International Journal of Botany Studies
ISSN: 2455-541X; Impact Factor: RJIF 5.12
Received: 05-02-2019; Accepted: 07-03-2019
www.botanyjournals.com
Volume 4; Issue 3; May 2019; Page No. 145-152

Population dynamics of sucking pests in liaison with transgenic Bt. v/s non-Bt. cotton varieties (*Gossypium hirsutum* L.), at innumerable temperature & relative humidity

Syed Ahtisham Masood[1], Muhammad Mazhar Saleem[2], Syed Burhan UD Din[3], Muhammad Yasin[4], Shahbaz Ahmad[5], Said Salman[6], Qurban Ali[7*]

[1, 3] Cotton Research Station, Khanpur, Rahim Yar Khan, Pakistan
[2] Pest warning & Quality Control of Pesticides, Rahim Yar Khan, Pakistan
[3] Department of Plant Breeding & Genetics, University of Agriculture Faisalabad, Pakistan
[4] Institute of Agricultural Sciences, University of the Punjab Lahore, Lahore, Pakistan
[5] Department of Plant Breeding and Genetics, Gomal University, Dera Ismail Khan, Pakistan
[6] Institute of Molecualr Biology and Biotechnology, University of Lahore, Lahore, Pakistan

Abstract
Cotton with diversified charisma to thrive in far-reaching agro-climatic zones, export value, multiple by products and stake in domestic earning is factual white gold to Pakistan. Predominantly whitefly (*Trialeurodes vaporariorum/ Bemisia tabaci)*, jassid (*Amrasca devastans*) and thrips (*Thrips tabaci)* are distressing the seed-cotton production in Pakistan. So, Contemporary study was premeditated to climax the population subtleties of listed sucking pests on Bt v/s non-Bt varieties at different episodes of temperature and relative humidity. Data on insect population from three fully stretched leaves from top, middle and bottom portions of single plant each, in dawn and ecological factors were documented for fifteen consecutive weeks from physiology department. Results established that population of whitefly and jassid was more on Bt varieties (transgenic) as compared to Non-Bt (non-transgenic) cotton varieties but it was almost same for thrips. Temperature and relative humidity were positively associated with whitefly, jassid and thrips population, whereas relative humidity was negatively correlated. Further, Maximum population of whitefly was recorded on V4 (FH-113) and the minimum population was on V3 (FH-154). Maximum population of jassid was noted on V2 (FH-1000) and the minimum population on V1 (CIM-496). Whereas, maximum population of thrips was recorded on V1 (CIM-496) and the minimum was on V5 (FH-114).

Keywords: Relative humidity, sucking insect pests, *Amrasca devastans*, *Thrips tabaci*, *Bemisia tabaci*, Population dynamics, Correlation

Introduction
Agriculture is the very imperative segment of Pakistan economy with 18.9 (%) share to GDP and engross 42.3 (%) of labor force. Cotton is major non-food Kharif, cash crop in Pakistan and a key source of raw material to textile industry. Fiscal year; 2017-18, cotton production mounted to 11.94 (million bales) with a boast of 11.8 (%) as compared to 10.7 (million bales) during fiscal year; 2016-17. Its share to GDP persisted to 1.0 (%) and agricultural value addition chronicled 5.5 (%) during the same period. Cotton crop witnessed 8.4 (%) increase in cultivated area of 2,699 (1000-hectares) against area of 2,489 (1000-hectares) over previous year in Pakistan. The production increased due to wholesome effect of cotton-promotional campaign, subsidized inputs availability, low population of sucking insects and better econ return (Pakistan Economic Survey, 2017-18) [43].

In developing country like Pakistan seed-cotton yield is far below that of technically sound developed cotton producing countries like Australia, China, USA and Brazil. Pakistan Bureau of Statistics reported that average cotton yield declined from 802 (Kgs/Hec.) in 2014-15 to 752 (Kgs/Hec.) in 2017-18. Poor quality, non-registered seed, water shortage, inclining input rates and hence increase in insect pest situation are major culprits behind such decline in overall production & average yield. So, there is unceasing need to improve per-hectare seed-Cotton yield due to the worth of cotton crop (USDA, 2016) [59]. Sinking cotton production is outcome of multiple biotic and abiotic factors of which crop damages at various physiological growth stages by sucking insect pests are highlights (Gaurkhede *et al*., 2015) [25]. There are many kinds of pest/insect which affect cotton production. Besides, with injudicious uses of pesticides, pest/insect compounds have profoundly changed and many minor pests became main pests of cotton. In Pakistan mites, American Bollworm and Aphids were not unique pests of cotton but they flared-up as a consequence of indiscriminate and large-scale arbitrary practices of pesticides. Overall, cotton cultivation needs high uses of irrigation, systematization and agro-chemicals that lead to a high prospective of negative ecological impacts. Further, futile uses of fertilizers add to water pollution and greenhouse effects.

