Journal of Research in Ecology
An International Scientific Research Journal
ISSN No: Print: 2319 –1546; Online: 2319– 1554

Original Research

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

Authors:
Hafiz Ghazanfer Abbas[1], Muhammad Rafiq Shahid[2], Arif Malik[3], Abid Mahmood[1], Muhammad Farooq[1], Muzammal Mateen Azhar[3] and Qurban Ali[3]

Institution:
1. Cotton Research Station Faisalabad, Ayub Agricultural Research Institute, Faisalabad, Pakistan.

2. Cotton Research Institute, Multan, Ayub Agricultural Research Institute, Faisalabad.

3. Institute of Molecular Biology and Biotechnology, University of Lahore, Lahore, Pakistan.

Corresponding author:
Qurban Ali

Email ID:
saim1692@gmail.com

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.

Article Citation:
Hafiz Ghazanfer Abbas, Muhammad Rafiq Shahid, Arif Malik, Abid Mahmood, Muhammad Farooq, Muzammal Mateen Azhar and Qurban Ali
Evaluating the effect of temperature on flower and boll opening density for selection of climate resilient cultivars in cotton
Journal of Research in Ecology (2018) 6(1): 1667-1676

Dates:
Received: 19 April 2018 **Accepted:** 18 May 2018 **Published:** 02 June 2018

Web Address:
http://ecologyresearch.info/documents/EC0550.pdf

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 to 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.

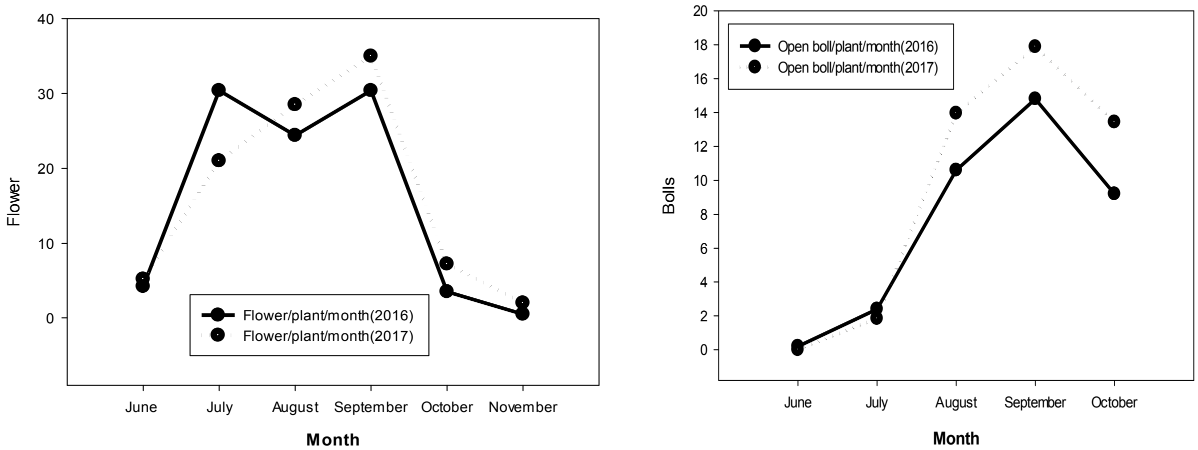

Figure 1. Flower and boll per plant during 2016 and 2017

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 bolls 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 initia-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 10.9ºC 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.

