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Original article

Micro-Climatic effect on Cotton Yield, quality, Bt toxin & GT Gene

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Abstract

Unsuitable change in climatic conditions cause decline in quality and yield of major crops. Plant growth is directly affected if temperature, rainfall or humidity are not optimum. A multi-location and multi season evaluation of climatic effects on quality and yield may produce a reliable data for future breeding. A set of 39 upcoming varieties of cotton were evaluated on six different Micro-climatic locations of Punjab i.e. Multan, Bahawalpur, Sahiwal, Rahimyar khan, Vehari and Faisalabad in a triplicated trial. The experiment was repeated next year on same locations. Data for three key environmental factors such as temperature, rainfall and humidity was recorded at each station. The crop was analyzed for yield, fiber length, fiber strength and fiber fineness. The genotypes were also evaluated for Bt toxin and Glyphosate tolerance gene (GTG). The analysis revealed that high temperature has negative effect on yield, Bt expression, fineness, uniformity and GTG. Precipitation and humidity had positive effect on fiber fineness and uniformity, whereas, negative effect of both environmental factors was recorded for fiber length and strength. Increase in precipitation at early cropping stage was associated with increase in yield whereas higher humidity has negative impact on yield. As compared to high average temperature and number of days above 400C, cotton yield is more sensitive to heat waves (maximum temperature). Varieties with high temperature tolerance in cotton should be breed for climate change scenario.

Keywords: Cotton, Climate Change, Gene Expression, Heat waves.

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INTRODUCTION

Climate change is adversely affecting our planet currently, resulting in heat waves, flooding, and droughts. These effects are not so visible quickly but over a period of time it results in increasing temperatures, sea level and changes in precipitation patterns. Climate is actually long term patterns of weather i.e. temperature, rainfall, and humidity. In late nineteenth century, changes in climate was obvious as a result of GHG's increasing concentrations (Weart 2004). Climate changes include changes in weather and occurrence of extreme events (US Natl. Res. Counc. 2016). In 1820 scientist understood the properties of certain gases and their ability to trap solar heat. Human activities like burning of fossil fuels (Coal and oil) has increased the level of carbon dioxide. Callendar's calculations suggested that doubling of carbon in earth atmosphere could warm earth by 2 degrees (3.6 ºF). Global climate change is becoming a serious threat to agriculture (Howden et al., 2007).

Agriculture mainly depends on climate, and varying climatic conditions are expected to have negative effects on agricultural productivity. According to IPCC 2014, agriculture industry is highly affected by climate change. Increasing global temperature is destroying agriculture. It will not only effect the production of agriculture commodities but also disturbs the economic steadiness affecting the supply and demand balance of agriculture commodities, profitability, trade and prices of these commodities (Kaiser and Drennen, 1993). Pakistan's agriculture sector is suffering from climate change and food security. These changes have negative effects on crops in Pakistan, especially in arid to semi-arid regions (IPCC, 2013, Abbas et al., 2017).

Cotton growth and productivity is negatively affected by increasing temperature and change in precipitation (Bange and Milroy, 2004; Gwimbi and Mundoga, 2010). It is most valuable cash crop providing raw material for a number of industries. It accounts more than 50% employment of industrial labor and over 60% of total exports (Abbas and Waheed 2017). It is a key fiber crop of tropical and subtropical regions. The temperature regime during the month of August, corresponding to peak flowering, is significantly associated with cotton yield. In cotton, for example, the production of successive nodes on the main stem and the time interval between the production of successive flowers on the successive fruiting branches on the main stem and between the first two flowers on the same fruiting branch is temperature dependent (Hesketh et al., 1972). Brown et al. (2003) proposed that environmental stresses, particularly water deficit, and temperature stress were mainly responsible for year-to-year variability in cotton yield. When temperature is below the optimum for net photosynthesis, a small increase in temperature can stimulate crop growth. The converse is true when temperature is near the maximum for yield. A small increase in temperature can dramatically reduce yield.

