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Research Article

Fiber Quality of *Bt* and Non-*Bt* Cotton Cultivars as Influenced by Different Edapho-Climatic Conditions in South Western Punjab

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ABSTRACT

Weather parameters not only influence the crop growth and productivity but also affect the produce quality. The fiber quality parameters of the *Bt* and non-*Bt* cotton are profoundly affected with the variation in the prevailing weather conditions during the crop period. With this objective, a field experiment was conducted during *Kharif* 2017 with three sowing dates (April 20, May 10 and May 30) in the main plots and four cultivars (*Bt*: NCS855 BGII and RCH650 BGII; non-*Bt*: F 2228 and F 1861) in sub plots of Split plot design replicated thrice. Results revealed that the early sown cotton exhibited higher fiber length (26.67-27.12 mm), more elongation (5.45-5.58%), less short fiber index (9.79-10.04) and better fiber strength (25.19-25.49 g tex^{-1} than late sown crop. Among cultivars, there was little variation in the quality traits of the cotton crop. The seed cotton yield was found to be increased with improved yield attributes such as more number of bolls plant^{-1} (r=>0.87), higher boll weight (r=>0.90) and better ginning outturn (r=>0.76) but, it was negatively correlated with the fiber quality parameters. Similarly, the fiber length of cotton was simultaneously improved with the superior fiber strength (<0.75), elongation (>0.50) and maturity ratio (>0.81) whereas, the uniformity ratio (r= ->0.76) and short fiber index (r= ->0.81) were negatively associated. For higher yield and better fiber quality cotton sowing around the first fortnight of April was suitable. The cotton crop growth, yield as well as the quality attributes were reduced with each successive delay in the crop sowing mainly due to the existence of sub-optimal weather conditions under delayed sowings.

Key words: *Bt* and non-*Bt* cotton, Fiber quality, Seed cotton yield, Sowing dates

Introduction

Cotton, (*Gossypium hirsutum* L.) popularly known as "king of fibers" or 'white gold', is one of the important cash crops in India and the world. It accounts 75% of the total raw material of the textile industries and 4% of the gross domestic products of India (Ban *et al.* 2015). India is the leading country with 37.56% (12.5 million hectare) of world's cotton area and 24.26% (36.0 million bales of 170 kg) of world's cotton production. Indian cotton production is unique, with respect to species cultivated, fiber quality, agronomic practices, plant types, soil types and climatic conditions (Blaise and Kranthi, 2019). In Punjab, cotton is mainly grown in semiarid-irrigated south-western parts of the state over 0.392 million hectare area (Anonymous, 2020). The fiber quality of the cotton is mostly dependent on the inherent genetic characters, crop management practices and the environmental conditions experienced by crop plants during fiber development

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phase. The prevailing environmental conditions influence both the quantity as well as quality of fibers (Singh *et al.*, 2013). The fiber quality is also deteriorated under drought (Nehra and Yadav, 2013) and insufficient nitrogen supply (Zhao *et al.*, 2012). Low temperatures prolongs fiber elongation phase and decrease the fiber length (Zheng *et al.*, 2012) and for fiber elongation the optimum temperature is usually lower than that was optimum for boll development period (Pettigrew, 2001). Similarly, period of cotton boll maturation is also extended by the decreasing temperatures (Gipson and Ray, 1969). The process of fiber development has to go through two major phases: fiber elongation phase and secondary wall formation phase. In the first phase, around first 25-40% of boll development period of the fiber length and formation of primary cell wall takes place. During the secondary wall formation phase, the fiber strength, micronaire and fiber weight are determined that occurs around 25-75% of the boll development period (Yeates *et al.*, 2010). The fiber length has a negative correlation with the difference between maximum and minimum temperatures, while the fiber strength has a positive connection with maximum growth temperature (Bradow and Davidonis, 2000). For maximum fiber length, the optimum night temperature range from 15 to 21°C and night temperature lower than 25°C reduces the fiber micronaire value depending on the genotype (Pettigrew, 1995). Reddy *et al.* (1999) also reported longer fiber length at a temperature below 25°C, increased fiber fineness and maturity up to 26°C temperature, declined short fiber length from 17 to 26°C temperature in controlled plant chambers. Pettigrew (2008) reported that fiber produced at 1°C warmer temperature was 3% stronger, 2% greater maturity and 1% lower reflectance percentage than that produced at ambient temperature. The fiber micronaire and uniformity exhibit a quadratic relationship with temperature with 25°C as optimum closer value and for short fiber content, a quadratic decreasing trend with an increase in temperature (Lokhabde and Reddy, 2014).

