Evaluating the effect of temperature on flower and boll opening density for selection of climate resilient cultivars in cotton

ABSTRACT:
Climate change is a great challenge that badly affects the agricultural economy all over the world. Studies on evaluating the effect of temperature on flower, boll opening density for selection of climate resilient cultivars in cotton were conducted for two crop seasons during 2016 and 2017. FH-Lalazar, FH-Kahkashan, FH-Noor, FH-326 and MNH-992 cultivars were used for experimentation following randomized complete block design with three replications. Temperature during 2016 was higher than 2017 that badly affected the flower and boll opening density. On the basis of fruiting behaviour FH-Noor and MNH-992 were early maturing as compared with FH-326. Cluster analysis exhibited that cluster-2 consisted of three months i.e., July, August and September. Maximum flowers on all cultivars were observed during these three months contributing maximum yield. Principal component analysis results demonstrated that first two Principal components having Eigen values ≥1 induced accumulative 90.7% variations. The variability was mainly due to minimum and maximum temperature. In fact, we could state that based on the correlation of 0.647% variation of this, principal component is primarily a measure of the minimum temperature. It was concluded that reproductive stage of cotton is very sensitive to increasing temperature and cultivation of FH-326 that will be very useful in the changing climate.

Keywords:
Climate change, Cotton, Cultivars, Correlation, Principal component analysis.
INTRODUCTION
Climate of Pakistan is highly diverse ranging from arid/semi-arid to humid and sub-humid in some areas of the country. However most of the agricultural area of Pakistan is in arid climate (Farooqi et al., 2005). Maximum temperature touches more than 40°C during sunshine of the summer day but minimum temperature of winter night falls below 0°C (Farooqi et al., 2005; Sajjad et al., 2009; Abid et al., 2015). Emission of carbon dioxide, methane and nitrous oxide gases are responsible for increase in the climatic temperature. Due to deforestation and massive use of fossil fuels in industries global temperature will rise on an average by 2.8°C (Stern, 2006; Kaushal et al., 2010; Abbas et al., 2016). Metabolic activities of plants are performed at an optimum temperature. Any change in minimum and maximum temperature influences their metabolic processes (Reddy et al., 2000).

Photosynthesis, respiration, water requirement and growth of crops are highly affected by heat and drought (Butt et al., 2005; Bibi et al., 2008; Aaliya et al., 2016; Ali et al., 2016). Negative effect of increasing temperature has been reported by various scientists. Quantity and quality of the produce are affected by day and night temperature. It was reported from a research that short period of sunshine boosted flower density and boll development in cotton (Sawan, 2012). Reproductive stage of cotton is very sensitive to increased temperature (Kakani et al., 2005; Bibi et al., 2008). At flowering stage when canopy temperature exceeded up to 32°C, pollen grain and pollen tube development are affected negatively therefore both yield and fiber quality of cotton are reduced (Conaty et al., 2015). Similarly, when night temperature increased from 27 to 30°C, the respiration rates as compared with control (at 24°C) was increased from 49% to 56% that induced yield reduction in cotton (Loka and Oosterhuis, 2010). Cotton cultivars indicated tolerance against high-temperature that exhibit high membrane thermo stability (Ahsan et al., 2013), boll retention, pollen grain viability and pollen tube developments (Kakani et al., 2002; Craufurd et al., 2003; Kakani et al., 2005). They ultimately produce good quality and quantity of the produce than the susceptible cultivars of cotton (Rahman et al., 2004; Puspito et al., 2015).

Tolerance ability of cotton cultivars to high-temperature would be useful to identify and grow in the changing climate in the future because pollen tube and pollen germination were affected with high temperature (Kakani et al., 2005; Bibi et al., 2008). Fruiting behaviour of cultivars is also very important in the changing climate. Some cultivars start fruiting under suitable climatic conditions and fruiting occurs earlier or after the extremes of climatic conditions. Therefore the impact of various meteorological parameters on crop growth and development needs to be studied. For this purpose month wise seasonal temperature and its impact on the yield of cotton cultivars were also observed during both years of study.