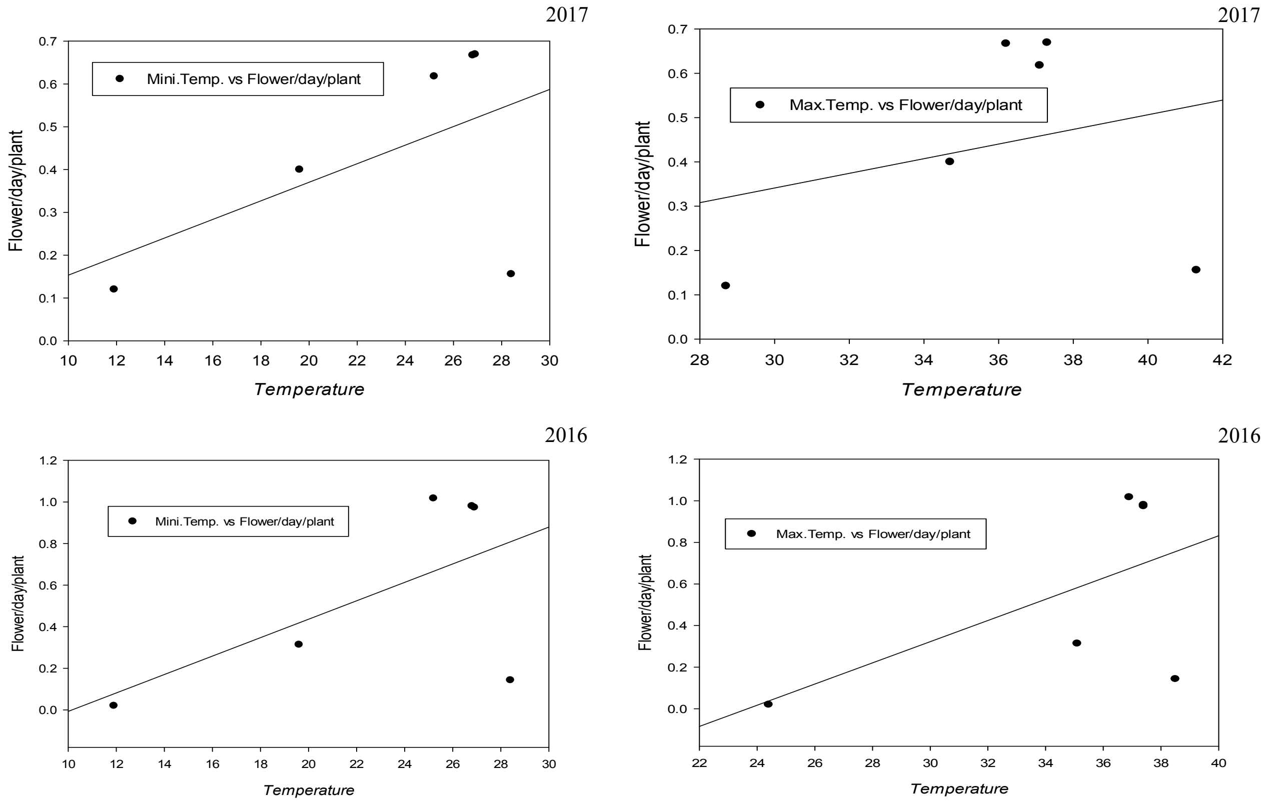

Figure 2. Scatter diagram showing correlation of minimum and maximum temperature with flower per plant per day during 2016 and 2017

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

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

S. No	Months	2016		2017		2016	2017	2016	2017
		Maximum ± SE	Minimum ± SE	Maximum ± SE	Minimum ± SE	Difference ± SE	Difference ± SE	Heat unit ± SE	Heat unit ± SE
1	June	41.3±0.001	28.4±0.03	38.5±0.001	26.3±0.003	12.9±0.001	12.2±0.001	6.45±0.01	6.1±0.031
2	July	37.3±0.021	26.9±0.04	37.4±0.054	27.5±0.022	10.4±0.032	9.9±0.021	5.2±0.012	4.95±0.001
3	August	36.2±0.011	26.8±0.002	37.4±0.032	26.9±0.021	9.4±0.011	10.5±0.011	4.7±0.002	5.25±0.011
4	September	37.1±0.023	25.2±0.001	36.9±0.021	23.4±0.023	11.9±0.001	13.5±0.031	5.95±0.004	6.75±0.012
5	October	34.7±0.004	19.6±0.012	35.1±0.001	18.6±0.041	15.1±0.021	16.5±0.013	7.55±0.002	8.25±0.032
6	November	28.7±0.02	11.9±0.032	24.4±0.011	10.9±0.001	16.8±0.022	13.5±0.001	8.4±0.001	6.75±0.001