Cotton is extremely sensitive to changes in its environment. A slight modification to cotton's ideal growing environment might have a significant effect and irreparable growth harm, lowering economic output (Reddy et al., 1992). The optimum temperature range for the cotton development is 27-28 ºC at this point, several enzymes become inactive and reduce the cotton ability to photosynthesize (Cottee et al., 2010). The sudden rises in temperatures along with other climatic factors are leading to serious threats to cotton production worldwide (Yousaf et al., 2023). Temperatures over 36°C are harmful to growth and development, especially during fruiting, whereas temperatures over 20°C for 170 days are appropriate and have a good impact on cotton phenology (Baloch et al., 2000). The emergence of seedlings, plant population per acre, vegetative development, and fruiting of crops are all negatively impacted by high temperatures (Rahman et al., 2004). High temperature stresses during reproductive stages of cotton causes major yield losses (Mercado Álvarez et al., 2022). High temperatures reduce the relative water content, fresh weight, and dry weight of plant subterranean and aerial components (Huang et al., 2021). High temperatures cause cotton to produce less because the pollen is sterile, the flowers and bolls shed, and the fruit does not set as well. The irregular fluctuation in climate and temperature is the cause of the average temperature's ongoing increase (Rahman et al., 2018).

Cotton is widely used to study the impacts of Bt genes for heat tolerance as it faces temperature peaks during growth season (Zhang et al., 2018). Bt protein levels fluctuates in cotton crop during growth season due to rising temperatures (Kranthi et al., 2005). It is noted that Bt insecticidal protein levels in cotton leaves, squares (early flower buds), and cotton bolls are lower at temperatures in the range of 32°C–40°C than they are at 25°C–32°C (Zhang et al., 2018). These variations in Bt insecticidal protein levels are due to temperature fluctuations throughout the growing season. At temperatures above 38°C, cotton bolls and squares appear to lose their Bt insecticidal protein quickly (Wang et al., 2015). Similarly high temperature can reduce the efficiency of glyphosate tolerant gene.

Climate change impact assessment studies offer a means of quantifying uncertainties related to climate risks, and provide decision-support for more sustainable crop production. A lot of studies (Schlenker and Roberts, 2009; Schlenker and Lobell, 2010; Welch et al., 2010; Chen et al., 2016; Gammans et al., 2017) concluded climate change is crucial for crops having low adaptability. To avoid destructive effects of climate change, breeding approaches to develop heat stress bearing abilities in crop pants can be useful. A detailed knowledge of plants response mechanisms to heat, physiological responses in plants and possible improving strategies is important. Developing thermo stability in plants is useful for to structural and functional maintenance in plants to avoid environmental extremes. So breeding for genotypes capable of bearing high temperatures is among main objectives of crop improvements. Punjab is an agricultural state of Pakistan. It comprises different climatic zones. The effect of climatic factors in all zones should be identified for future cultivar development. The average temperature, rainfall and humidity is different in all zones. There is a need to identify importance of environmental factors on cotton yield and quality. The current project involves two season data to make reliable hypothesis.

MATERIALS AND METHODS

Experimental Material

A set of 39 cotton genotypes (Table 1) submitted to Pakistan Central Cotton Committee (PCCC) for National Coordinated Varietal Trail (NCVT) were grown at six different locations of Punjab i.e. CRS Multan, CRS Faisalabad, CRS Sahiwal, CRS Vehari, CRS Bahawalpur, and CRS Rahim Yar Khan in triplicated randomized complete block design(RCBD) during the year 2019 and 2020. Plant to plant distance was kept 23cm and row to row distance was 75cm. Seed were sown manually and seed depth was kept 5cm at beds. Herbicides and insecticides were applied at proper time. First irrigation after sowing was given after 4 days, second, third, and fourth irrigation were at 7 days interval, and rest of irrigations were applied when required. In total 14 irrigations were applied to the crop. Recommended fertilizer was applied to crop i.e. 95kg K20, 75kg P2O5, and 100kg N/h. The experiment was repeated next year using same 39 genotypes on same six locations. The environmental factors such as temperature (^{O}C), humidity (%) and precipitation (mm) was recorded on daily basis very carefully.