Among sucking insect pests in Pakistan predominantly whitefly, jassid and thrips cause significant yield reduction (Aslam *et al*., 2004; Amjad and Aheer, 2007) [18, 13]. Even, prevailing weather during crop season especially relative humidity, temperature and rainfall have mammoth impact on incidence and development of sucking pests in ecosystem (Anonymous, 2013). Foremost sucking insect

pests designated as key pests causing most of the damage to the cotton crop are whitefly; Bemisia tabaci (Genn.), thrips; Thrips tabaci (Lind.) jassid; Amrasca devastans (Dist.) and aphid; Aphis gossypii (Glov.). Whitefly sucks the cell sap, damages the plant ensuing in 50% decline in boll-production (Ahmad *et al*., 2002) and also frightening our cotton-based economy by acting as vector to induce Cotton leaf curl virus disease (CLCuV) (Nelson *et al*., 1998). Jassid is another detrimental pest of cotton in Pakistan. A variety of techniques most noticeable the resistant varieties can play extensive role to reduce the crop damage (Diouf *et al*., 2011). Among sucking insect pest on cotton, Thrips tabaci is the most significant early-season pest (Wilson and Bauer, 1993). Temperature and relative humidity have positive association with thrips population on cotton (Li *et al*., 1992; Shah, 2003). Panickar and Patel (2001) revealed the effect of weather factors on the activity of thrips and concluded that the activity of T. tabaci on cotton leaves started from second week of August and continued until first week of January and had positive correlation with wind and average temperature. Bai *et al*., (2002) reported that the population of sucking insect pests was more in transgenic cotton varieties (Bt.) as compared to conventional ones. Shah (2003) in his studies found that highest population of whitefly occurred on variety FH-901 in the month of July and lowest on the varieties in the months of October and November with positively and negative correlation with temperature & relative humidity respectively. Likewise, jassid population was maximum for variety NIAB-Karishma during second week of July and minimum on CIM-499 & NK-2002 in the months of September and November. Thrips population did not have significant effect on relative humidity instead relative humidity and whitefly had significant positive association. Whereas, difference among Bt and non-Bt cotton for jassid, whitefly and thrips outbreak was insignificant (Arshad and Suhail, 2010). Additional, high temperature displayed noteworthy encouraging effect on all the sucking pests (Shivanna *et al*. (2011).

Hence, the objective of present study was to draft the population dynamics of common sucking pest in relation to environmental fluctuations e.g. temperature & relative humidity in Pakistan with their resultant impression on Bt. & non-Bt. varieties, comparatively.

Material and Methods

Tentative study area and design

The field experiment was carried out in the research area of Agriculture department, Rahim yar Khan, Pakistan during the cotton season 2017-18. The experimental field was designed in a Randomized Complete Block Design (RCBD) with three replications of each experimental plot having five varieties in each plot. Each replicated plot had an area of 25 × 10 feet. To avoid the influence of treatments on insect population in neighbouring plots, an area of 3 feet was left vacant (Men *et al*., 2003). The experimental plots were planted in the 2nd week of May i.e. 11th may 2017. All the agronomic practices for the treatments in the experimental fields remained same. The treatments include 3 transgenic Bt. (FH-113, FH-114 and FH-154) and 2 Non-Bt. varieties (FH-1000 and CIM-496).

Plant inspection

The inspection of cotton crop was carried out on weekly basis. Examination of crop started from seedling emergence and continued till the harvesting. The plant examination method was used for sampling and the populations of three major target sucking pests (whitefly, jassid and thrips) were recorded early in the morning at weekly interval from 15 leaves of 15 plants selected randomly from each plot. The sampling was done from the 1st leaf from upper portion of the 1st plant, the 2nd leaf from middle portion of the 2nd plant and the 3rd leaf from bottom portion of the 3rd plant and so on (Sohail *et al*., 2003; Amjad and Aheer, 2007, Diouf *et al*., 2011) [13].

Meteorological data

Meteorological data about temperature and relative humidity was obtained from crop reporting department and extension wing, Rahimyar Khan, Pakistan.

Statistical analysis

Data were analyzed by using analysis of variance (Steel *et al*., 1997) [57] and correlation was estimated by using Kwon and Torre (1964) technique. Data regarding analysis of variance, LSD of overall mean population, per week population of whitefly on different cotton varieties and correlation of environmental factors and population of sucking pests has been analyzed using Statistix 9.

Results and Discussion

Whitefly population Comparison between Bt. and Non-Bt. Varieties of Cotton

Overall comparison of Whitefly population means of three Bt. and two Non-Bt varieties of cotton is shown in Figure 1. This indicates that population of whitefly was more on Bt. varieties (3.1/per leaf) as compared to Non-Bt varieties (2.66/per leaf). Overall mean population of whitefly on different transgenic and traditional cultivars of cotton has been shown in Figure 2.

Jassid population Comparison between Bt. and Non-Bt. Varieties of Cotton

Overall comparison of Jassid population means of three BT and two Non-BT varieties of cotton is shown in Figure 1a. This indicates that population of jassid was more on BT varieties (1.99/per leaf) as compared to Non-Bt varieties (1.94/per leaf). Overall mean population of jassid on different transgenic and traditional cultivars of cotton has been shown in Figure 2a.

Thrips population Comparison between Bt. and Non- Bt. Varieties of Cotton

As far as, overall comparison of thrips population means of three Bt and two Non-Bt varieties of cotton is shown in Figure 1b. This indicates that population of thrips was more on non-BT varieties (4.62/per leaf) as compared to Bt. varieties (4.22/per leaf). Overall mean population of thrips on different transgenic and traditional cultivars of cotton has been shown in Figure 2b. These comparison consequences are in agreement with Naveen *et al*. (2007) [40], Men *et al*. (2005) [37] who reported that higher population of aphid, jassid and whitefly in Bt. cotton as compared to conventional cotton. Population of jassid, thrips and whitefly was low on Bt. cotton as compared to conventional cotton varieties are in agreement with consequences of Whitehouse *et al*. (2005) [61] whereas most of the studies showed that sucking pests were found in equal abundance in Bt and non-Bt cotton varieties Sisterson *et al*. (2004) [56],

Bambawale *et al*. (2004) [21], Abro *et al*. (2004) [4], Sharma and Pampapathy, (2006) [53]. However the results of present research show high population of sucking pests on Bt. cotton varieties which may be due to varietal response and favorable environmental condition toward sucking pest.