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

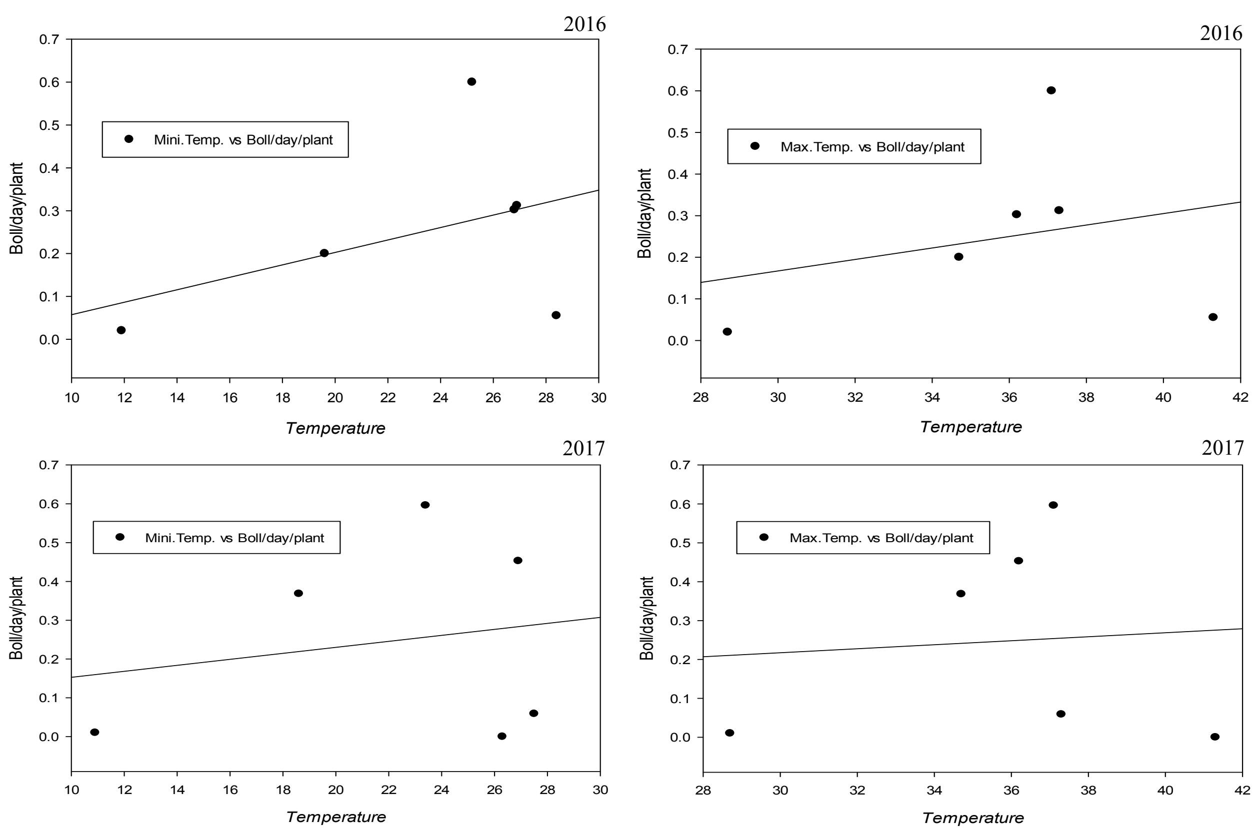

Figure 3. Scatter diagram showing correlation of minimum and maximum temperature with boll per plant during 2016 and 2017