MATERIALS AND METHODS
Present studies were conducted for two years during 2016 and 2017 on the experimental area of Cotton Research Station, Faisalabad, Pakistan, situated between 31°25N, 73°06E and 214 m. The area is nearly plain and 186.54 m above sea level (Quddus, 1987).

Experimental setup
FH-Lalazar, FH-Kahkashan, FH-Noor, FH-326 and MNH-992 cotton cultivars were used for experimentation following randomized complete block design with three replications. Sowing was done on 15th April during 2016 and on 18th of April during 2017. Crop completed its seedling growth and vegetative stage during May and started their initial flowering from June onward, therefore data regarding number of flowers, open boll was collected from June onward. Data of all cultivars continued till crop started to terminate and had negligible number of flowers.
Seasonal temperature

Temperature data of same season were taken from the Department of Physiology, Ayyub Agricultural Research Institute, Faisalabad. Maximum temperature was found at air temperature of the day and minimum temperature was during the night temperature in degree centigrade.

Data analysis

Most of the bolls during late crop season could not open due to low temperature therefore objective of the present study is to observe suitable temperature during peak flowering period and to find out flowers of which month that become open boll and contribute maximum toward per acre yield of cotton. For this purpose, month wise flowers were tagged to find out which flower develop as open boll. Fruiting behaviour of the selected cultivars during different months was also observed during both years of the study. Therefore, it was to find out which set variety responded best in the changing climate on the basis of trend of flowers and bolls.

Statistical analysis

The recorded data were subjected to scatter diagram to estimate the association between independent variables of temperature and flower and opened bolls. A dendrogram among the selected months was generated for cluster analysis among cultivars by Jaccard’s coefficient of similarity expressed as Euclidean genetic distances. The cultivars were categorized into appropriate groups with minimum error using Minitab software (Sneath et al., 1975). Principle component analysis was also conducted for determining the contribution of maximum and minimum temperature on flower initiation, peak flowering and opened bolls.

RESULTS

Seasonal Temperature during 2016 and 2017

Results demonstrated that seasonal temperature during 2016 was higher than the year 2017 (Figure 1). Maximum temperature was observed during the months of June and July. Day, night temperature during 2016 was 41.3, 28.4 for June and 37.3 and 26.9 of July respectively. Day, night was 38.5, 26.3 during June and 37.4, 27.5 in July 2017 respectively. Temperature was 36.2, 26.8 and 37.1, 25.2 during August and September 2016 whereas it was 37.4, 26.9; and 36.9, 23.4 during August and September 2017. Day temperature during October and November 2016 was 34.7 and 28.7°C; night temperature was 19.6 and 11.9 but during 2017 day temperature was 35.1 and 24.4°C; and 18.6 and 10.9°C was night temperature.

Number of flowers/day/ plant during 2016 and 2017

Maximum flowers were recorded during the months of July and September and then in August.
However, minimum flowering was during the months of June, October and November, 2016. This trend of flowering was slightly changed during 2017 because number of flowers gradually increased from June, July, and August that were maximum during September. Flowers were decreased during October and November.

**Number of open bolls/day/plant during 2016 and 2017**

Similar trend of open bolls per plant per day were observed during both years i.e., 2016 and 2017. During August and September, bolls were maximum. Then there was an abrupt decline in open bolls per plant per day. However number of open boll per plant were more during 2017 as compared to 2016.

**Trend of flowers with maximum and minimum temperature during 2016 and 2017**

Scatter diagram demonstrated that temperature had positive correlation with flowers per day per plant.

![Scatter diagram showing correlation of minimum and maximum temperature with flower per plant per day during 2016 and 2017](image)

