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# PLANTING TIME AND N NUTRITION ON CELL MEMBRANE THERMOSTABILITY, BOLLS' RETENTION AND FIBRE TRAITS IN COTTON

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## ABSTRACT

Bolls retention in cotton was assessed under varying temperature regimes and nitrogen rates in field conditions for two consecutive years, 2009 and 2010. Treatments comprised March and May planting (main plots) of a Bt and a non-Bt variety (sub plots) at three nitrogen levels (115, 145 and 175 kg ha$^{-1}$) kept in sub-sub plots. Means showed more opened bolls and less insects' damaged, un-opened and total bolls on a plant in mid March planting than in mid May planting during both years. Varietal comparison showed more opened bolls; un-opened bolls and less number of insects' damaged bolls per plant in FH-113. Among nitrogen levels more insects' damaged bolls, opened as well as un-opened bolls and total bolls per plant were recorded with 175 kg N ha$^{-1}$ and minimum with 115 kg N ha$^{-1}$. Maximum number of insects' damaged bolls per plant was recorded in CIM-496 at mid may planting while minimum in FH-113 at mid March planting. FH-113 showed more cell membrane thermo stability (heat tolerance) both in early and late planting than CIM-496. Quality characters were most affected by varieties, least by nitrogen and not by sowing date.

**Key words:** Heat tolerance, Bolls retention, Fiber quality, Bt and non-Bt, nitrogen and sowing dates.

## INTRODUCTION

Among the fiber crops, Cotton (*Gossypium hirsutum* L.) occupies first position (Killi and Aloglu, 2000). Being an important cash crop, it earns major portion of foreign exchange for Pakistan (Ahmad *et al*., 2009). During 2010, Bt cotton was grown on an area of 2.4 million hectares in Pakistan (Bilal *et al*., 2012). According to geographical position, cotton belt of Pakistan is present in a zone of high temperature where summer temperature reaches to 45 $^{o}$C, hence cotton crop experiences heat stress resulting reduced fiber yield and quality (Rahman *et al*., 2004).

Hall (2004) reported that heat sensitive genotype is less productive than heat tolerant genotype in those environments where heat stress condition prevails. Variation in cotton yield is associated with changes in temperature during the peak flowering as high temperatures are often associated with poor yield while low maximum temperatures are considered favorable for better yield (Sarwar *et al*., 2012). Pettigrew (2008) reported that slight elevations in temperature (approximately 1°C above control temperatures) under field conditions were not sufficient to cause a decline in seed weight but were sufficient to cause a significant decline in seed number per boll, which was the primary cause of reduced yield under high temperature conditions. So heat tolerance can be defined as the relative performance of a plant or plant process under heat stress conditions compared its performance under optimum condition. Field evaluation of cotton cultivars under high temperature is a practical approach to observe heat response (Hall, 2001). Relative cell injury level is used for detecting genetic variability in heat tolerance in warm season crop (Ismail and Hall, 1999). Relative cell injury percentage (RCI %) can be used to estimate heat tolerance. Heat-tolerant strains are more stable with respect to yield and fiber quality as compared to non heat-tolerant strains. The relationship between RCI and lint yield/fiber quality was strong and negative (Azhar *et al*., 2009).

Late planted cotton bears less bolls than early sown cotton cultivars (Butter *et al*., 2004). April planting produced more yield than May planting (Hezhong *et al*., 2006). Bt cotton produced more bolls than non Bt hybrids when planted earlier, however, in case of late sowing non Bt cotton produced more bolls than Bt cotton (Mayee *et al*., 2004). Bt varieties incorporate Bt Cry1Ac gene and have natural resistance against certain insect pests (Perlack *et al*., 2001) so, Bt produced more yield than that of non-Bt (Hofs *et al*., 2006). However, transgenic Bt cotton cultivars showed variation in resistance against lepidopteron pests (Babar *et al*., 2013), may be due to varying prevailing temperatures.