Population Trend of whitefly

Mean population of whitefly on different transgenic and traditional varieties of cotton as per week is shown in Figure 2. Population recorded on different dates as shown in Figure 3 indicated that it started increasing from the first week of July to mid of July, the highest one is in the mid of July which is the first population peak. Then the population decreased continuously from the mid of July to the mid of August. Then the population of whitefly started increasing from end of August to third week of September from, the third week of September shows second population peak of whitefly. The mean whitefly population per leaf was lower during last week of August to all three weeks of September.

Population Trend of Jassid

Mean population of jassid on different transgenic and traditional varieties of cotton as per week is shown in Figure 2a. Population recorded on different dates as shown in Figure 3a indicated that it started increasing from the first week of July to mid of July, the highest one is in the mid of July which is the first population peak. Then the population decreased continuously from the mid of July to the mid of August. Followed by an increase in the population of jassid that started increasing from August to third week of September and then from the third week of September it showed second population peak.

Population Trend of Thrips

Mean population of thrips on different transgenic and traditional varieties of cotton as per week is shown in Figure 2b. Population recorded on different dates as shown in Figure 3b indicated that it started increasing from the first week of July to mid of July, the highest one is in the end of July which is the first population peak. Then the population decreased continuously from the end of July to the mid of August. These results are parallel to that of Khan and Ullah (1994) [33]. Gupta *et al*. (1997) [26] Joginder *et al*. (1998) [32] and Inee-Gogoi *et al*. (2000) [29] who studied that population of sucking pest high in mid of July and last week of August.

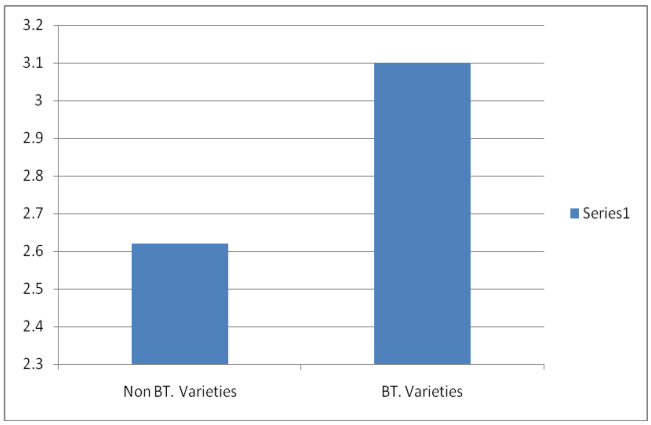

Fig 1: Overall comparison of whitefly population means of three Bt. and two non-Bt. Varieties of cotton.

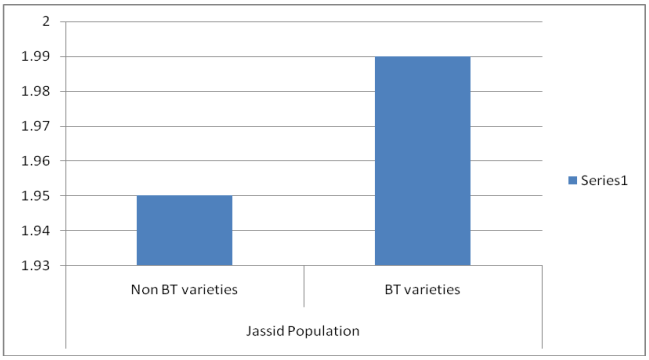

Fig 1a: Overall comparison of Jassid population means of three Bt. and two Non- Bt. Varieties of cotton

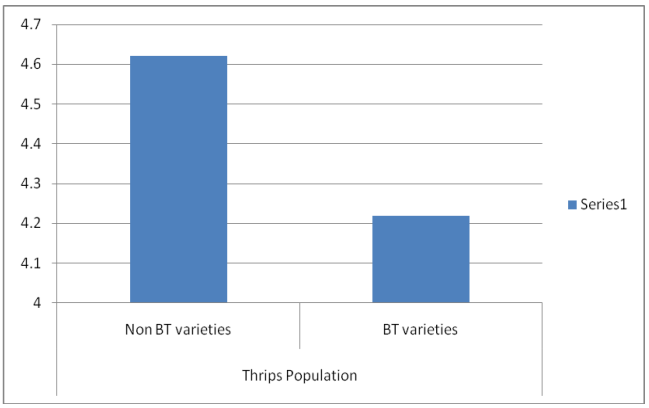

Fig 1b: Overall comparison of Thrips population means of three Bt. and two Non- Bt. Varieties of cotton.

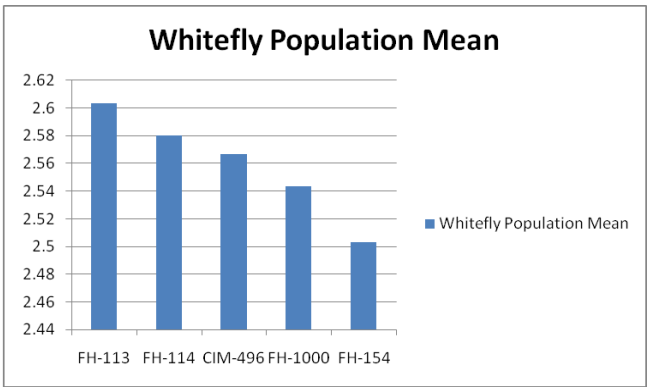

Fig 2: Overall mean population of whitefly on different transgenic and traditional varieties of cotton under unsprayed conditions recorded from 23rd June, 2017 to 29th September, 2017