**Table 1. Day, night temperature during different months of 2016 and 2017**

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<tbody>
<tr>
<td>1</td>
<td>June</td>
<td>41.3±0.001</td>
<td>28.4±0.03</td>
<td>38.5±0.001</td>
<td>26.3±0.003</td>
<td>12.9±0.001</td>
<td>12.2±0.001</td>
<td>6.45±0.01</td>
<td>6.1±0.031</td>
</tr>
<tr>
<td>2</td>
<td>July</td>
<td>37.3±0.021</td>
<td>26.9±0.04</td>
<td>37.4±0.054</td>
<td>27.5±0.022</td>
<td>10.4±0.032</td>
<td>9.9±0.021</td>
<td>5.2±0.012</td>
<td>4.95±0.001</td>
</tr>
<tr>
<td>3</td>
<td>August</td>
<td>36.2±0.011</td>
<td>26.8±0.002</td>
<td>37.4±0.032</td>
<td>26.9±0.021</td>
<td>9.4±0.011</td>
<td>10.5±0.011</td>
<td>4.7±0.002</td>
<td>5.25±0.011</td>
</tr>
<tr>
<td>4</td>
<td>September</td>
<td>37.1±0.023</td>
<td>25.2±0.001</td>
<td>36.9±0.021</td>
<td>23.4±0.023</td>
<td>11.9±0.001</td>
<td>13.5±0.031</td>
<td>5.95±0.004</td>
<td>6.75±0.012</td>
</tr>
<tr>
<td>5</td>
<td>October</td>
<td>34.7±0.004</td>
<td>19.6±0.012</td>
<td>35.1±0.001</td>
<td>18.6±0.041</td>
<td>15.1±0.021</td>
<td>16.5±0.013</td>
<td>7.55±0.002</td>
<td>8.25±0.032</td>
</tr>
<tr>
<td>6</td>
<td>November</td>
<td>28.7±0.02</td>
<td>11.9±0.032</td>
<td>24.4±0.011</td>
<td>10.9±0.001</td>
<td>16.8±0.022</td>
<td>13.5±0.001</td>
<td>8.4±0.001</td>
<td>6.75±0.001</td>
</tr>
</tbody>
</table>
and data points were found scattered closer to the positively sloped line. However when night temperature (27°C) and day temperature (38°C) exceeds the position of scatter point and were away from the trend line, they demonstrated decline in flower per plant per day during both years of study (Table 1 and Figure 2).

**Trend of bolls/day/plant with maximum and minimum temperature during 2016 and 2017**

Scatter diagram demonstrated that temperature had positive correlation with boll per plant per day as data points were found scattered closer to the positively sloped line. However when night temperature (28°C) and day temperature (37°C) exceeds the position of scatter points and were away from the trend line and they demonstrated decline in boll per plant per day during both years of study (Figure 3).

**Number of flowers on the selected cultivars of cotton during different months of 2016 and 2017**

Flowers per plant per day were more abundant during the months of July, August and September during both years of study, however negligible flowering on all cultivars were observed in June during both years of study (Figure 4). During 2016 number of flowers were 29.79 on MNH-992 followed by 22.18 on FH-Noor and 14.69 on FH-326, remaining cultivars had intermediate flowers during July. FH-Kahkshan had 27.27 flowers during August and MHH-992 had 14.48 flowers while other cultivars had intermediate number of flowers during August. During September FH-326 had 27.0 followed by 24.99 on FH-Lalazar and least number was observed on FH-Kahkshan. While remaining cultivars showed intermediate flowers between maximum and minimum number of flowers. During October and November negligible number of flowers was observed on all cultivars of cotton during 2016. During 2017, similar trend of flowers were observed on the selected cultivars of cotton where FH-Noor and MNH-992 demonstrated earliness as compared with FH-326.
because maximum number of flowers per plant were observed during July on FH-Noor (39.33) and MNH-326 (36.5), intermediate (33.9) on FH-Lalazar and (29.5) on FH-Kahkshan, whereas least (11.99) flowers were observed on FH-326. Similarly in August, 38.1 flowers were observed on FH-Kahkshan followed by 35.7 on FH-Lalazar and 29.9 on both MNH-992 and FH-Noor but least 16.89 were recorded on FH-326. However during September FH-326 demonstrated maximum flowering (56.42) as compared (25.09) on both MNH-992 and FH-Noor, 24.9 by Lalazar and 18.1 of FH-Kahkshan. During October and November flower per plant on all cultivars were very negligible.