Table 1. List of genotypes used in experiment

Sr. No.	Genotypes	Origin	Sr. No.	Genotypes	Origin
1	**ASLP-709**	Australian Sector Linkages Program	21	**IR-NIBGE-15**	NIBGE, Faisalabad
2	**ASPL-710**	Australian Sector Linkages Program	22	**MNH-1050**	Cotton Research Institute, Multan
3	**BH-224**	Cotton Research Station Bahawalpur	23	**NIA-88**	NIA, Tandojam
4	**CIM-602**	Central Cotton Research Institute Sakrand	24	**NIA-89**	NIA, Tandojam
5	**CIM-775**	Central Cotton Research Institute Multan	25	**NIAB-512**	NIAB, Faisalabad
6	**CIM-785**	Central Cotton Research Institute Multan	26	**RH-Afnan-II**	Cotton Research Institute, Khanpur
7	**CKC-5**	CEMB, Lahore	27	**Rohi-2**	Rohi Seeds Corporation, Rajanpur
8	**CKC-6**	CEMB, Lahore	28	**Rustam-11**	Jullundur Seeds Corporation, Rahim Yar Khan
9	**CRIS-638**	Central Cotton Research Institute Sakrand	29	**Sahara-300**	Patron Seeds Corporation Multan
10	**CRIS-644**	Central Cotton Research Institute Sakrand	30	**Sahara-Klean-5**	Patron Seeds Corporation Multan
11	**Cyto-226**	Central Cotton Research Institute Multan	31	**Saim-102**	Auriga Seed Corporation Lahore
12	**Diamond-2**	Suncrop Seeds Corporation, Multan	32	**Sayban-209**	Auriga Seed Corporation Lahore
13	**Eagle-4**	Four Brothers Seed Corporation Multan	33	**SLH-33**	Cotton Research Station Sahiwal
14	**Eye-22**	Kanzo Seed Corporation Multan	34	**Suncrop-3**	Suncrop Seeds Corporation, Multan
15	**FH-492**	Cotton Research Station Faisalabad	35	**Tahafuz-15**	Suncrop Seeds Corporation, Multan
16	**FH-Anmol**	Cotton Research Station Faisalabad	36	**WEAL-AG-201**	Weal-Ag Seeds Corporation, Multan
17	**Ghauri-2**	Four Brothers Seed Corporation Multan	37	**WEAL-AG-CKC-301**	Weal-Ag Seeds Corporation, Multan
18	**GH-Himalaya**	Cotton Research Station Ghotki	38	**YBG-2222**	Yunus Brothers Group
19	**GH-Sultan**	Cotton Research Station Ghotki	39	**YBG-2323**	Yunus Brothers Group
20	**IR-NIBGE-14**	NIBGE, Faisalabad			

Data Recording

Climatic factors i.e. Temperature (ºC), Relative humidity (%) and Precipitation (mm) were recorded for all said locations on daily basis. Yield of all genotypes was recorded from all locations in

Kg/ha at the time of maturity. Fiber traits i.e. Length (mm), Strength (g/tex), Fineness (µg/inch) and uniformity (%) was analyzed for all genotypes using High Volume Instrument (HVI). Bt toxin protein and Glyphosate Tolerance Gene protein was checked using ELISA protocol. Enzyme-linked immunosorbent assays (ELISAs) are plate-based assays for detecting and quantifying a specific protein in a complex mixture. The detection and quantification of target-specific protein in a sandwich ELISA is accomplished by using highly specific antibodies that immobilizes the target protein (antigen) to the plate and indirectly detects the presence of the target protein.