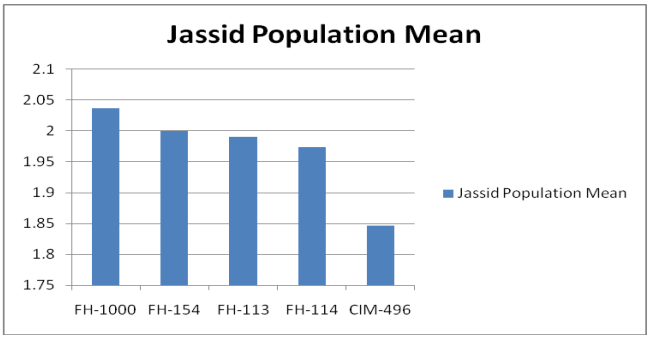

Fig 2a: Overall mean population of Jassid on different transgenic and traditional varieties of cotton under unsprayed conditions recorded from 23rdJune, 2017 to 29th September, 2017

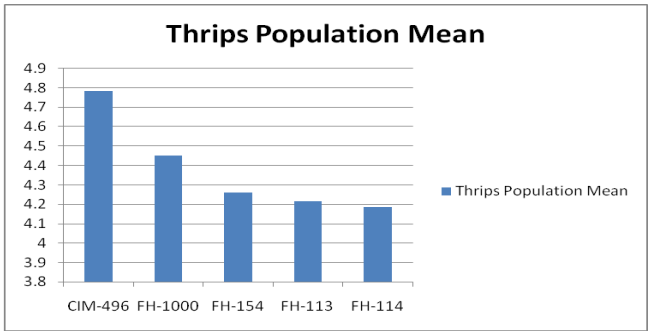

Fig 2b: Overall mean population of Thrips on different transgenic and traditional varieties of cotton under unsprayed conditions recorded from 23rd June, 2017 to 29th September, 2017

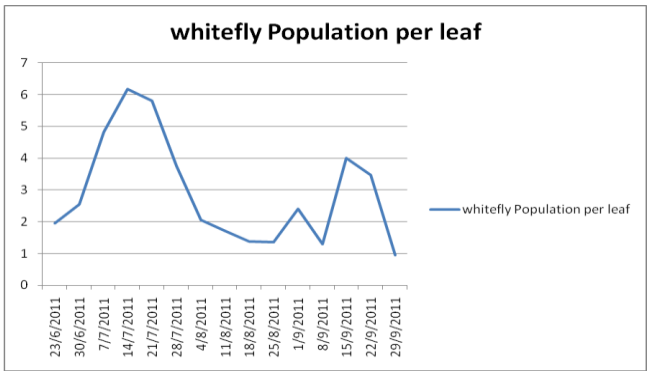

Fig 3: Per Leaf whitefly population on different transgenic and traditional Conditions recorded from 23rd June, 2017 to 29th September, 2017

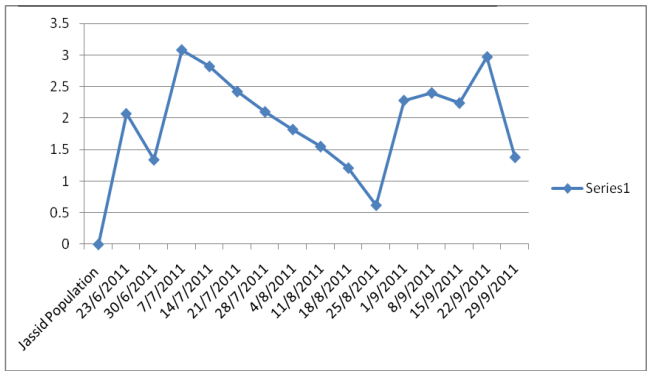

Fig 3a: Per leaf jassid population on different transgenic and traditional varieties of cotton under un-sprayed conditions recorded from 23rd June, 2017 to 29th September, 2017

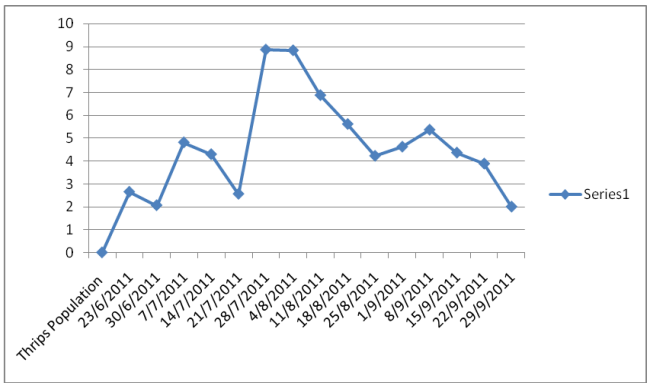

Fig 3b: Per leaf thrips population on different transgenic and traditional varieties of cotton under unsprayed conditions recorded from 23rd June, 2017 to 29th September, 2017 at Research area of Agriculture department Rahimyar Khan (Punjab), Pakistan.

Correlation of weather factors and whitefly population on different varieties of cotton under unsprayed conditions:

Correlation of weather factors and whitefly population showed that there was a positive correlation between temperature and whitefly population as shown in Figure 4, whereas relative humidity was negatively correlated with whitefly population (Figure 5). These findings are in concurrence with those of Avidov (1956) [19], Kumawant *et al*. (2000) [34], who reported that whitefly population is positively correlated with temperature. Similarly Jagdev and Butter (1988) [30], Ali *et al*., (2016) [1-3, 11, 48-49], Rote and Puri (1991) [50], Rao and Chari (1992) [46], Wahla *et al*. (1996), Murugan and Uthamasamy (2001), and Shah (2003) also reported that whitefly population was positively interconnected with temperature and negatively correlated with relative humidity. There result are not at par with the results of Nandihalli *et al*. (1993), Sharma and Sharma (1997), Umar *et al*. (2003), Jalal *et al*. (2006) who reported that relative humidity is positively correlated with whitefly population.

