16	4.62	0.99	0.56	0.59
Grand mean	4.70	4.89	28.03	27.63	87.43	87.20	28.73	29.62	40.36	38.61
Maximum	5.35	5.48	30.51	29.84	90.33	90.33	39.33	37.50	42.67	42.37
Minimum	4.05	4.28	24.55	25.71	85.33	85.33	18.40	24.30	36.67	34.57
Standard deviation	0.34	0.33	1.49	1.05	1.74	1.76	4.37	2.68	1.75	2.42
Environmental variance	0.02	0.03	0.19	0.27	2.47	2.16	4.65	0.99	0.56	0.59
Genotypic variance	0.09	0.08	2.04	0.83	0.54	0.95	14.44	6.22	2.52	5.28
Phenotypic variance	0.11	0.11	2.23	1.09	3.02	3.10	19.09	7.20	3.08	5.87
Environmental co-efficient of variance	3.08	3.50	1.57	1.86	1.80	1.68	7.51	3.35	1.86	1.99
Genotypic co-efficient of variance	6.49	5.67	5.09	3.30	0.84	1.12	13.22	8.42	3.93	5.95
Phenotypic co-efficient of variance	7.18	6.66	5.33	3.79	1.99	2.02	15.21	9.06	4.35	6.28
Heritability (Broad sense)	81.59	72.37	91.30	75.86	18.01	30.49	75.63	86.29	81.76	89.97
Genetic advance i= 1.76	0.48	0.41	2.39	1.39	0.55	0.94	5.78	4.05	2.51	3.82
Genetic advance %	10.25	8.44	8.51	5.03	0.63	1.08	20.13	13.69	6.22	9.88

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Heat stress results for staple length of CIM-602 and IUB-65 revealed higher staple in both years respectively (Table 6). Fibre maturity was least affected by heat stress and cultivars exhibited tolerance during 15th April sown cotton which was already evident in this context (Farooq *et al*., 2018). Whereas, low temperature at boll maturation time due to late sown cotton deteriorated the fibre maturity (Ban *et al*., 2015). The maximum fibre maturity was observed in VH-363 under heat stress during both years (Table 6).

Fibre strength was observed high during 15th April sowing (heat stress) in both years (Tables 3 and 4) and such results also in line with Ban *et al*. (2015), Usman *et al*. (2016) and Farooq *et al*. (2018). Sitara-14 revealed the best results for fibre strength under heat stress in consecutive years (Table 6) The overall improvement was observed in ginning out turn under heat stress which gave an indication for early sowing of cotton cultivars (Usman *et al*., 2016; Shah *et al*., 2017; Farooq *et al*. 2018). The tolerant cultivars

Table 6: Mean values of fiber traits for selected cotton cultivars under control and heat stress condition during 2017 and 2018

Traits	Treatments	2017		2018	
		Cultivar	Mean	Cultivar	Mean
Fibre fineness (µg inch^{-1})	Control	CIM-602	4.60	VH-Gulzar	4.05
	Heat Stress	CIM-602	4.02	Weal-AG-Shahkar	4.28
Staple length (mm)	Control	CIM-602	27.76	FH-342	30.51
	Heat Stress	CIM-602	28.11	IUB-65	29.84
Fibre maturity (%)	Control	FH-342	90.66	IR-NIBGE-9	90.33
	Heat Stress	VH-363	90.33	VH-363	90.33
Fibre strength (g tex^{-1})	Control	Weal-AG-1606	25.30	MNH-886	39.33
	Heat Stress	Sitara-14	31.82	Sitara-14	37.50
Ginning out turn (%)	Control	Weal-AG-1606	41.43	NIAB-878	42.66
	Heat Stress	IR-NIBGE-8	42.86	IR-NIBGE-9	42.37

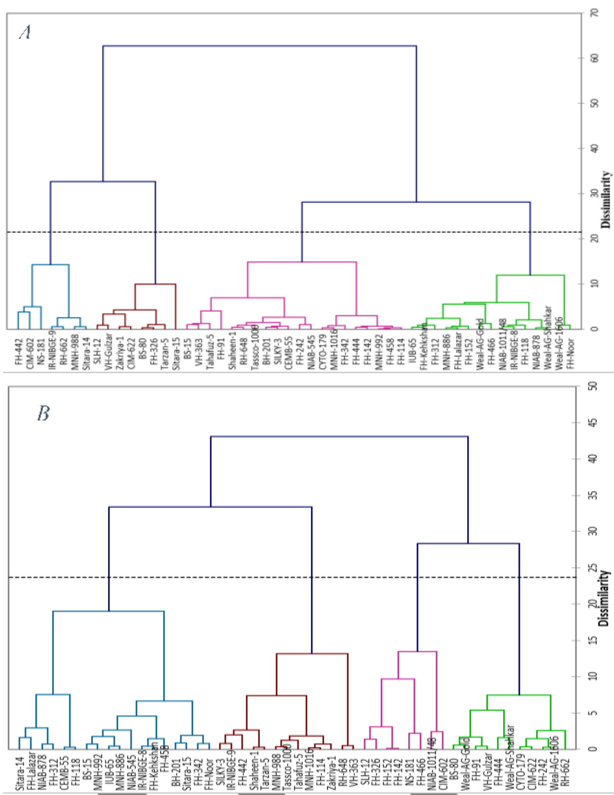

Fig. 1: Dendrogram of fifty cotton cultivars based on fibre traits variations under A = Control and B = Heat Stress during 2017