Over the decades, genotypic improvements in yield and fiber quality characters by researchers have made desirable cotton fiber for processing. However, adverse environmental and management conditions frequently mask such improvements. Besides the environmental variations, even within the plant, bolls that develop early in the season have different fiber quality than those that develop later in the season (Pettigrew, 1995). Likewise on the same plant, bolls developing at different positions/nodes has different maturation periods, weight, fiber quality characters and fiber physiological parameters (Zhao *et al.*, 2012). Even in a single seed, longer fibers occur near the lower end (chalaza) of the seed and shorter fibers are found near the pointed end (micropyle) of the seed (Bradow and Davidonis, 2000).

Among agronomic practices, sowing time is the key management factor for producing high yielding and high quality cotton crop (Mishra *et al.*, 2021). Former studies indicate the influence of sowing time on fiber quality parameters. Shah *et al.* (2017) reported that the early and mid-sowing cotton crop had better fiber strength than late sown crop caused by more mature fibers. In Pakistan, Ali *et al.* (2009) observed higher fiber strength, more micronaire value and brighter fiber characters for early sown crop but no significant effect on fiber length. Similarly, Ban *et al.* (2015) also reported significant reduction in span length, uniformity ratio, micronaire, fiber strength, elongation, maturity ratio and higher short fiber index under late sown conditions. Higher temperature, water deficit conditions and availability of nutrients during reproductive phase significantly affects the fiber length, fiber strength, colour and percentage of short fibers. Besides the sowing environment these fiber quality parameters also vary with the type of cultivars (Ban *et al.*, 2015). Although, fiber quality traits are majorly governed by inherent genetic characters (Shen *et al.*, 2006), but weather conditions and moisture status during fiber cell development phase directly influence the lint quality (Kaur *et al.*, 2023; Girma *et al.*, 2007). The fiber properties heavily rely on the temperature fluctuations between 18°C and 22°C (Lokhande and Reddy, 2014). Suboptimal temperatures hinder the cellulose synthesis process, resulting in compromised fiber elongation, maturity, and the production of poor-quality fibers (Loka and Oosterhuis, 2010). Such reduction is attributed to changes in the expression of proteins involved in cell wall loosening and biosynthesis, osmotic adjustment, and cytoskeleton homeostasis (Zheng *et al*., 2012). The fiber processing and marketable properties are directly related to fiber quality characteristics. So fiber quality, is one of the important character for recommendation of a genotype for a specific region. Therefore, an experiment was planned for studying the influence of variation in the weather conditions under different sowing environments on fiber quality parameters of *Bt* and non-*Bt* cotton cultivars.