Nitrogen is an important nutrient that controls new growth, influences boll development, increases boll number and weight thus leading to increased crop yield (Mahey and Ansari, 2003). Nitrogen is an essential component of plant dry matter and energy-rich compounds like ATP, which regulate photosynthesis (Sawan *et al*., 2009). According to Khan and Dar (2006), varying nitrogen levels caused marked differences in cotton yield and yield components. Marsh *et al*. (2000) emphasized the use of optimum doses of nutrients particularly of nitrogen for achieving maximum seed cotton yield. The present experiments were undertaken to look into the impact of planting date and nitrogen rate on boll retention, insect pest attack, cell membrane stability and fiber traits of Bt vs. non-Bt cotton.

## MATERIALS AND METHODS

**Experimental detail:** Performance of Bt and non-Bt cotton genotypes was compared in a two years (2009 and 2010) field study at Students' Farm, University of Agriculture, Faisalabad, Pakistan. The three factors experiment was laid out in a split-split design and replicated thrice. Main plot factor included two sowing times (Mid March and Mid May planting), sub plot factor included two cotton genotypes; a Bt (FH-113) and a non Bt (CIM-496) whereas three nitrogen rates (115, 145 and 175 kg $ha^{-1}$) were randomized in sub-sub plots. Net plot size (6m x 3m) was same for each treatment. Soil samples were taken before sowing of crop to a depth of 0 to 6 inches and 6 to 12 inches for physio-chemical analysis (Table-1). Land was fallow before planting cotton during both years of study.

**Crop husbandry:** The two cotton cultivars were planted manually on 75 cm apart well prepared ridges keeping plant to plant distance of 30 cm. The crop was sown on $13^{th}$ of March and $15^{th}$ of May, 2009 and on $15^{th}$ of March and $14^{th}$ of May during 2010. Full P (115 kg $ha^{-1}$) + $1/3^{rd}$ N (as per treatment) was applied as basal dose. Remaining N was applied in two equal splits viz half with $1^{st}$ irrigation and half with $2^{nd}$ irrigation. A total of nine irrigations were applied throughout growing period. Crop was kept free of weeds by manual hoeing and free of sucking insects by chemical spray as and when required. When seedlings were well established ten plants were randomly selected and tagged from each plot

**Measurements:** Opened bolls per plant were counted at first and second picking of ten tagged plants. On the basis of physical observation, insects' damaged bolls were also counted from the same tagged plants before first and second picking and after second picking (bolls were cracked to see insect damage). To count unopened bolls, data were collected after last picking of same ten plants in each plot. All the above three counting of bolls were summed up to have total bolls per plant.

To measure cell membrane thermostability, fully expanded young leaf (20-22 days) was selected at peak flowering stage. Tagging was done on the day (taking as day 1) when leaf get unfolded. Percent relative cell injury (RCI%) was computed as suggested by Sullivan (1972):

RCI % = 1-[1-(T1/T2)/1-(C1/C2)] x 100

where

T = EC of heat treated vials

C= EC of controlled vials

$_1$= $1^{st}$ EC reading

$_2$= Final EC reading

Electrical conductivity was measured with EC-meter (Model JENWAY-4510). We computed cell membrane thermo stability by subtracting RCI % from 100.

Produce of all the pickings was weighed on electric balance and yield per plant was calculated. Lint was separated by roller ginning and ginning out turn (GOT) was calculated as suggested by Singh (2004):

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

High volume instruments (HVI) were used to determine lint quality parameters at Department of Fiber Technology University of Agriculture, Faisalabad.

**Statistical analysis:** Data on all the above mentioned measurements were statistically analyzed using MSTAT-C programme (Anonymous 1986) and means were separated using LSD at 5 % probability (Steel *et al*., 1997).

## RESULTS

**Number of opened bolls per plant:** Number of opened bolls per plant is highly important trait of yield in cotton crop. Significantly ($P \leq 0.05$) higher number of opened bolls per plant (16.94 & 15.82) were recorded with mid March planting than with May sowing (14.04 & 13.20). Among genotypes, more opened bolls per plant (16.74 & 15.74) were produced by FH-113 than by CIM-496 (14.24 & 13.28). Among nitrogen levels maximum opened bolls per plant (17.38 & 16.32) were observed in $N_2$ (145 kg $ha^{-1}$) which were statistically similar to those obtained with $N_3$ (175 kg $ha^{-1}$) and least number (12.75 & 11.81) was observed with $N_1$ (115 kg $ha^{-1}$) during 2009 and 2010, respectively. Neither of the interactive effects was significant on number of opened bolls (Table-2).