Correlation of weather factors and Jassid population on different varieties of cotton under unsprayed conditions:

Correlation of weather factors and jassid population showed that there was a positive correlation between temperature and jassid population as shown in Figure 4a, whereas humidity was negatively correlated with jassid population (Figure 5a). These findings are in agreement with those of Ali *et al*. (1993), Bishnol *et al*. (1996), Inee-Gogoi *et al*. (2000) [29], Wahla *et al*. (1996), Rashid *et al*., (2016a,b), Rehman *et al*., (2017), Shah (2003), Jalal *et al*. (2006) who reported that jassid population is positively correlated with temperature and negatively correlated with relative humidity however the results of Inee-Gogoi *et al*. (2000) [29] regarding relative humidity indicated that relative humidity favors the jassid population.

Correlation of weather factors and thrips population on different varieties of cotton under unsprayed conditions:

Correlation of weather factors and thrips population showed in Figure 4b that there was a positive correlation between temperature and thrips population, whereas humidity was negatively correlated with thrips population (Figure 5b). These results are similar with findings of Khan and Ullah, (1994) [33], Ali *et al*. (1994), Abbas *et al*., (2016a, b), Wahla *et al*. (1996) [60], Panickar and Patel (2001) [44], Jalal *et al*. (2006) [31] who stated that that there was a positive correlation between temperature and thrips population whereas relative humidity and rainfall was negatively correlated with thrips population.

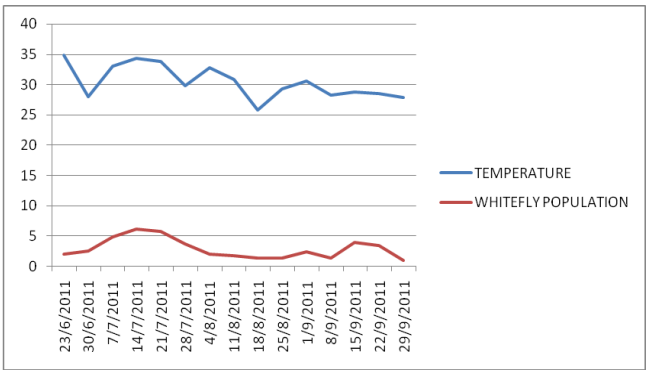

Fig 4: Relationship of mean temperature (°C) to mean per whitefly population on different transgenic and traditional cultivars of cotton.

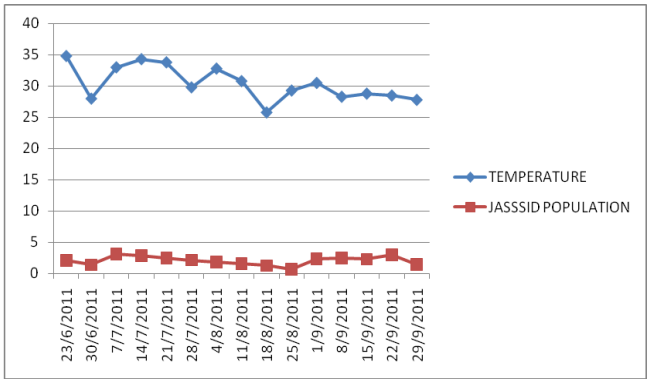

Fig 4a: Relationship of mean temperature (°C) to mean per Jassid population on different transgenic and traditional cultivars of cotton.

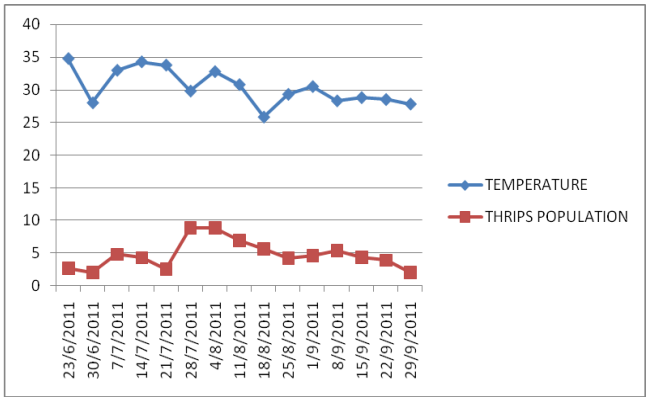

Fig 4b: Relationship of mean temperature (°C) to mean per Thrips population on different transgenic and traditional cultivars of cotton.

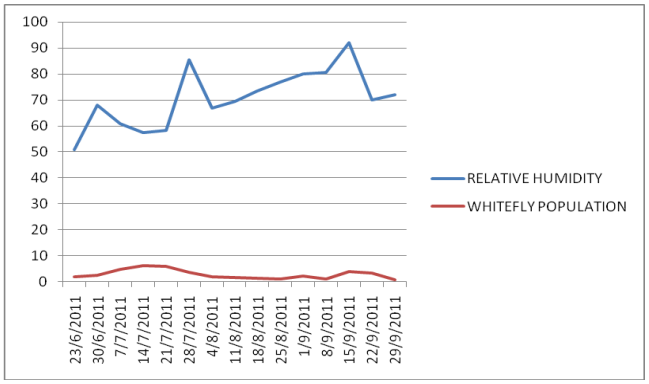

Fig 5: Relationship of mean relative humidity (%) to mean per whitefly population on different transgenic and traditional cultivars of cotton.