Material and Methods

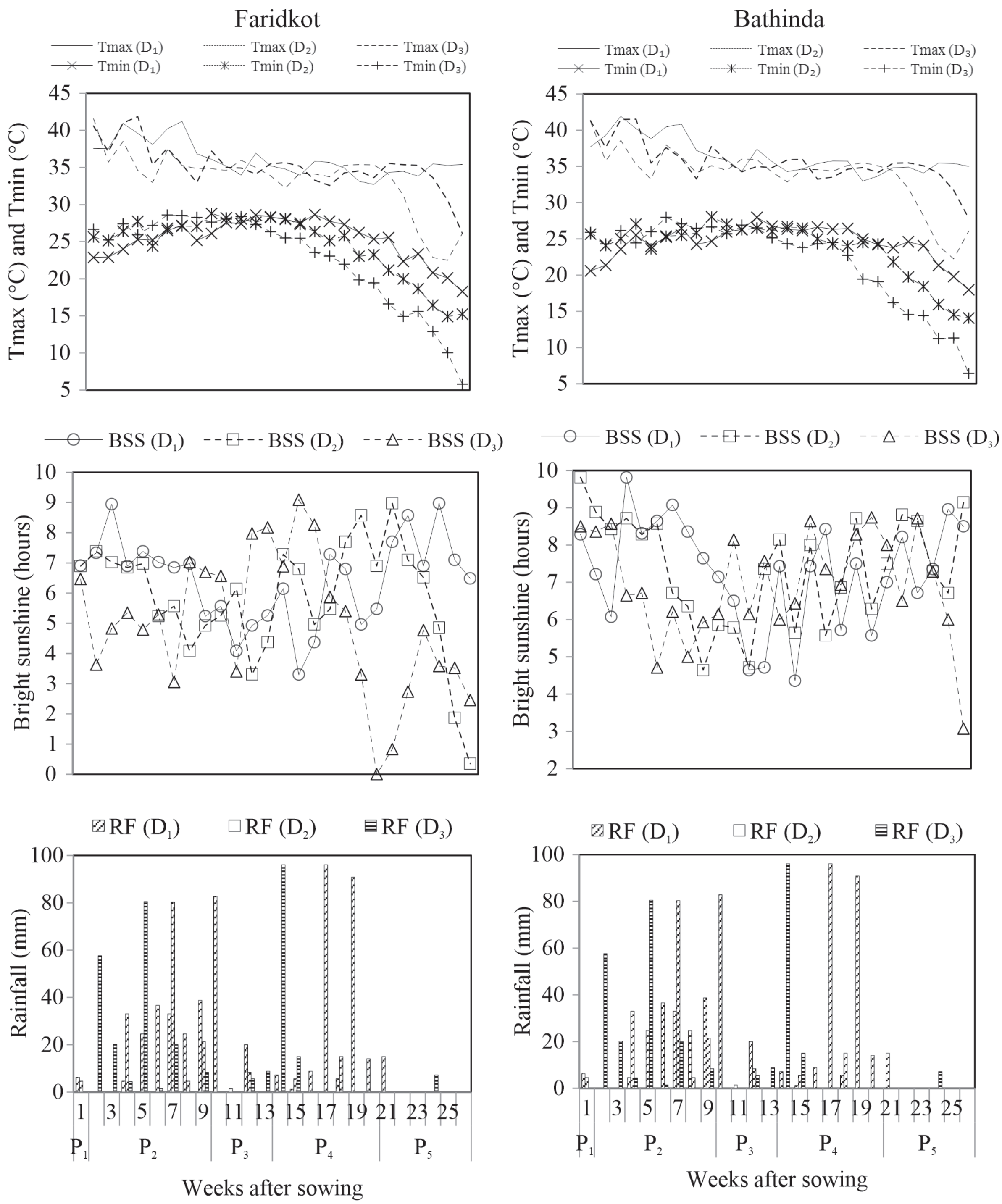
A field experiment was conducted at two different locations, Regional Research Station, Faridkot (30°40′ N, 74°44′ E, 200m amsl) and Regional Research Station, Bathinda (30°58′ N, 74°18′ E, 211m amsl) of Punjab Agricultural University, Ludhiana during *kharif* 2017. Both the experimental locations lie in the south-western region of Punjab state, characterized by semi-arid climate, poor rainfall, low soil fertility with cotton-wheat is predominant cropping pattern. The average annual rainfall at Faridkot and Bathinda sites is 419 mm and 440 mm, respectively. The experiment was laid in split plot design had three sowing dates (April 20, May 10 and May 30) in the main plot and four cotton cultivars *viz*., two non-*Bt* cultivars (F 2228 and F 1861) and two *Bt* hybrids (NCS855 BGII and RCH650 BGII) in subplot with three replications. The soil of both the experimental locations were slightly alkaline with normal EC (< 0.80 ds m^{-1}), medium in P (< 22.5 kg ha^{-1}), high in K (>138 kg ha^{-1}) and medium in organic carbon (0.40-0.75%). Weather data related to maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, bright sunshine hours and rainfall, at both the locations was recorded from agro-meteorological observatories installed at both the locations.