**Number of insects' damaged bolls per plant:** Treatments' means showed that varieties and nitrogen levels differed (P 0.05) for number of insects' damaged bolls per plant while among interactions sowing date x variety showed significant differences for the parameter under discussion. Sowing dates' means and all other interactions remained non significant (Table-2). Statistically more insects' damaged bolls per plant (32.31) were recorded when CIM-496 was sown in May, followed by March sown CIM-496 (21.49), than by May sown FH-113 (15.11) and least were recorded by March sown FH-113 (13.96) during 2009. Although non-significant, but trend was similar during 2010. Among nitrogen levels, maximum insects' damaged bolls per plant were observed in $N_3$ and minimum in $N_1$.

**Number of unopened bolls per plant:** Significantly more unopened bolls per plant were observed in late planted crop than in early planting. Varietal comparison showed more unopened bolls per plant in FH-113 and less in CIM-496 (Table-2). Sowing dates x variety interaction was significant during 2010 which recorded maximum un-opened bolls per plant (7.16) in $S_2$ x $V_1$ (FH-113 planted in May). More un-opened bolls were observed with 175 kg N ha$^{-1}$ while nitrogen level of 145 and 115 kg ha$^{-1}$ showed non significant differences for unopened bolls. All other two way and three way interactions showed non-significant effect on this character (Table-2).

**Total number of bolls per plant:** Total bolls per plant were influenced only by planting date and nitrogen means while varieties and all interactions showed non-significant effect in this respect (table-3). Total bolls per plant were more in late planting than in early planting. Comparison of treatments' means showed that number of bolls per plant went on increasing with increasing N dose during both years of study. On an average, total number of bolls per plant was more during 2009 than 2010.

**Cell membrane thermostability (%):** Maximum value for CMT was recorded when variety FH-113 was sown in March; although it was statistically at par with mid May planting, followed by $S_1V_2$ (CIM-496 sown in March) and $S_2V_2$ (CIM-496 sown in May) during 2009 and 2010. Whereas nitrogen and other interactions' effect on cell membrane thermostability was non significant (Table-3). It is also clear from table 3 that relatively more CMT values were recorded during 2009 than 2010.

**Seed cotton yield per plant (g):** Table-3 indicated higher seed cotton yield (63.15 g & 64.04 g) per plant picked from early (March) sown crop and less (51.89 g & 40.62 g) in late (May) sown crop, while cultivar $V_1$ (FH-113) performed better than $V_2$ (CIM-496) in this respect. Among the nitrogen rates, $N_3$ (175 kg ha$^{-1}$) and $N_2$ (145 kg ha$^{-1}$) were statistically similar while $N_1$ (115 kg ha$^{-1}$) showed less seed cotton yield per plant (g) during 2009 and 2010. Other interactions showed non-significant effect on seed cotton yield per plant (g) during both years of study. Relatively more seed cotton yield was recorded during 2009 than 2010. Relationship between CMT vs seed cotton yield was positive but not strong (Table-6).

**Fiber quality traits:** Comparison of treatments' means (Table 4 & 5) showed maximum ginning out turn (%), fiber strength (g/tex), fiber length (mm), fiber uniformity (%) and fiber elongation (%)recorded in $V_2$ (CIM-496) and minimum were recorded in $V_1$ (FH-113), opposite trend was recorded for the fiber fineness (Micronaire) during both years of study. Among nitrogen levels medium (145 kg N ha$^{-1}$) and high (175 kg N ha$^{-1}$) doses were statistically similar with each other with respect to ginning out turn (%) and fiber length (mm) and N1 (115 kg ha$^{-1}$) showed decreasing trend. While more fiber strength was measured in $N_1$ (115 kg ha$^{-1}$) that was statistically similar with $N_2$ (145 kg ha$^{-1}$) and less fiber strength was measured in $N_3$ (175 kg ha$^{-1}$) during both years. The remaining effects were non significant on quality traits. Coefficient of determination ($r^2$) for CMT vs ginning out turn (%), fiber length (mm), fiber strength (g/tex) was negative but weak; however CMT vs fiber uniformity (%) and fiber elongation (%) was strong negative; whereas CMT vs fiber fineness (Micronaire) was positive and strong (Table-6). Year comparison showed more ginning out percentage during 2009 than 2010.