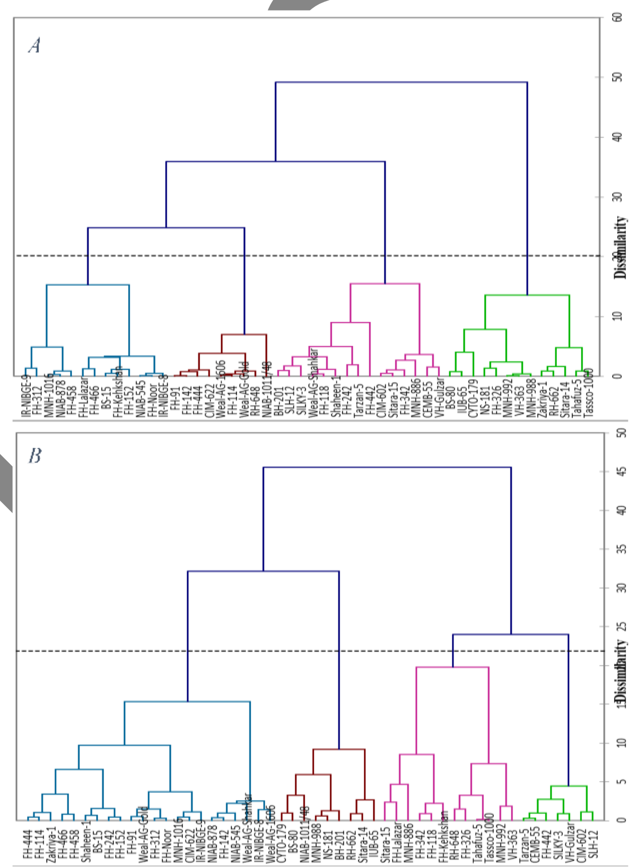

Fig. 2: Dendrogram of fifty cotton cultivars based on fibre traits variations under A = Control and B = Heat Stress during 2018

IR-NIBGE-8 and IR-NIBGE-9 were selected for further improvement in ginning out turn under heat stress (Table 6).

The genetic components including genotypic, phenotypic variances and their coefficients of variances for all the studied fibre quality traits were found almost equal at each treatment level in consecutive years of study. Similarly, high heritability (broad sense) accompanied by low genetic advance was observed in all fibre traits except fibre maturity with low heritability and low genetic advance (Tables 4 and 5). Genetic components revealed all fibre traits were under the control of non-additive gene action. The non-additive gene action for such traits revealed selection for improvement could be misleading or non-rewarding (Babu *et al.*, 2017). Non-additive gene action further suggested heterosis breeding may be useful for the improvement of all studied fiber traits (Shakeel *et al.*, 2015; Kaleem *et al.*, 2016; Li *et al.*, 2018). Contrary to findings of the present study, additive gene action for all traits was reported and improvement through selection was suggested (Shah *et al.*, 2018; Tonk *et al.*, 2019).

Cluster analysis in consecutive years of study revealed remoteness and similarities among the cultivars for fibre quality traits which further gave the directions of breeding program (Rana *et al*. 2011; Spasova *et al.*, 2016; Rathinavel *et al.*, 2017). Among clusters, the identification of heat tolerant cultivars objectively included in cluster-I & II showed maximum inter and intra-cluster variability during heat stress of 2017 (Fig. 1B). Cluster-II & III showed maximum inter and intra-cluster variability during heat stress of 2018 (Fig. 2 B). Sitara-14 and IR-NIBGE-8 revealed maximum variation and found in cluster-I following CIM-602 in cluster-II and VH-363 in cluster-III could be selected for improvement of different fibre traits under heat stress during the first year of the study (Fig. 1B). IR-NIBGE-9 and Weal-AG-Shahkar in cluster-I, VH-363 in cluster-II and Sitara-14, IUB-65 found in cluster -III during heat stress treatment of 2018 (Fig. 2B). Sitara -14 and VH-363 found most diverse and tolerant cultivars in both year study which could be used in different recombination breeding programs to generate potential and promising hybrids (Ashokkumar and Ravikesavan, 2011; Shakeel *et al*., 2015). Maximum variability between inter and intra-cluster cultivars could be combined to get advantages for various fibre characters and broadening the genetic base of newly developed recombinants (Sezener *et al*., 2006; Iqbal *et al*., 2015; Farooq *et al*., 2015b).

Conclusions

Fibre quality traits including fibre fineness, staple length, fibre maturity, fibre strength and ginning out turn influenced by heat stress due to variation of temperature at peak flowering/boll maturation period. The genetic variability was classified by cluster analysis and maximum inter and intra-cluster tolerant cultivars were selected for heat stress. Genetic components revealed non-additive gene action for all the fibre traits that lead towards their improvement against heat stress through heterosis breeding after selecting tolerant cultivars i.e. Sitara-14, IR-NIBGE-8, CIM-602, VH-363, IR-NIBGE-9, Weal-AG-Shahkar and IUB-65.

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