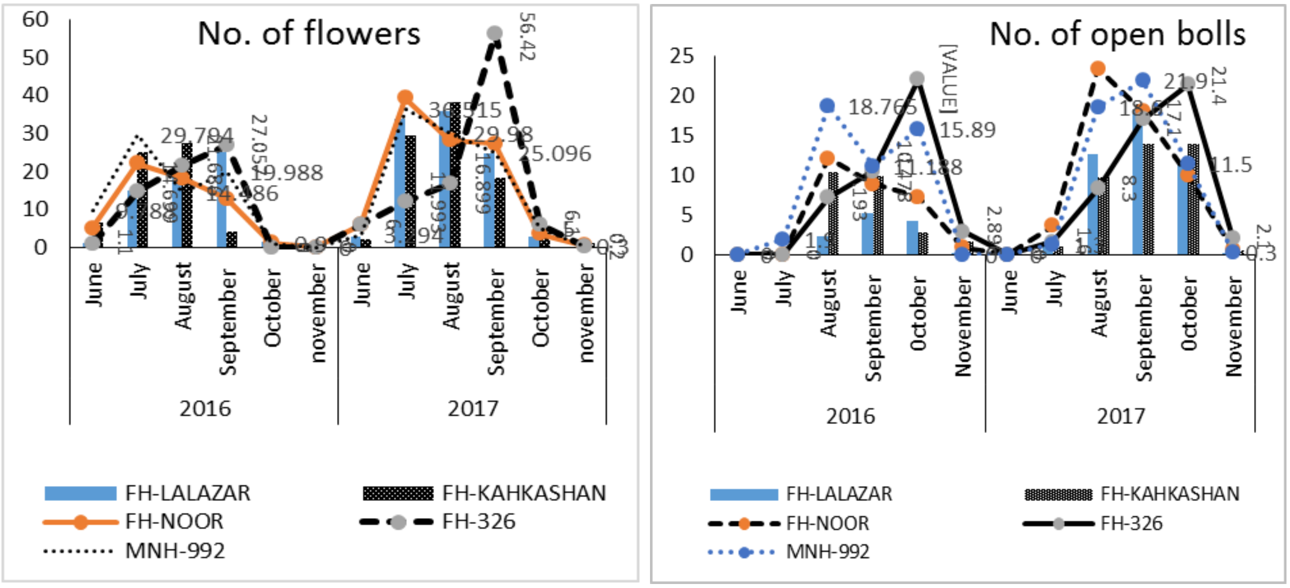

Figure 4. Number of flowers and bolls on selected cultivars of cotton during different months of 2016 and 2017

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

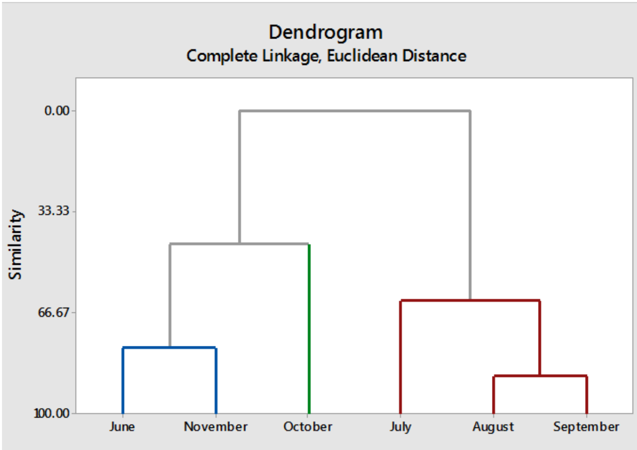

Figure 5. Cluster diagram showing similarity index of different months regarding effect of temperature on flower and bolls in cotton