## DISCUSSION

Variation in opened bolls per plant was significant ($P \leq 0.05$) due to varying nitrogen rates (Sawan *et al*., 2006), cultivar (Copur, 2006) and sowing time (Arain *et al*., 2001). In present experiments, more opened bolls per plant were recorded in earlier planting than late planting of cotton crop, because in earlier planting temperature regime (Fig-1) during peak flowering stage was favorable for more flower retention which resulted in more bolls opening than late planting of cotton crop. The differential response of cultivars for depression in opened bolls suggested that varieties differed in heat tolerance. The genotype having ability to produce higher number of viable pollens, developed pollen tube that is responsible for successful fertilization under heat stressed condition which resulted in more number of bolls per plant. Nitrogen fertilizer increased the leaf photosynthesis rate and is important in preventing the abscission of bolls (Borowski, 2001); our results showed that number of opened bolls per plant increased by higher N dose, but N dose above the optimum decreased the opened bolls per plant; the reason might be excessive vegetative tendencies that delayed maturity (Rinehardt *et al*., 2004). In both years of study more number of insects' damaged bolls per plant were observed in the highest N application treatment; insect pests attraction was higher to lush green plants. Less insects' damaged bolls were observed from March sown crop than mid May planting because peak flowering time of May sown crop synchronized with the most active period of insect pest attack. It is also worth mentioning that in May planting crop temperature fell down after the physiological cut out stage (Fig-1); so decrease in temperature and sun shine hours caused hindrance in sink source relationship leading to more unopened bolls in late planted crop. Higher boll retention, less insect pest infestation in Bt cultivar FH-113 was due to its genetic makeup as compared with non-Bt cotton CIM-496. Our results confirmed earlier findings of higher boll retention in Bollgard II cultivars (Wilson *et al*., 2004). To control boll worms, use of Bt cotton is a novel approach (Pemsl *et al*., 2004). Total bolls per plant increased with increasing nitrogen rate (Ali and El-Sayed, 2001).

Management practices like early sowing of crop may avoid its flowers to fall due to temperature stress.

Temperature is a key factor for determining boll retention in cotton (Reddy *et al*., 2002). In mid March planting, when crop was at physiologically cut out stage the rise in temperature resulted premature boll drop that lowered the total number of bolls per plant. So far as year comparison is concerned, less bolls during 2010 was attributed to quite higher daily maximum temperature (Fig. 1) from March to end August as this is the ideal time for cotton crop to bear squares, flowers and young bolls. Figure 1 also indicated more rainfall from July to August during 2010 than 2009; high humidity resulting from high rainfall combined with higher temperature created death valley causing more bolls to drop.

**Table-1. Physio-chemical analysis of soil.**

| **Characteristics** | **Unit** | **Value** | | | |
|---|---|---|---|---|---|
| | | **2009** | | **2010** | |
| **A) Depth of sample** | cm | 0-6 | 6-12 | 0-6 | 6-12 |
| **B) Mechanical analysis** | | | | | |
| Sand | % | 49 | 49 | 49 | 49 |
| Silt | % | 22 | 22 | 22 | 22 |
| Clay | % | 29 | 29 | 29 | 29 |
| Textural class | | Loam | | | |
| **C) Chemical analysis** | | | | | |
| Saturation | % | 32 | 32 | 31 | 31 |
| EC | mS/cm | 0.60 | 0.48 | 0.60 | 0.48 |
| pH | -- | 7.4 | 7.4 | 7.4 | 7.4 |
| Organic matter | % | 0.75 | 0.55 | 0.74 | 0.56 |
| Total nitrogen | % | 0.041 | 0.037 | 0.042 | 0.036 |
| Available phosphorus | ppm | 8.5 | 7.2 | 8.6 | 7.1 |
| Available potassium | ppm | 230 | 210 | 235 | 205 |