The sowing was done by dibbling two seeds per hill, at a plant spacing of 67.5×75 cm for *Bt* and 67.5×60 cm for non-*Bt* cultivars. A nutrient dose of phosphorus @30 kg/ha was supplied at the time of sowing, whereas nitrogen was given in two splits, first at thinning and second at flowering stage @150 kg/ha for *Bt* and @75 kg/ha for non-*Bt* cultivars. All recommended cultural and plant protection measures were taken following standard “package of practices for *kharif* crops of Punjab” (Anonymous, 2018). At both locations, two manual pickings of mature open cotton bolls have been done for each sowing date. First and second picking was done on October 10 and October 20 for early crop sown on April 20, which was October 20 and October 30 for May 10 sown crop, and October 30 and November 10 for late crop sown on May 30, respectively. The crop duration varied over both the test locations. Total crop duration was 167-172 days after sowing (DAS) for April 20, 156-160 DAS for May 10 and 141-146 DAS for May 30. For fiber quality parameters, five plants from each plot were selected and ten bolls from each plant were picked and clean-dried samples were ginned with a single roller electric gin. Then the ginned samples were used for fiber quality testing with Premier ART2 1.17 (ICC testing mode) at 63% relative humidity and 26.9°C temperature to test fiber length 2.5% (mm), fiber length 50 % (mm), uniformity ratio (%), fiber strength ($gtex^{-1}$), elongation (%), micronaire ($uginch^{-1}$), whiteness (Rd), yellowness (+b), short fiber index and maturity ratio (%). The data was analyzed using CPCS-I statistical software (Cheema and Singh, 1991) and further correlation analysis was carried out using a *corrplot* package available in R-studio following Taiyun and Viliam (2017).

Result and Discussion

Prevailing weather conditions

The weather conditions varied among the sowing dates at both the experimental sites. For the early, mid and late sowings the weekly maximum temperature was 32.7-41.2°C, 26.1-41.9°C and 22.5-41.6°C at Faridkot while, at Bathinda it was33.0-41.9°C, 27.8-41.5°C and 22.2-41.2°C (Fig. 1). Similarly, minimum temperature was 18.3-28.7°C, 14.9-28.8°C and 5.8-28.6°C for early, mid and late sown crops, with a corresponding value of18.0-28.0°C, 14.1-28.0°C and 6.4-28.0°C respectively for Bathinda. The duration of bright sunshine hours, were highest (37.7 hours) at Bathinda in comparison to Faridkot that leads to the highest evaporation (799.4 mm) at former location. Total rainfall during the crop season was 336.5 mm at Faridkot and 344.2 mm at Bathinda.



Tmin & Tmax= minimum & maximum temperature (°C); BSS: total bright sunshine duration (hour); RF=Total rainfall (mm); P_1: sowing to emergence (DAS); P_2: emergence to 50% squaring; P_3: 50% squaring to 50% flowering; P_4:50% flowering to 50% boll formation; P_5: 50% boll formation to maturity (DAS)

Fig. 1. Weekly weather parameters during crop growing season at Faridkot and Bathinda

Effect of sowing dates on quality parameters

Early and mid sown crops produced maximum fiber length, higher fiber strength, more elongated fibers and less short fiber index than late sown crop. The maximum fiber length 2.5% (27.12 mm) was observed in the May 10 sown crop, followed by April 20 (26.75 mm) and May 30 (26.45 mm) sown crop at Faridkot (Table 1). A similar trend was observed at Bathinda *i.e*. higher in May 10 sown crop (27.03 mm) than April 20 (26.67 mm) and May 30 (26.33 mm) in accordance with the results of Shah *et al.* (2017). Uniformity ratio decreased (45.47-46.67%) significantly under mid sown crop (May 10) at both the experimental sites. However, fiber strength, short fiber index and maturity ratio remained unaffected by the sowing dates. The late sowing produced more fiber whiteness characters. Highest fiber elongation was observed under May 10 sown crop (5.55-5.58%) followed by April 20 and May 30 sown crops at both the environments (Table 2). Decreased fiber length in the late sown crop, was mainly due to lower night / minimum temperature and reduced bright sunshine hours as explained by Pettigrew (1995). Under late sown conditions, lower temperature was the main reason for decreasing fiber strength and weight during boll development period (Reddy *et al.*, 1999). Lokhande and Reddy (2014) found that a mean daily temperature of 22 °C was optimum for fiber length and departure from this significantly decreased fiber length. Although fiber strength was insignificant between the sowing dates, but it was also weakened in late sown environments at both locations mainly due to the prevailing lower temperature (Fig. 1). Zhao *et al.* (2012) found that late sown crop had higher sucrose and callose content, but lower rate of transformation of sucrose into cellulose mainly due to unfavourable environmental conditions.