**Number of bolls on the selected cultivars of cotton during 2016 and 2017**

Negligible fruiting on all cultivars was observed in June and July during both years of study (Figure 4). During 2016, number of bolls were 18.76 on MNH-992 followed by 12.08 on FH-Noor, remaining cultivars had intermediate bolls during August, 2016. FH-Kahkshan had 27.27 flowers during August and MHH-992 had 14.48 flower while other cultivars had intermediate number of flowers during August. During September FH-326 had 27.0 followed by 24.99 on FH-Lalazar and least number was observed on FH-Kahkshan. While remaining cultivars had intermediate between maximum and minimum number of bolls. During October FH-326 bolls per plant remained maximum with 22.09 bolls followed by MNH-992 (15.89) as compared with all other tested cultivars of cotton i.e., 7.28, 4.28 and 2.79 on FH-Noor, FH-Lalazar and FH-Kahkshan. During November the number of bolls was negligible on all cultivars of cotton during 2016. During 2017 similar trend of flower was observed on selected cultivars of cotton where FH-Noor and MNH-992 demonstrated earliness as compared with FH-326 because maximum number of opened bolls per plant were observed during August on FH-Noor (23.44) followed by 18.6 on MNH-992. FH-Lalazar (12.64) and FH-Kahkshan (9.7) had intermediate number of opened bolls but minimum (8.3) were observed on MNH-326. In September MNH-992 (21.9), FH-Lalazar (18.38), FH-326 (17.1) and FH-Kahkshan (14.0) had number of bolls. During October FH-326 had maximum bolls (21.4) and minimum (10.0) on FH-Noor remaining cultivars had intermediate bolls i.e., FH-Kahkshan (14.0) FH-Lalazar (11.8), MNH-992 (11.5). Bolls per plant were negligible during November 2017.

Six months of crop season were categorized into three different clusters in dendrogram with the help of
cluster analysis. Clusters were made on the basis of maximum, minimum temperature and number of flowers and opened bolls on the selected cultivars of cotton. Cluster-1 comprised of two months i.e., June and November that demonstrated similarity with each other with minimum number of flowers on all cultivars. Cluster 2 consisted of a group of August, September and July months. Among these three months, August and September exhibited maximum similarity with maximum flowers on all cultivars. Cluster 3 consisted of October that showed intermediate response for flower and bolls as compared with cluster 1 and 2 (Figure 5).

At first two principal components having Eigen values ≥1 were taken because they demonstrated maximum role and induced accumulative 90.7% variations. The results further revealed that in PC1 all variables except flowers established positive association. Effect of night temperature on flowers was maximum than the maximum temperature (day temperature). The variability was 55.5 and 45.5% due to minimum and maximum temperature respectively. The results indicated that the variability in temperature from minimum to maximum temperature; showed that there may be adverse affect of minimum temperature on the growth and development of cotton. It was found from our study that the first principal component was strongly correlated with the minimum temperature. In fact, we could state that based on the correlation of 0.647% variation, this principal component is primarily a measure of the minimum temperature. PC2 increases with increasing open bolls and number of flowers but decreases with minimum and maximum temperature. The correlation of 0.907% variation of this PC2 is due to the open bolls. The entire remaining PC’s contributed least variation as compared with PC1 and PC2 (Table 2).

**DISCUSSION**

Present studies conducted under field conditions demonstrated that during the month of June, temperature during day time was extreme viz., 41.3 and 38.5°C for 2016 and 2017 respectively. Temperature requirement of each crop showed variations and metabolic process of growing plants depend upon the fluctuation in temperature. Activities are ceased at freezing temperature and protein is coagulated at 50°C. In cotton heat tolerant genotypes can be developed on the basis of

![Figure 5. Cluster diagram showing similarity index of different months regarding effect of temperature on flower and bolls in cotton](image)