**Table-2. Effect of sowing dates, varieties and nitrogen levels on number of opened, unopened and insects' damaged bolls per plant of cotton.**

| | **OBPP** | | **IDBPP** | | **UOBPP** | |
|---|---|---|---|---|---|---|
| | **2009** | **2010** | **2009** | **2010** | **2009** | **2010** |
| **Sowing dates (S)** | | | | | | |
| Mid March ($S_1$) | 16.94 a | 15.82 a | 17.73 b | 17.07 b | 4.55 b | 4.42 b |
| Mid May ($S_2$) | 14.04 b | 13.20 b | 23.71 a | 25.45 a | 5.77 a | 5.61 a |
| **LSD (p=0.05)** | 2.56 | 2.36 | 5.12 | 4.21 | 0.31 | 0.15 |
| **Varieties (V)** | | | | | | |
| FH-113 ($V_1$) | 16.74 a | 15.74 a | 14.54 b | 18.68 b | 6.67 a | 6.36 a |
| CIM-496 ($V_2$) | 14.24 b | 13.28 b | 26.90 a | 23.85 a | 3.66 b | 3.67 b |
| **LSD (p=0.05)** | 2.52 | 2.19 | 4.29 | 4.21 | 0.40 | 0.27 |
| **Sowing dates x Varieties** | | | | | | |
| $S_1$ x $V_1$ | 18.51 | 17.43 | 13.96 c | 13.57 | 5.90 | 5.56 b |
| $S_1$ x $V_2$ | 15.37 | 14.20 | 21.49 b | 20.58 | 3.21 | 3.28 d |
| $S_2$ x $V_1$ | 14.97 | 14.05 | 15.11 bc | 23.79 | 7.44 | 7.16 a |
| $S_2$ x $V_2$ | 13.11 | 12.36 | 32.31 a | 27.11 | 4.10 | 4.05 c |
| **LSD (p=0.05)** | NS | NS | 6.08 | NS | NS | 0.38 |
| **Nitrogen rate (kg ha$^{-1}$) (N)** | | | | | | |
| 115 ($N_1$) | 12.75 b | 11.81 b | 15.72 c | 16.67 c | 4.94 b | 4.63 b |
| 145 ($N_2$) | 17.38 a | 16.32 a | 21.79 b | 22.21 b | 5.08 b | 4.86 b |
| 175 ($N_3$) | 16.33 a | 15.39 a | 24.65 a | 24.90 a | 5.46 a | 5.55 a |
| **LSD (p=0.05)** | 1.66 | 1.57 | 2.79 | 2.21 | 0.34 | 0.62 |
| **S x N, V x N, S x V x N** | NS | | | | | |

Means not sharing a letter in common within a column differ significantly at 5% probability level. NS= Non-significant
**OBPP:** Opened bolls per plant, **UOBPP:** Un-opened bolls per plant, **IDBPP:** Insect's damaged bolls per plant,

**Table-3. Effect of sowing dates, varieties and nitrogen levels on total number of bolls per plant, cell membrane thermostability and seed cotton yield per plant of cotton.**

| | TNBPP | | CMT | | SCY | |
|---|---|---|---|---|---|---|
| | **2009** | **2010** | **2009** | **2010** | **2009** | **2010** |
| **Sowing dates (S)** | | | | | | |
| Mid March ($S_1$) | 39.03 b | 37.32 b | 49.33 a | 53.16 a | 63.15 a | 64.04 a |
| Mid May ($S_2$) | 48.25 a | 44.27 a | 39.94 b | 44.88 b | 51.89 b | 40.62 b |
| **LSD (p=0.05)** | 4.75 | 5.76 | 6.76 | 7.31 | 9.82 | 8.60 |
| **Varieties (V)** | | | | | | |
| FH-113 ($V_1$) | 42.72 | 40.78 | 54.00 a | 59.05 a | 62.32 a | 56.88 a |
| CIM-496 ($V_2$) | 44.55 | 40.80 | 35.27 b | 39.00 b | 52.72 b | 47.78 b |
| **LSD (p=0.05)** | NS | NS | 1.83 | 1.43 | 9.10 | 7.43 |
| **Sowing dates x Varieties** | | | | | | |
| $S_1$ x $V_1$ | 38.48 | 36.56 | 58.88 a | 61.77 a | 69.08 | 70.56 |
| $S_1$ x $V_2$ | 39.57 | 38.07 | 39.77 b | 44.55 b | 57.22 | 57.52 |
| $S_2$ x $V_1$ | 46.96 | 45.00 | 49.11 a | 56.33 a | 55.56 | 43.20 |
| $S_2$ x $V_2$ | 49.54 | 43.54 | 30.77 c | 33.44 c | 48.22 | 38.04 |
| **LSD (p=0.05)** | NS | NS | 2.51 | 2.02 | NS | NS |
| **Nitrogen rate (kg ha$^{-1}$) (N)** | | | | | | |
| 115 ($N_1$) | 34.82 c | 33.13 b | 45.50 | 49.83 | 46.91 b | 42.46 b |
| 145 ($N_2$) | 46.62 b | 43.40 a | 43.91 | 48.91 | 64.85 a | 58.85 a |
| 175 ($N_3$) | 49.47 a | 45.85 a | 44.50 | 48.33 | 60.81 a | 55.68 a |
| **LSD (p=0.05)** | 2.16 | 2.92 | NS | NS | 6.26 | 5.64 |
| **S x N, V x N, S x V x N** | NS | | | | | |