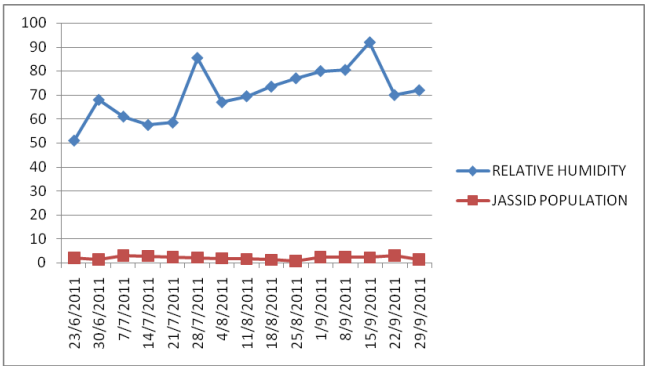

Fig 5a: Relationship of mean relative humidity (%) to mean per Jassid population on different transgenic and traditional cultivars of cotton.

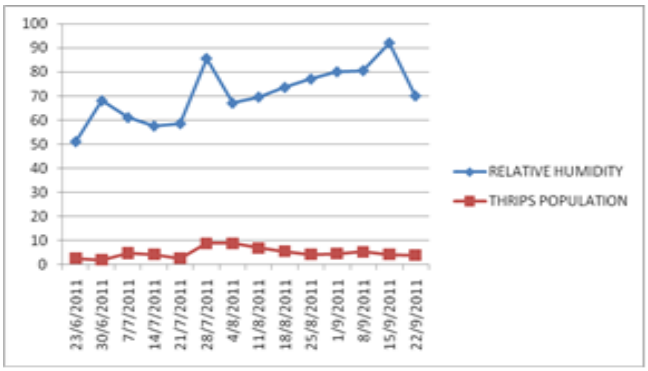

Fig 5b: Relationship of mean relative humidity (%) to mean per Thrips population on different transgenic and traditional cultivars of cotton.

Conclusion

In the light of the experimental findings it was established that Bt. varieties had higher percentage of sucking pests than non-Bt. varieties. In addition, whitefly and jassid populaion mount to peak during mid-july and thrips attack finds its maximum strength at end of july. Second peak for whitefly & jassid were during 3rd week of august and third week of september, respectively. Moreover, temperature was in direct positive association altogrther with whitefly, jassid and thrips population. While, Relative humidity had negative association to population of these sucking insect pests. In toto, preferment of cotton varieties that can endure the adversities of insect pests with trifling changes to their physiology in relation to environs, improved agronomic rehearses and integrated pest management during hotspots is pivotal to enhance average yield of cotton.

Supplementary

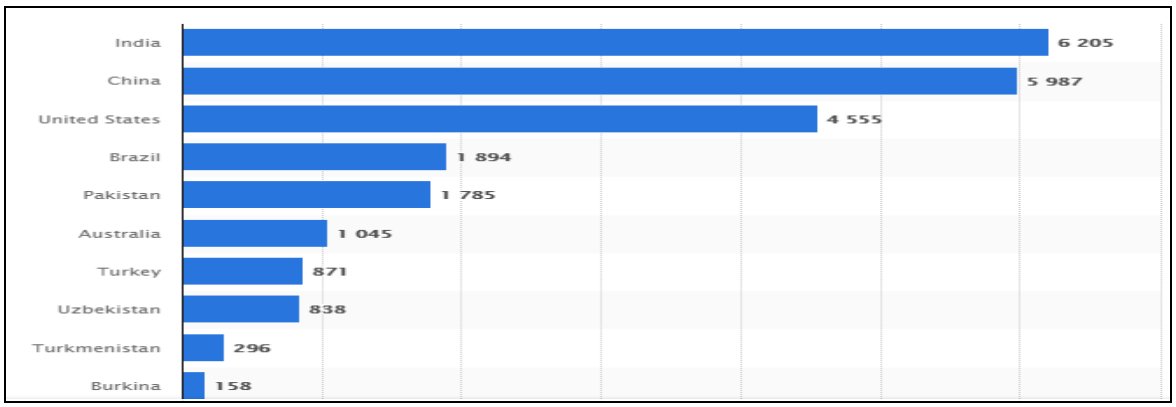

Fig 6: Cotton production by country worldwide in 2017/2018 (in 1,000 metric tons) (Statistica/Statistics Portal) [https://www.statista.com/statistics/263055/cotton-production-worldwide-by-top-countries/]