Statistical Analysis

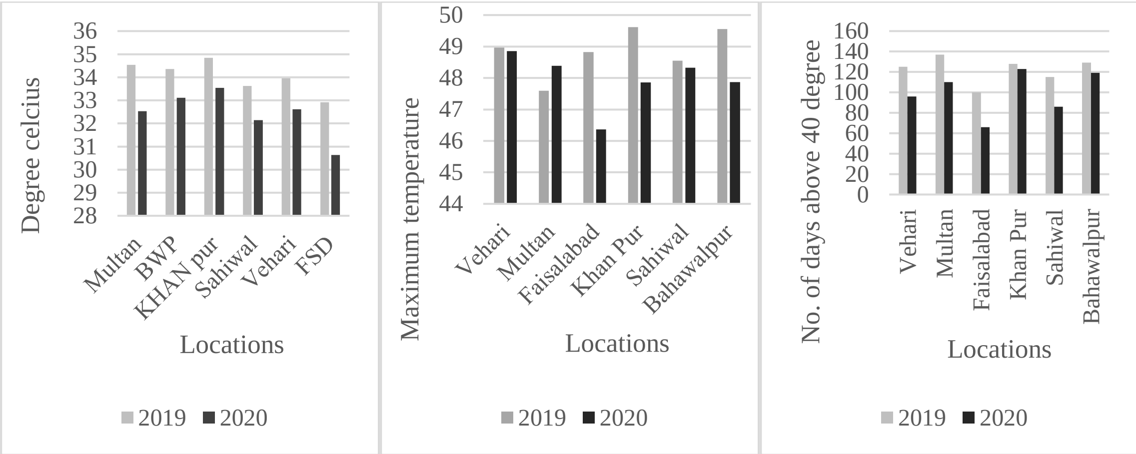
Analysis of variation (ANOVA) was recorded for all the traits under study as by (Steel et al., 1986). And correlation was calculated for the all traits to check the association among the traits as used by (Dewey and Lu 1959) to check association among the traits.

RESULTS and DISCUSSIONS

Analysis of variance showed yield, fiber length, strength, uniformity, fineness GTG, Bt content; all were significant. Correlation analysis showed that yield is positively associated with minimum temperature and negatively associated with maximum temperature. The Bt-toxin expression was found negatively associated with all three temperature regimes i.e. maximum temperature, minimum temperature and average temperature, and positively associated with relative humidity and precipitation. A negative correlation was found between Bt-toxin and yield. In case of fiber traits, fiber length was positively associated with fiber strength and negatively associated with fiber fineness.

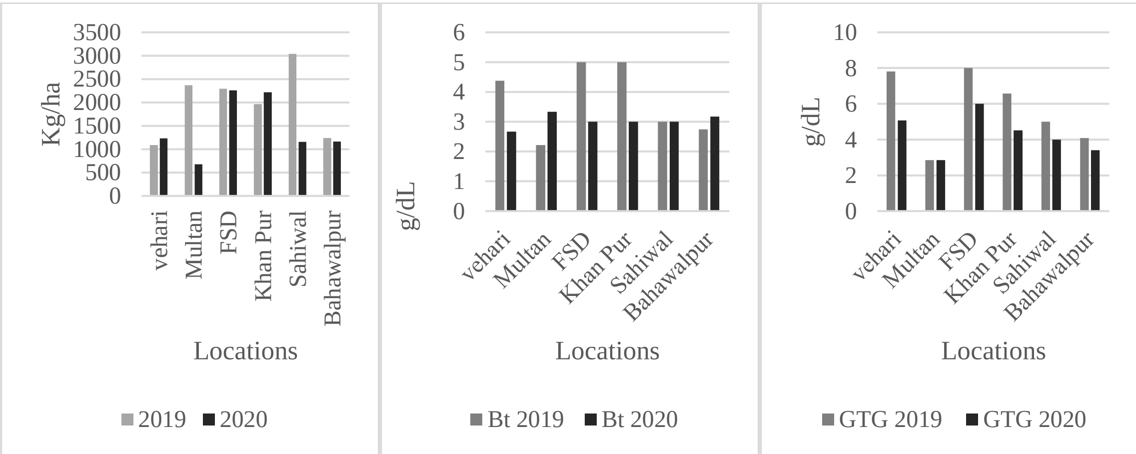
Table 2. Correlation Analysis among yield, Bt-content (Bt), GTG-content (GTG), Fiber length (FL), strength(FS), fineness (FF), uniformity (FU), average temperature (Av. T), maximum temperature (Mx. T), minimum temperature (Mn. T), relative humidity (RH) and precipitation (Prec).