Means not sharing a letter in common within a column differ significantly at 5% probability level. NS= Non-significant
**TNBPP:** Total number of bolls per plant, **CMT:** Cell membrane thermostability (%), **SCY**: Seed cotton yield per plant (g),

**Table-4. Effect of sowing dates, varieties and nitrogen levels on ginning out turn (%), fiber length (mm) and fiber strength (g/tex) of cotton.**

| | GOT | | FL | | FS | |
|---|---|---|---|---|---|---|
| | **2009** | **2010** | **2009** | **2010** | **2009** | **2010** |
| **Sowing dates (S)** | | | | | | |
| Mid March ($S_1$) | 39.09 | 36.94 | 27.42 | 27.36 | 24.12 | 24.13 |
| Mid May ($S_2$) | 39.07 | 37.07 | 27.44 | 27.40 | 24.01 | 23.90 |
| **LSD (p=0.05)** | NS | NS | NS | NS | NS | NS |
| **Varieties (V)** | | | | | | |
| FH-113 ($V_1$) | 38.63 b | 36.50 b | 27.00 b | 26.95 b | 23.46 b | 23.47 b |
| CIM-496 ($V_2$) | 39.53 a | 37.52 a | 27.86 a | 27.81 a | 24.67 a | 24.56 a |
| **LSD (p=0.05)** | 0.82 | 0.59 | 0.79 | 0.68 | 0.89 | 0.78 |
| **Sowing dates x Varieties** | | | | | | |
| $S_1$ x $V_1$ | 38.56 | 36.41 | 26.94 | 26.91 | 23.50 | 23.53 |
| $S_1$ x $V_2$ | 39.62 | 37.47 | 27.90 | 27.82 | 24.74 | 24.72 |
| $S_2$ x $V_1$ | 38.69 | 36.59 | 27.06 | 27.00 | 23.43 | 23.40 |
| $S_2$ x $V_2$ | 39.45 | 37.56 | 27.82 | 27.81 | 24.60 | 24.39 |
| **LSD (p=0.05)** | NS | NS | NS | NS | NS | NS |
| **Nitrogen rate (kg ha$^{-1}$) (N)** | | | | | | |
| 115 ($N_1$) | 37.89 b | 35.76 b | 26.40 b | 26.39 b | 24.61 a | 24.50 a |
| 145 ($N_2$) | 39.49 a | 37.53 a | 27.89 a | 27.77 a | 24.90 a | 24.82 a |
| 175 ($N_3$) | 39.86 a | 37.74 a | 28.00 a | 27.99 a | 22.69 b | 22.71 b |
| **LSD (p=0.05)** | 1.05 | 1.12 | 0.76 | 0.77 | 1.17 | 1.14 |
| **S x N, V x N, S x V x N** | NS | | | | | |

Means not sharing a letter in common within a column differ significantly at 5% probability level. NS= Non-significant
**GOT:** Ginning out turn (%), **FL:** Fiber length (mm), **FS:** Fiber strength g/tex.