References

1. Aaliya K, Qamar Z, Nasir IA, Ali Q, Munim AF. Transformation, evaluation of gtgene and multivariate genetic analysis for morpho-physiological and yield attributing traits in Zea mays. Genetika. 2016; 48(1):423-443.
2. Abbas GH, Shahid MR, Mahmood A, Ali Q. Characterization of plant spacing best fit for economic yield, fiber quality, whitefly and CLCuV disease management on upland cotton. Nature and Science. 2016; 14(5):12-16.
3. Abbas HG, Mahmood A, Ali Q. Zero tillage: a potential technology to improve cotton yield. Genetika (0534-0012), 2016, 48(2).
4. Abro GH, Syed TS, Tunio GM, Khuhro MA. Performance of transgenic Bt cotton against insect pest infestation. Biotechnology. 2004; 3:75-81.
5. Aheer GM, Ahmed KJ, Ali A. Role of weather in fluctuating aphid density in wheat crop. Journal of Agriculture Research. 1994; 32:295-301.
6. Aheer GM, Ali A, Hussain S. Varietal resistance against jassid, Amrasa devastans (Dist.). In cotton and role of abiotic factors in population Fluctuation. Journal of Agriculture Research. 2006; 44(4):299-305.
7. Ahmad M, Arif MI, Ahmad Z, Denholm I. Cotton whitefly (Bemisia tabaci), 2002.
8. Ahmed Z, Attique MR, Rashid A. An estimate of the loss in cotton yields in Pakistan attributable to the jassid Amrasca devastans Dist. Crop Protection. 1985; 5:105-108.
9. Ali A, Aheer GM. Varietal resistance against sucking insect pests of cotton under Bahawalpur ecological conditions. Journal of Agriculture Research. 2007; 45(3):1-5.
10. Ali A, Aheer GM. Varietal resistance against sucking insect pests of cotton under Bahawalpur ecological conditions. Journal of Agriculture Research. 2007; 45:205-208.
11. Ali Q, Ahsan M, Kanwal N, Ali F, Ali A, Ahmed W, Saleem M. Screening for drought tolerance: comparison of maize hybrids under water deficit condition. Advancements in Life Sciences. 2016; 3(2):51-58.
12. Ali A, Bhatti MA, Ahmad KJ. Role of weather in fluctuating the population of Amrasca devastans (Dist.) and Thrips tabaci (Lind.). Proceedings of Pakistan congress of zoology. 1993; 13:133-139.
13. Amjad M, Bashier MH, Afzal M. Comparative resistance of some cotton, 2009.
14. Anonymous US. Cotton Market Monthly Economic Letter, Cotton Incorporated Strategic planning, 2005.
15. Anonymous. Economic survey of Pakistan, 2007-08. Ministry of Food, Agriculture and Livestock statistics Government of Pakistan, 2008, pp. 20.
16. Anonymous, http://www.saveblueplanet.com/effects of global warming. html, 2013.
17. Arshad M, Suhail A. Studying the sucking insect pests community in transgenic Bt cotton. International journal of Agriculture and Biology. 2010; 12:764-768.
18. Aslam M, Razaq M, Shah SA, Ahmad F. Comparative efficacy of different insecticides against sucking pests of cotton. Journal of Research in Science teaching. 2004; 15:53-58.
19. Avidov Z. Bionomics of the tobacco whitefly (Bemisia tabaci) in Israel. Israel Ktcrvm. 1956; 7:25-41.
20. Bai L, Longwa Z, Xiaobo C, Janjin F, Guohua G, Zongqing G, Chune S. Preliminary studies on effects of transgenic cotton varieties on composition of insect community. Chinese Journal of Biological Control. 2002; 18:115-119.
21. Bambawale OM, Singh A, Sharma OP, Bhosle BB, Lavekar RC, Dhandapani A, *et al*. Performance of Bt cotton (MECH-162) under Integrated Pest Management in farmers' participatory field trial in Nanded District, Central India Current Science. 2004; 12(25):1628-1633.
22. Bishnol OP, Singh M, Raq VUM, Niwas R, Sharma PD. Population dynamics of cotton pests in relation to weather parameters. Indian Journal of Entomology. 1996; 58(2):103-107.
23. Cultivars against sucking insect pests. Pakistan Journal of Life and Social Science, 7(2), 144-147.
24. Diouf J. 2011. See http://www.fao.org/news/story/0/item/20568/icode/en/ (accessed, 18 February 2011).
25. Gaurkhede AS, Bhalkare SK, Sadawarte AK, Undirwade DB. Bioefficacy of new chemistry molecules against sucking pests of Bt transgenic cotton. International Journal of Plant Protection. 2015; 8(1):7-12.
26. Gupta MP, Sandeep S, Shrivastava SK, Sharma S. Population build-up of some sap-sucking insects on cotton in Madhya Pardesh. Journal of Insect Science. 1997; 10(2):153-156.