<table>
<thead>
<tr>
<th>S. No</th>
<th>Eigen value</th>
<th>PC1</th>
<th>PC2</th>
<th>PC3</th>
<th>PC4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Proportion of variation</td>
<td>0.647</td>
<td>0.259</td>
<td>0.090</td>
<td>0.004</td>
</tr>
<tr>
<td>2</td>
<td>Cumulative variation of PCs</td>
<td>0.647</td>
<td>0.907</td>
<td>0.996</td>
<td>1.000</td>
</tr>
<tr>
<td>3</td>
<td>Variables</td>
<td>Contribution of variables in PCs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Maximum temperature</td>
<td>0.455</td>
<td>-0.348</td>
<td>0.451</td>
<td>-0.607</td>
</tr>
<tr>
<td>5</td>
<td>Minimum temperature</td>
<td>0.555</td>
<td>-0.431</td>
<td>-0.061</td>
<td>0.709</td>
</tr>
<tr>
<td>6</td>
<td>Flower</td>
<td>-0.516</td>
<td>0.328</td>
<td>-0.745</td>
<td>-0.269</td>
</tr>
<tr>
<td>7</td>
<td>Bolls</td>
<td>0.343</td>
<td>0.766</td>
<td>0.489</td>
<td>0.238</td>
</tr>
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</table>
physiological parameters like stomata conductance (Radin et al., 1994; Lu et al., 1998; Ali et al., 2014a; Ali et al., 2014b), cell membrane thermo stability (Rahman et al., 2004), percent boll retention, pollen tube growth and pollen grains survival to high temperature (exposure up to 35°C for 15 minutes) (Rodriguez-Garay and Barrow, 1988). Principal component analysis analysis used to screen multivariate data with higher significant correlations (Johnson, 1998). The results of the present studies revealed that the effect of night temperature on flowers was maximum as compared with the day time maximum temperature, because variability was 55.5 and 45.5% due to minimum and maximum temperatures respectively. This component can be viewed as a measure of minimum and maximum temperature. Increase in night temperature also increased the water requirement of crop (Butt et al., 2005; Bibi et al., 2008), it also exerted negative effect on respiration, ATP and carbohydrates level. Night temperatures (30/28°C) exposure for four weeks increased respiration to 39% and 21%, however reduced ATP to 38% and 37% respectively as compared with normal 30/20°C day/night temperature. When night temperature increased from 27 to 30°C the respiration rates were also increased from 49% to 56% as compared with control (at 24°C). Results of present studies also depicted that night temperature during June, 2016 was high i.e., 25.2 as compared with 23.4 °C during 2017 respectively (Loka and Oosterhuis, 2010).

Extremes of temperature also had effect on photosynthetic activity of plants (Butt et al., 2005; Bibi et al., 2008). The maximum photosynthetic activity of cotton was at 20-30°C (Reddy et al., 1997). The optimum temperature for pollen germination was 28°C (Burke et al., 2004) indicating that reproductive stage of cotton is very sensitive to the increased temperature (Kakani et al., 2005; Bibi et al., 2008). Increase in temperature affected the growth and development of cotton plants due to the effect on pollen germination, sporogenesis injury and influence on boll setting (Cross et al., 2003; Young et al., 2004). Climate resilient are those cultivars that produce flowering and fruiting at optimum temperature. Such cultivars play an important role to avoid extremes of climatic temperature. Results of the present studies revealed that FH-326 started flower initiation under mild temperature and produced maximum (27.0 flowers/month) followed by 24.99 on FH-Lalazar and FH-Kahkshan during September 2016. Season wise peak flowering was also observed in September when day temperature was 37.1 and 36.9°C during 2016 and 2017 respectively. Results further exhibited that number of flowers and bolls were maximum when day temperature was less during 2017. FH-326 had maximum flowering during September, 2017 (56.42/month) as compared with 25.09 flowers on both MNH-992 and FH-Noor, followed by Lalazar (24.9) and FH-Kahkshan (18.1 flowers/month) respectively. It is therefore suggested that FH-326 should be recommended for general cultivation in south Punjab because FH-326 has boll opening quality until the month of October and is well suited for the poor farmers of southern Punjab.

CONCLUSION

Principal component analysis results demonstrated that variations among flower initiation and boll opening were mainly due to minimum and maximum temperature, however minimum temperature accounted much up to 0.647% variation. It was further concluded that reproductive stage of cotton is very sensitive to increasing temperature and cultivation of FH-326 will be very useful in the changing climate because it has boll opening quality until the month of October.

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