Effect of cultivars on quality parameters

The non-*Bt* cultivars exhibited higher fiber length, more elongated fibers and maximum maturity ratio over *Bt* cultivars. The fiber length (50%) and short fiber index did not differ among the cultivars with the exception of *Bt* cultivar RCH650 BGII at Bathinda, which showed highest (13.43) short fiber index. Similarly, Sankaranarayanan *et al.* (2020) also

Table 1. Fiber quality parameters as affected by sowing dates and cultivars at Faridkot

Treatments	Fiber length 2.5% (mm)	Uniformity ratio (%)	Fiber strength (g tex^{-1})	Elongation (%)	Micronaire (ug inch^{-1})	Whiteness (Rd)	Yellowness (+b)	Short fiber index	Maturity ratio
				Sowing dates					
April 20	26.75^{b}	48.56^{a}	25.49^{a}	5.48^{a}	4.25^{b}	75.91^{b}	5.28^{a}	9.79^{a}	0.905^{a}
May 10	27.12^{a}	46.67^{b}	23.23^{a}	5.58^{a}	4.73^{a}	75.80^{b}	6.54^{a}	12.26^{a}	0.910^{a}
May 30	26.45^{c}	47.40^{ab}	23.75^{a}	5.31^{b}	4.43^{b}	77.69^{a}	6.26^{a}	12.73^{a}	0.903^{a}
LSD (0.05)	0.28	1.29	NS	0.16	0.27	1.30	NS	NS	NS
				Cultivars					
F 2228	27.65^{a}	46.47^{b}	26.43^{b}	5.75^{a}	4.63^{a}	77.08^{b}	6.32^{a}	11.55^{a}	0.928^{a}
F 1861	27.67^{a}	46.86^{b}	29.80^{a}	5.72^{a}	4.30^{b}	75.68^{c}	6.67^{a}	10.70^{a}	0.937^{a}
NCS 855 BGII	25.91^{b}	48.81^{a}	21.15^{c}	5.25^{b}	4.82^{a}	76.05^{c}	6.25^{a}	11.23^{a}	0.900^{b}
RCH 650 BGII	25.85^{b}	48.03^{ab}	19.23^{c}	5.10^{b}	4.14^{b}	79.72^{a}	4.87^{a}	12.88^{a}	0.858^{c}
LSD (0.05)	1.10	1.63	2.03	0.15	0.31	0.69	0.35	NS	0.01

Means within every column followed by a similar letter are not statistically different ($P < 0.05$)

Table 2. Fiber quality parameters as affected by sowing dates and cultivars at Bathinda

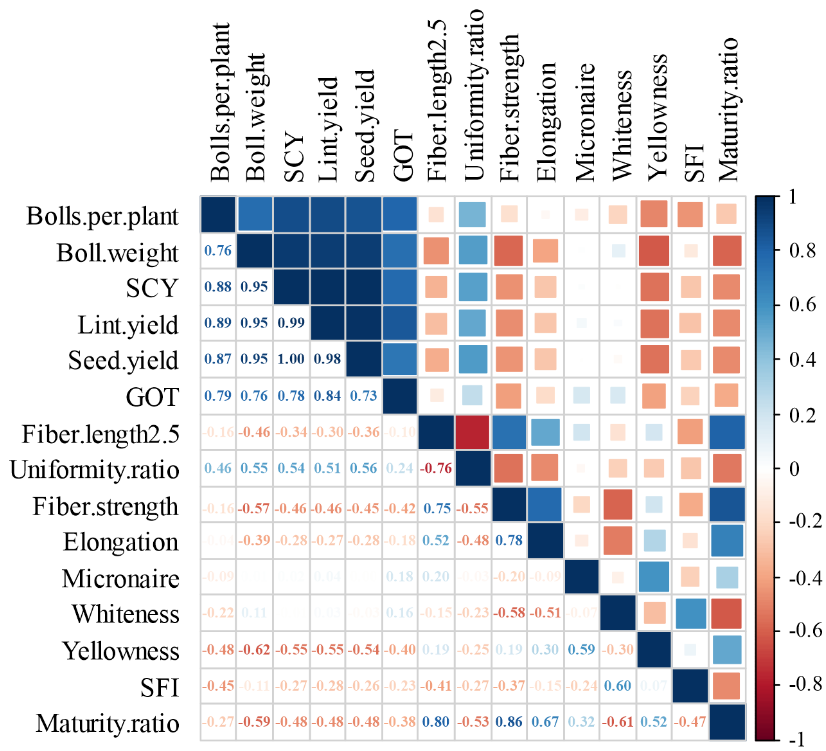
Treatments	Fiber length 2.5% (mm)	Uniformity ratio %	Fiber strength (g tex^{-1})	Elongation (%)	Micronaire (ug inch^{-1})	Whiteness (Rd)	Yellowness (+b)	Short fiber index	Maturity ratio
Sowing dates									
April 20	26.67 ^{b}	47.31 ^{a}	25.19 ^{a}	5.45 ^{ab}	4.13 ^{b}	76.11 ^{b}	5.32 ^{b}	10.04 ^{b}	0.900 ^{a}
May 10	27.03 ^{a}	45.47 ^{b}	23.74 ^{a}	5.55 ^{a}	4.69 ^{a}	77.81 ^{a}	6.48 ^{a}	12.35 ^{a}	0.905 ^{a}
May 30	26.00 ^{c}	46.17 ^{ab}	23.50 ^{a}	5.29 ^{b}	4.37 ^{ab}	77.88 ^{a}	6.15 ^{a}	12.61 ^{a}	0.898 ^{a}
LSD (0.05)	0.21	1.28	NS	0.16	0.35	0.61	0.46	1.12	NS
Cultivars									
F 2228	27.48 ^{a}	45.28 ^{b}	26.51 ^{b}	5.73 ^{a}	4.55 ^{a}	77.22 ^{b}	6.28 ^{b}	11.56 ^{b}	0.923 ^{a}
F 1861	27.59 ^{a}	45.65 ^{b}	30.30 ^{a}	5.69 ^{a}	4.09 ^{c}	75.98 ^{c}	6.55 ^{a}	10.63 ^{b}	0.932 ^{a}
NCS 855 BGII	25.67 ^{b}	47.55 ^{a}	20.97 ^{c}	5.23 ^{b}	4.66 ^{a}	76.13 ^{c}	6.31 ^{b}	11.04 ^{b}	0.895 ^{b}
RCH 650 BGII	25.54 ^{b}	46.79 ^{ab}	18.79 ^{d}	5.08 ^{b}	4.28 ^{b}	79.74 ^{a}	4.79 ^{c}	13.43 ^{a}	0.853 ^{c}
LSD (0.05)	0.58	1.56	1.02	0.15	0.17	0.34	0.17	1.15	0.01