27. https://bqrnd.com/role-of-cotton-crop-in-agriculture-of-pakistan/. FAIZA MEHMOOD
28. https://www.pakissan.com/2017/03/14/the-role-of-cotton-in-pakistan/
29. Inee-Gogoi, Dutta BC, Gogoi I. Seasonal abundance of cotton jassid, Amrasca biguttula biguttula Ishida. On okra. Journal 0f Agriculture Science, Society-of-North-East-India. 2000; 13(1):22-26.
30. Jagdev S, Butter NS. Influence of climatic factors on the buildup of whitefly (Bemisia tabaci) on cotton. Indian Journal Entomology. 1988; 47(3):359-360.
31. Jalal AM, Gogi MD, Mirza M, Zia K, Hafeez F. Impact of Plant Spacing and Abiotic Factors on population dynamics of sucking insect pests of cotton. Pakistan Journal of Biological Sciences. 2006; 9(7):1364-1369.
32. Joginder SB, Seklon S, Singh J. Population build up of cotton jassid, Amrasca bigutulla bigutulla on different varieties of cotton. Journal of Insect Science. 1998; 11(1):53-55.
33. Khan SM, Ullah Z. Population dynamics of insect pests of cotton in Dera Ismail Khan. Sarhad Journal of Agriculture. 1994; 10:285-290.
34. Kumawant RL, Pareek BL, Meena BL. Seasonal incidence of jassid and whitefly on okra and their correlation with abiotic factors. Annals Biology. 2000; 16(2):167-169.
35. Kwon SH, Torrie JH. Heritability and inter-relationship among traits of two Soybean Populations. Crop Sci. 1964; 4:196-198.
36. Li JZ, Zang HJ, Zhang ZM. Observation on the time and spatial dynamics of the diurnal cycle of tobacco thrips. Chinese Journal of Entomology. 1992; 18:26-30.
37. Men XY, Ge F, Yardim E, Parajulee MN. Behavioral response of Helicoverpa armigera (Lepidoptera: Noctudae) to cotton with and without expression of the CryIAc delta-endotoxin protein of Bacillus thuringiensis Berliner. Journal of Insect Behavior, 2005.
38. Murugan M, Uthamasamy. Dispersal behavior of cotton whitefly (Bemisia tabaci) under cotton based garden land agroecosystem of Coimbatore. Madras Agriculture Journal. 2001; 88(1-3):1-6.
39. Nandihalli BS, Patil BV, Lingappa S. Population dynamics of cotton whitefly, Bemisia tabaci (Genn.). Journal of Agriculture Science. 1993; 6(1):25-29.
40. Naveen A, Brar DS, Butter GS. Evaluation of Bt and non Bt version of two cotton hybrids under different spacing against sucking insect pests and natural enemies. Journal of Cotton Research and Development. 2007; 21(1):106-110.
41. Nelson MR, Nadeem A, Ahmad W, Orum TV. Global assessment of cotton viral diseases. In Proceeding of Beltwide cotton Conference, San Diego, CA. 5-9 Jan., 1998. National cotton council of America in Memphis, TN, 1998, p. 161-162.
42. Pakistan Economic Survey. Govt. of Pakistan, Ministry of Finance, Economic Advisor's Wing, Islamabad, 2016-17.
43. Pakistan Economic Survey. Govt. of Pakistan, Ministry of Finance, Economic Advisor's Wing, Islamabad, 2017-18.
44. Panickar BK Patel JR. Population dynamics of different species of thrips on chilli, cotton and pigeon pea. Indian Journal of Entomology. 2001; 63(2):170-175.
45. Rehman I, Aftab B, Bilal Sarwar M, Rashid B, Ali Q, Majid MU, Husnain T. gene expression in response to cotton leaf curl virus infection in Gossypium hirsutum under variable environmental conditions. Genetika. 2017; (0534-0012):49(3).
46. Rao GR, Chari MS. Population dynamics of whitefly, Bemisia tabaci (Genn.) In cotton and tobacco in relation to weather factors. Tobacco Research. 1992; 18(1-2):73-78.
47. Resistance to organophosphate and pyrethroid insecticides in Pakistan. Pest Management Science, 58, 203-208.
48. Rashid B, Kousar S, Yousaf M, Ali Q, Fatima F, Parveen S, Husnain T. Biotechnology: Future Tools for Stable Insect Pest and Weed Control in Cotton. Cotton Genomics and Genetics, 2016, 7.
49. Rashid BHT, Yousaf I, Rasheed Z, Ali Q, Javed F, Husnain T. Roadmap to sustainable cotton production. Life Science Journal. 2016; 13(11):41-48.
50. Rote NB, Puri N. Population dynamics of whitefly, Bemisia tabaci on cotton and its relationship with weather parameters. Journal of Cotton Research and Development. 1991; 5(2):181-189.
51. Shah SIH. Effect of abiotic factors on the incidence and development of sucking insect pests complex on different advanced genotypes of cotton under unsprayed conditions. M.sc. Thesis Deptment of Entomology University of Agriculture Faisalabad, 2003.
52. Sharma GN, Sharma PD. Population dynamics of cotton jassid (Amrasca biguttula bigutulla) and whitefly (Bemisia tabaci) on cotton and okra in relation to the physical factor of environment in Haryana. Annul. Bio. Ludhiana. 1997; 13(1):179-183.
53. Sharma HC, Pampapathy G. Influence of transgenic cotton on the relative abundance and damage by target and non-target insect pests under different protection regimes in India. Crop Protection. 2006; 25(8):800-813.
54. Shivanna BK, Gangadhara NB, Basavaraja MK, Nagaraja R, Kalleswara SCM, Karegowda C. Impact of abiotic factors on population dynamics of sucking pests in transgenic cotton ecosystem. International Journal of Science and Nature. 2011; 2(1):72-74.
55. Singh J, Sohr AS, Brar DS, Denholm I, Russel D, Briddon R. Management of cotton leaf curl viral diseases in India. In. Proceeding of the ICAC- CCRI Regional Consultation, Insecticide Resistance Management in Cotton. Central Cotton Research Institute Multan, Pakistan, 1999, pp. 277-278.
56. Sisterson MS, Biggs RW, Olson C, Carrie` re Y, Dennehy TJBE. Tabashnik BE. Arthropod abundance and diversity in Bt and non-Bt cotton fields. Environmental Entomology. 2004; 33(4):921-929.
57. Steel RGD, Torrie J, Dickey DA. Principles and Procedures of Statistics: A biometrical approach (3rd ed.). McGraw-Hill, New York, USA, 1997.
58. Umar MS, Arif MJ, Murtaza MA, Gogi MD, Salman M. Effect of abiotic factors on the population fluctuation of whitefly, Bemisia tabacii, in nectaried and nectariless genotypes of cotton. International Journal of Agriculture and Biology. 2003; 5(3):362-363.
59. USDA. Cotton: World Markets and Trade. United States Department of Agriculture, Foreign Agricultural Service, Circular Series. FOP: 01-10. 2010; 18(1):33-

50.
60. Wahla MA, Arif MJ, Afzal MA. THE impact of physical factors on the population dynamics of sucking insect pests of FH- 87 cotton. Pakistan Entomologist. 1996; 18(1-2):81-83.
61. Whitehouse MEA, Wilson LJ, Fitt GP. A comparison of arthropod communities in transgenic Bt and conventional cotton in Australia. Environmental Entomology. 2005; 34(5):1224-1241.
62. Wilson LJ, Bauer LR. Species composition and seasonal abundance of thrips (Thysonoptera) on cotton in the Namoi Valley. Journal of the Australian Entomological Society. 1993; 32:187-192.