	Yield	Bt	GTG	FL	FF	FS	FU	Av. T	Mx. T	Mn. T	RH	Prec
Yield	**1**											
Bt	**-0.14**	**1**										
GTG	-0.02	**0.10**	**1**									
FL	-0.04	-0.03	0.05	**1**								
FF	-0.05	0.07	-0.02	**-0.10**	**1**							
FS	-0.04	-0.00	0.00	**0.29**	-0.04	**1**						
FU	-0.03	0.04	0.08	0.00	0.06	0.00	**1**					
Av. T	0.03	**-0.24**	-0.01	0.04	-0.06	0.00	-0.03	**1**				
Mx. T	**-0.09**	**-0.14**	-0.01	0.02	-0.03	0.00	-0.01	**0.96**	**1**			
Mn. T	**0.09**	**-0.28**	-0.02	0.05	-0.07	0.00	-0.03	**0.99**	**0.92**	**1**		
RH	-0.01	**0.26**	0.02	-0.05	0.06	-0.01	0.04	**-0.97**	**-0.93**	**-0.96**	**1**	
Prec	0.06	**0.21**	0.02	-0.04	0.05	-0.01	0.03	**-0.98**	**-0.97**	**-0.94**	**0.98**	**1**



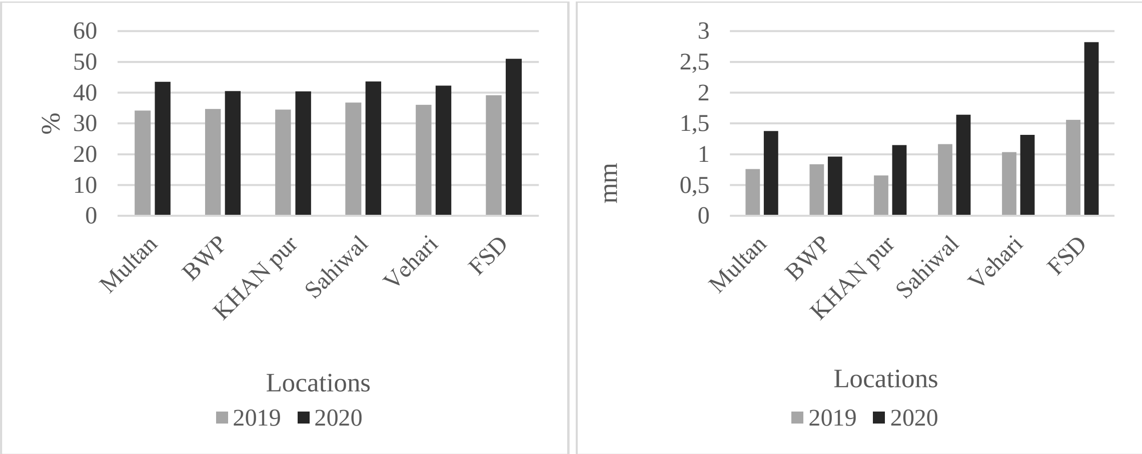
Average daily temperature Maximum temperature No. of days Above 40ºC

Figure 1. Average temperature, maximum temperature, and number of days above 40 ^{O}C at six locations for both seasons