Means within every column followed by a similar letter are not statistically different ($P < 0.05$)

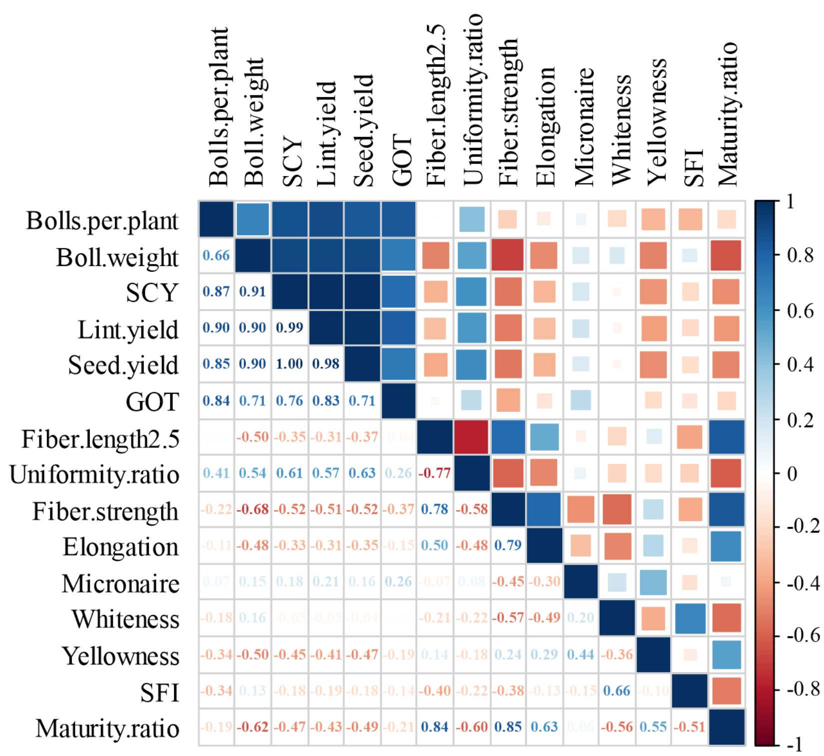
found little influence of genotypes on quality parameters. However, uniformity ratio was highest in the *Bt* cultivars. A significantly highest fiber strength was observed in cultivar F 1861 (29.80-30.30 g tex^{-1}) and lowest was in RCH650 BGII (18.79-19.23 g tex^{-1}). Contrarily, Ban *et al.* (2015) observed higher fiber length (2.5%) and fiber strength under *Bt* hybrids than non-*Bt* cultivars. Also, cultivar NCS855 BGII (4.66-4.82 ug inch^{-1}) showed highest micronaire value than the other cultivars while the lowest was for RCH650 BGII (4.14 ug inch^{-1}) at Faridkot and F 1861 at Bathinda (4.09 ug inch^{-1}). Whiteness was more for RCH650 BGII at both the experimental sites. Such variations are normal occurrence owing to the different genetic structures of tested cultivars.