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 as compared with July while 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 PC_1 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. PC_2 increases with increasing open bolls and number of flowers but decreases with minimum and maximum temperature. The correlation of 0.907% variation of this PC_2 is due to the open bolls. The entire remaining PC's contributed least variation as compared with PC_1 and PC_2 (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

Table 2. Principal component analysis for maximum, minimum, flower and bolls per plant

S. No	Eigen value	PC_1	PC_2	PC_3	PC_4
		2.5892	**1.0375**	**0.3582**	**0.0151**
1	Proportion of variation	0.647	0.259	0.090	0.004
2	Cumulative variation of PCs	0.647	0.907	0.996	1.000
3	Variables	Contribution of variables in PCs			
4	Maximum temperature	0.455	-0.348	0.451	-0.607
5	Minimum temperature	0.555	-0.431	-0.061	0.709
6	Flower	-0.516	0.328	-0.745	-0.269
7	Bolls	0.343	0.766	0.489	0.238

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 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.

REFERENCES

Aaliya K, Qamar Z, Ahmad NI, Ali Q, Munim FA and Husnain T. 2016. Transformation, evaluation of GT gene and multivariate genetic analysis for morpho-physiological and yield attributing traits in *Zea mays*. *Genetika,* 48(1): 423-433.

Abbas HG, Mahmood A and Ali Q. 2016. Zero tillage: a potential technology to improve cotton yield. *Genetika,* 48(2): 0534-0012.

Abid M, Scheffran J, Schneider U and Ashfaq M. 2015. Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. *Earth System Dynamics,* 6: 225-243.

Ahsan M, Farooq A, Khaliq I, Ali Q, Aslam M and Kashif M. 2013. Inheritance of various yield contributing traits in maize (*Zea mays* L.) at low moisture condition. *African Journal of Agricultural Research,* 8: 413 -420.

Ali Q, Ahsan M, Kanwal N, Ali F, Ali A, Ahmed W, Ishfaq M and Saleem M. 2016. Screening for drought tolerance: comparison of maize hybrids under water deficit condition. *Advancements in Life Sciences,* 3(2): 51-58.

Ali Q, Ali A, Ahsan M, Ali S, Khan NH, Muhammad S, Abbas HG, Nasir IA and Husnain T. 2014a. Line×Tester analysis for morpho-physiological traits of *Zea mays* L seedlings. *Advancements in Life sciences,* 1 (4): 242-253.

Ali Q, Ali A, Awan MF, Tariq M, Ali S, Samiullah TR, Azam S, Din S, Ahmad M, Sharif N, Muhammad S, Khan NH, Ahsan M, Nasir IA and Husnain T. 2014b. Combining ability analysis for various physiological, grain yield and quality traits of *Zea mays* L. *Life Science Journal,* 11(8s): 540-551.

Bibi A, Oosterhuis D and Gonias E. 2008. Photosynthesis, quantum yield of photosystem II and membrane leakage as affected by high temperatures in cotton genotypes. *Journal of Cotton Science*, 12:150-159.

Burke JJ, Velten J and Oliver MJ. 2004. *In vitro* analysis of cotton pollen germination. *Agronomy Journal,* 96(2): 359-368.

Butt TA, McCarl BA, Angerer J, Dyke PT and Stuth JW. 2005. The economic and food security implications of climate change in Mali. *Climatic change,* 68(3): 355-378.

Conaty W, Brodrick R, Mahan J and Payton P. 2015. Cotton: Climate and its interaction with cotton morphology. American Society of Agronomy, Inc., Crop Science Society of America, Inc., and Soil Science Society of America, Inc., 401-418 p.

Craufurd P, Prasad PV, Kakani V, Wheeler T and Nigam S. 2003. Heat tolerance in groundnut. *Field Crops Research,* 80(1): 63-77.

Cross R, McKay S, McHunghen AG, Bongam-Smith P. 2003. Heat-stress effects on reproduction and seed set in *Linum usitatissimum* L. (flax). *Plant, Cell and Environment,* 26: 1013-1020.