Average yield (kg/ha) ` Average Bt-toxin Average GTG-content

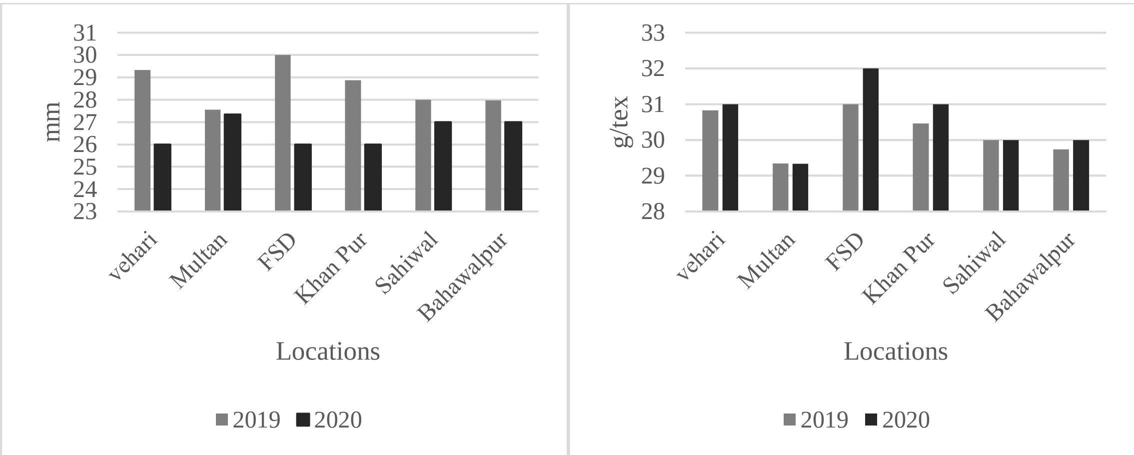
Figure 2. Average yield, Average Bt-toxin, and Average GTG-content at six locations for both seasons



Average daily relative humidity

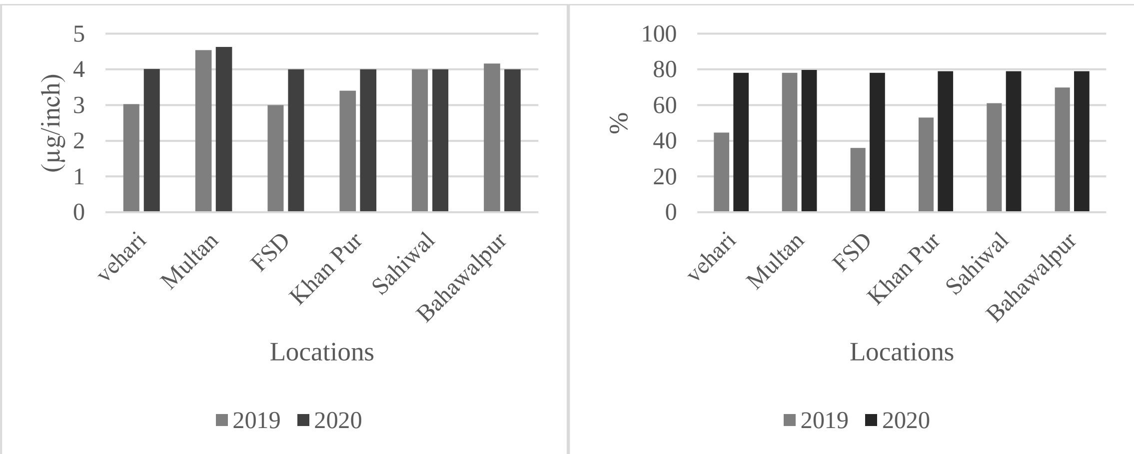
Average daily precipitation

Figure 3. Average daily relative humidity and Average daily precipitation at all six locations for both seasons



Fiber Length

Fiber Strength



Fineness

Uniformity

Figure 4. Fiber length, Fiber strength, Fiber fineness, Fiber uniformity at all six location for both years