Correlation analysis

Correlation coefficients (significant at 0.05) among the different yield attributes, seed cotton yield and fiber quality parameters were analyzed for all combinations (Fig. 2a and b). Most of the yield attributes were positively correlated with seed cotton yield while most of the fiber quality parameters were negatively correlated with the exception of uniformity ratio of both the experimental sites. Seed cotton yield was positively correlated with bolls plant^{-1} (r= >0.87), boll weight (r= >0.90), lint yield (r= >0.99), seed yield (r= >0.99), ginning outturn (r= >0.76) and uniformity ratio (r= >0.54) at both the environments in line with the findings of Snider *et al.* (2016). The fiber length (2.5%) was positively correlated with fiber strength (r= >0.75), elongation (r= >0.50) and maturity ratio (r= >0.81), while it was negatively related to uniformity ratio (r= >0.76) at both the locations. However, fiber strength was positively correlated with elongation (r= >0.77) and maturity ratio (r= >0.84) and negatively correlated with whiteness (r= >0.56).Positive correlation among the bolls plant^{-1}, boll weight, lint yield, seed yield and ginning outturn with seed cotton yield, revealed that these attributes acts together for increasing the final seed cotton yield. Kashif *et al.* (2019) also found a positive correlation between seed cotton yield and yield attributes and among the fiber quality traits.

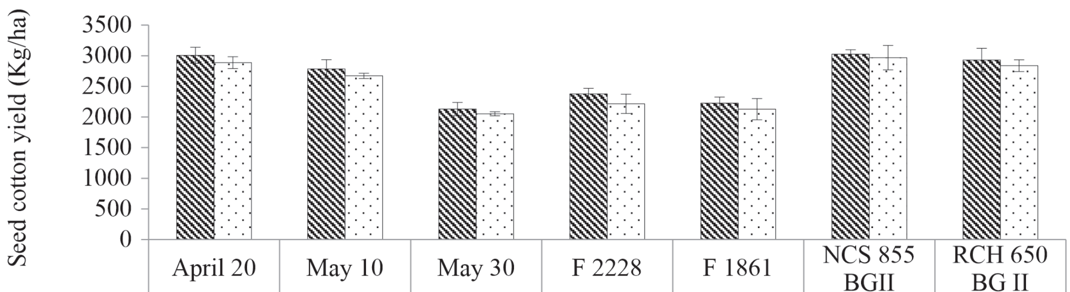


(a)



(b)

Fig. 2. Correlation among the different yield attributes and fiber quality parameters at Faridkot (a) and Bathinda (b)



	April 20	May 10	May 30	F 2228	F 1861	NCS 855 BGII	RCH 650 BG II
Faridkot	3006.4	2783.1	2129.5	2376.3	2225.8	3026.6	2930.0
Bathinda	2887.2	2671.0	2052.3	2214.2	2127.4	2968.2	2837.4

Fig. 3. Seed cotton yield as influenced by sowing dates and cultivars at Faridkot and Bathinda

Conclusion

Variation in the weather conditions due to change in the sowing dates affects crop growth, seed cotton yield and fiber quality. Very early and/ or too late sowing causes to decline the growth, productivity and quality attributes of cotton crop. The present investigation concluded that for better fiber quality with respect to higher fiber length, more uniformity ratio, higher strength, more elongation and lower short fiber index, the second fortnight of April to first fortnight of May was a suitable environment for cotton crop sowing at both the studied locations. However, tested cultivars showed little difference with respect to quality parameters except for fiber length, elongation and maturity where non-*Bt* cultivars were better. Correlation analysis showed that the seed cotton yield had a significant positive correlation with other yield attributes and also among the fiber quality traits.

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