Several traits are considered indicators of heat tolerance but Cell membrane thermostability is a unique more reliable technique for identification of heat tolerant cotton (Azhar *et al*., 2009). In the present study cell membrane thermostability of varieties interacted with sowing time; Bt cultivar performed similar at both planting times, whereas non-Bt cotton was less thermostable especially in late sown conditions. Rahman *et al*., (2004) concluded that CMT is an indirect selection measure in non-heat stressed condition. Our study further concluded that CMT could not be altered by increased or decreased application of N to cotton crop in field conditions. Higher temperature during 2010 might have triggered the plant defense system to produce certain proteins causing hardening of cotton crop; thus less cell injury and more CMT was recorded during 2010 than 2009.

More seed cotton yield per plant (g) in March planting was due to the more number of opened bolls compared with May sown crop. Cultivars differed non-significantly for number of bolls per plant but difference in seed cotton yield per plant may be due to less insect pest infestation in Bt cotton as compared to non-Bt cotton cultivar. More seed cotton yield during 2009 was attributed to more total number of bolls per plant produced during this year than during 2010.

Difference in fiber quality between cultivars was prominent; more ginning out turn (%), fiber strength (g/tex), fiber length (mm), fiber uniformity (%), fiber elongation (%) and less fiber fineness (Micronaire) were observed in non-Bt cultivar than in Bt cultivar in both the years of study. Cotton genotypes vary for GOT (Arshad *et al*., 2007), fiber length (Copur, 2006), fiber strength (Faircloth, 2007) and fiber elongation (Saleem *et al*., 2010). Fiber quality traits are more influenced by the genetic and least by cultural practices like N application (Hussain *et al*., 2000). Less GOT during 2010 was attributed to high maximum temperature reached during this year than during 2009 (Fig. 1) as already confirmed by Pettigrew (2008) that slight elevations in temperature (approx. 1$^{o}$C) under field conditions were sufficient to cause significant decline in lint yield and seed number per boll.

**Table-5. Effect of sowing dates, varieties and nitrogen levels on fiber fineness, fiber uniformity and fiber elongation of cotton.**

| | **FF** | | **FU** | | **FE** | |
|---|---|---|---|---|---|---|
| | **2009** | **2010** | **2009** | **2010** | **2009** | **2010** |
| **Sowing dates (S)** | | | | | | |
| Mid March ($S_1$) | 4.29 | 3.37 | 49.85 | 49.40 | 6.56 | 6.61 |
| Mid May ($S_2$) | 4.29 | 3.23 | 49.70 | 49.90 | 6.57 | 6.55 |
| **LSD (p=0.05)** | NS | NS | NS | NS | NS | NS |
| **Varieties (V)** | | | | | | |
| FH-113 ($V_1$) | 4.51 a | 3.45 a | 48.50 b | 48.44 b | 6.22 b | 6.22 b |
| CIM-496 ($V_2$) | 4.07 b | 3.16 b | 51.05 a | 50.85 a | 6.90 a | 6.93 a |
| **LSD (p=0.05)** | 0.26 | 0.17 | 1.38 | 1.38 | 0.32 | 0.36 |
| **Sowing dates x Varieties** | | | | | | |
| $S_1$ x $V_1$ | 4.50 | 3.56 | 48.47 | 48.08 | 6.20 | 6.25 |
| $S_1$ x $V_2$ | 4.08 | 3.18 | 51.22 | 50.71 | 6.92 | 6.96 |
| $S_2$ x $V_1$ | 4.52 | 3.33 | 48.52 | 48.80 | 6.25 | 6.20 |
| $S_2$ x $V_2$ | 4.06 | 3.13 | 50.88 | 51.00 | 6.88 | 6.90 |
| **LSD (p=0.05)** | NS | NS | NS | NS | NS | NS |
| **Nitrogen rate (kg ha$^{-1}$) (N)** | | | | | | |
| 115 ($N_1$) | 4.24 | 3.25 | 49.70 | 49.65 | 6.58 | 6.59 |
| 145 ($N_2$) | 4.27 | 3.29 | 49.88 | 49.60 | 6.47 | 6.51 |
| 175 ($N_3$) | 4.36 | 3.36 | 49.75 | 49.69 | 6.64 | 6.63 |
| **LSD (p=0.05)** | NS | NS | NS | NS | NS | NS |
| **S x N, V x N, S x V x N,** | NS | | | | | |

Means not sharing a letter in common within a column differ significantly at 5% probability level. NS= Non-significant
**FF:** Fiber fineness (Micronaire), **FU:** Fiber uniformity (%), **FE:** Fiber elongation (%).