Farooqi AB, Khan AH and Mir H. 2005. Climate change perspective in Pakistan. *Pakistan Journal of Meteorology*, 2(3): 11-21.

Johnson DE. 1998. Applied multivariate methods for data analysts. Duxbury Resource Center, 592 p.

Kakani V, Prasad PV, Craufurd P and Wheeler T. 2002. Response of *in vitro* pollen germination and pollen tube growth of groundnut (*Arachis hypogaea* L.) genotypes to temperature. *Plant, Cell and Environment,* 25: 1651-1661.

Kakani V, Reddy K, Koti S, Wallace T, Prasad PV, Reddy V and Zhao D. 2005. Differences in in vitro pollen germination and pollen tube growth of cotton cultivars in response to high temperature. *Annals of Botany,* 96(1): 59-67.

Kaushal SS, Likens GE, Jaworski NA, Pace ML, Sides AM, Seekell D, Belt KT, Secor DH and

Wingate RL. 2010. Rising stream and river temperatures in the United States. *Frontiers in Ecology and the Environment,* 8(9): 461-466.

Loka D and Oosterhuis D. 2010. Effect of high night temperatures on cotton respiration, ATP levels and carbohydrate content. *Environmental and Experimental Botany,* 68(3): 258-263.

Lu Z, Percy RG, Qualset CO and Zeiger E. 1998. Stomatal conductance predicts yields in irrigated Pima cotton and bread wheat grown at high temperatures. *Journal of Experimental Botany*, 49: 453-460.

Puspito AN, Rao AQ, Hafeez MN, Iqbal MS, Bajwa KS, Ali Q, Rashid B, Abbas MA, Latif A, Shahid AA (2015) Transformation and Evaluation of Cry1Ac+ Cry2A and GT gene in *Gossypium hirsutum* L. *Frontiers in Plant Science,* **6**: 943.

Quddus SA. 1987. Pakistan from Khyber to Karachi. Islamic Book Center, 424 p.

Radin JW, Lu Z, Percy RG and Zeiger E. 1994. Genetic variability for stomatal conductance in Pima cotton and its relation to improvements of heat adaptation. *Proceedings of the National Academy of Sciences,* 91 (15): 7217-7221.

Rahman ur H, Malik SA and Saleem M. 2004. Heat tolerance of upland cotton during the fruiting stage evaluated using cellular membrane thermostability. *Field Crops Research,* 85(2-3): 149-158.

Reddy KR, Hodges HF and Kimball BA. 2000. Crop ecosystem responses to climatic change: Cotton. Climate change and global crop productivity. CAB Int., New York, 161-187.

Reddy KR, Hodges HF and McKinion JM. 1997. A comparison of scenarios for the effect of global climate change on cotton growth and yield. *Functional Plant Biology,* 24(6): 707-713.

Rodriguez-Garay B and Barrow JR. 1988. Pollen selection for heat tolerance in cotton. *Crop science,* 28 (5): 857-859.

Sajjad S, Hussain B, Khan MA, Raza A, Zaman B and Ahmed I. 2009. On rising temperature trends of Karachi in Pakistan. *Climatic change,* 96(4): 539-547.

Sawan ZM. 2012. Cotton (*Gossypium barbadense*) production as affected by climatic factors and soil moisture status. *Acta Ecologica Sinica,* 32(3): 123-137.

Sneath PHA Sokal RR and Freeman WH. 1975. Numerical taxonomy. The principles and practice of numerical classification. *Systematic Zoology*, 24(2): 263-268.

Stern N. 2006. What is the economics of climate change? World Economics-Henley on Thames-**7**, 1-10 p.

Young LW, Wilen RW and Bonham-Smith PC. 2004. High temperature stress of *Brassica napus* during flowering reduces micro and megagametophyte fertility, induces fruit abortion, and disrupts seed production. *Journal of Experimental Botany,* 55(396): 485-495.