The interaction of genetic makeup of plant and environment mainly determines yield and fiber quality in cotton crop. Temperature is the major factor which mainly affects the quality and yield of cotton. Among climatic conditions, sudden rise in temperature affects badly to the cotton yield. In this study; average temperature effects, effect of most number of days above 40 oC and effect of maximum temperature (sudden change in temperature) is analyzed. The results indicate that the peak temperature for a few days is more destructive to the cotton yield as compared to average rise in temperature or high number of days above 40 OC. Heat waves cause shedding of flowers reducing bolls per plant and ultimately lead to reduction in yield (Zhao et al. 2005; Snider et al. 2010; Iqbal et al. 2017). Pakistan cotton faces high temperature in growing season that reaches upto 50 oC which is 20 oC above than the optimum temperature (Mohamed and Abdel-Hamid 2013). It is maximum among all cotton growing countries of the world. High temperature is also the most devastating as compared to unfavorable humidity and precipitation. The study suggests to improve cultivars with heat shock genes which could resist sudden change in temperature. High temperature affects fiber strength of cotton. The cellulose production increase in different plant due to genetic and temperature stress may change rate of attractive cellulose along with reducing fiber strength (Zeng and Pettigrew, 2015). The value of micronaire is reduced when the night temperature below 25 ^{o}C. Rain fall, humidity and temperature change seed and growth of fiber. During fiber growth and anthesis, when variation of temperature has been concerned in changes in fiber quality. Raising temperature in first 50 days keep bad effect and 100 to 150 days after sowing showed better results on fiber maturity (Saleem et-al, 2010). The fiber growth and collection parameters like sucrose, cellulose and callose play important role in fiber quality of cotton (Wenqing et-al, 2012). Mendez-Natera et al. (2012) found fiber strength and cotton yield were negatively correlated. Asif et al. (2008) and Karadimer et al. (2010) observed staple length had negative relation with seed cotton yield, strength and fineness. In current studies length was found negatively correlated with uniformity and positively associated with fiber strength.

There was a strong negative correlation between high temperature and cotton yield in Arkansas (Oosterhuis, 2002). Similar results were recorded in this study that a sudden rise in temperature resulted in yield losses. Gipson and Joham (1969) and Gipson and Ray (1969) demonstrated that initial stages of fiber elongation were highly sensitive to high night temperatures, whereas the later stages appeared to be less sensitive to temperature. Hesketh and Low (1968) found that among fiber characters the greatest effect was an increase in fiber strength with increased temperature, along with reduced ginning percentage; however, changes in fiber length and micronaire were less consistent. Average high temperature, number of days above 40^{O}C as well as maximum temperature affects quantity of Bt toxin. As a result pest may break the resistance in genetically modified cotton. High temperature affects growth and Bt toxin, which ultimately affects yield.

Conclusion

Cotton crop growth is more sensitive to heat waves as compared all other climatic factors. High temperature also affects Bt toxin level in genetically modified cotton. Cultivars which could resist sudden rise in temperature should be breed for high yield under current climatic condition.

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Original article

Effect of Fertilizing Method, Silt Soil, and Application of Effective Microorganism on Growth and Yield of Tomato (*Lycopersicon esculentum*) in a Greenhouse

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Abstract

The experiment was conducted on a private farm at Northern Elselait Scheme, Khartoum State, Sudan to study the effect of fertilization method, soil type, and microorganism application on the growth and yield of tomatoes crop op under greenhouse conditions. Silt soil and two types of fertilizing units (injector and by-pass) were used for applying effective microorganisms (EM) in two levels (0 and 12 L/ha), at fortnight intervals after 45 days to 90 days from planting. A split-plot design was used with three replications. The data collected were: plant height, number of leaves, stem diameter, number of flowers, number of fruits, and weight of fruits per plant. . The production indicators showed that tomato crop agronomic parameters were significantly ($P \leqslant 0.05$) affected by the method of fertigation and application of effective microorganisms. A mean yield of 5.4 tons per hectare of plants grown on silt soil and fertilized with effective microorganisms (EM) using an injector fertilizing unit, when fertilization was done by a by-pass fertilizer system applying effective microorganisms (EM) gave a yield of 4.6 ton/ha and yield ton per hectare of silt soil fertilized by injector fertilizer with non-applied effective microorganisms (EM0) was 7.3 ton/ha, while with silt soil fertilized by a by-pass fertilizer unit with non-applied effective microorganisms (EM0) it was 5.5 ton/ha.

Keywords: Silt soil, Effective microorganisms, Tomato, and fertilization method.

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