**Table-6. Linear regression coefficient ($r^2$) between cell membrane thermostability % (CMT) vs. fiber quality traits and seed cotton yield of cotton**

| Characters | Linear regression coefficient ($r^2$) Years | |
|---|---|---|
| | 2009 | 2010 |
| CMT vs. Ginning out turn (%) | -0.209 | -0.266 |
| CMT vs. Fiber length (mm) | -0.238 | -0.245 |
| CMT vs. Fiber strength (g/tex) | -0.190 | -0.143 |
| CMT vs. Fiber uniformity (%) | -0.731 | -0.895 |
| CMT vs. Fiber elongation (%) | -0.744 | -0.751 |
| CMT vs. Fiber fineness (micronaire) | 0.724 | 0.739 |
| CMT vs. Seed cotton yield per plant (g) | 0.332 | 0.289 |

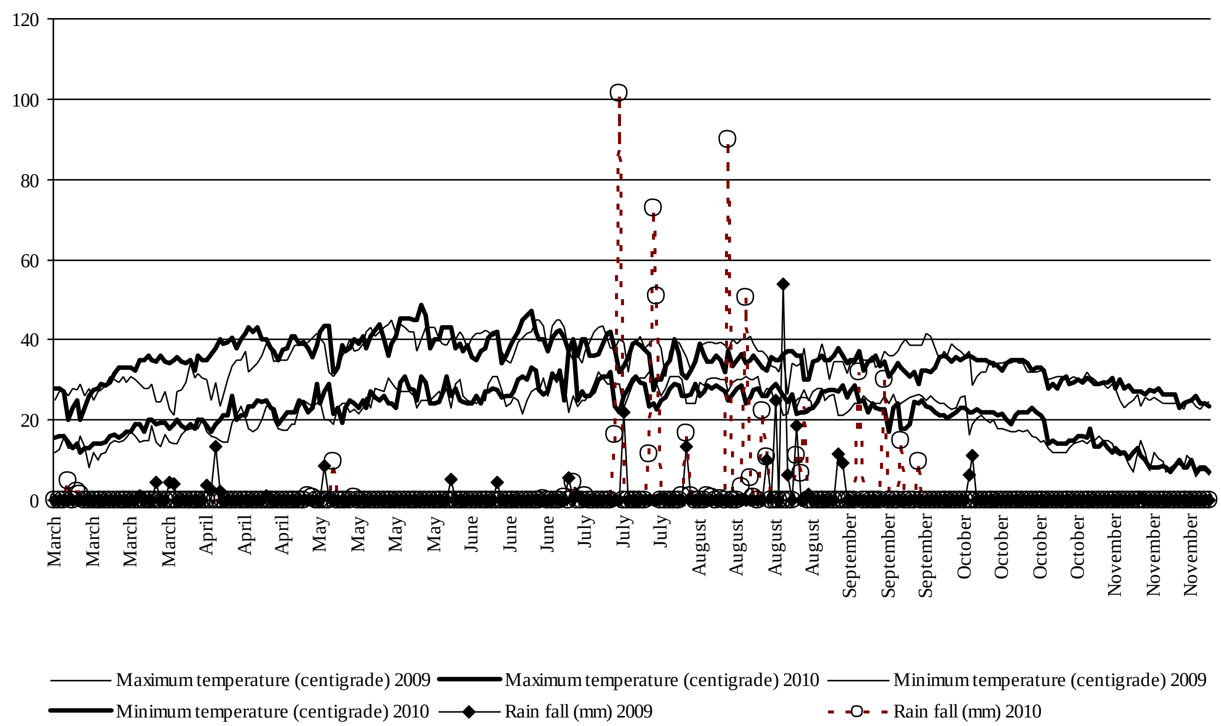


**Fig-1. Weather conditions during cotton crop growth period.**

**Conclusion:** Early planting (March) and medium N dose (145 kg $ha^{-1}$) can help cotton to escape from late season heat stress and/or minimize insect pests' damage leading to better growth and yield. Cultivar FH-113 (Bt) can be adopted for higher yield but varieties like CIM-496 (Non-Bt) cannot be ignored due to their better fiber quality traits.

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