Research Article

Spatial Survey of Cotton (*Gossypium hirsutum* L.) Insect Pests and Leaf Curl Virus (CLCuV) in Relation to Weather Parameters in Muzaffargarh, Punjab, Pakistan

Muhammad Nasir[1], Muhammad Usman Asif[2]*, Abdul Hayee Abid[1], Qurat ul Ain Haneef[1] and Muhammad Awais[2]

[1]Pest Warning and Quality Control of Pesticides, Punjab Agriculture Department, Lahore, Pakistan; [2]Plant Protection Division, Nuclear Institute of Agriculture, Tandojam, Pakistan.

Abstract | A three year spatial field survey of different insect pests of cotton and leaf curl virus (CLCuV) in relation to weather parameters was conducted in four tehsils viz. Alipur, Jatoi, Kot Addu and Muzaffargarh of district Muzaffargarh (Punjab, Pakistan). In each tehsil pest scouting was conducted in 40-50 spots (five acres each) per week selected randomly starting from 1st June to 30th October each year. Hot spots (pest incidence at and above Economic Threshold level, ETL) for each tehsil were determined weekly, and then the combined infestation was calculated at the district level. The results showed that the weather conditions, during all the three years, had a significant impact on the insect pest abundance. The maximum percentage of whitefly hot spots ranged in line from 8.36-24.14% during three years study period followed by mealybug (6.71-11.79%), jassid (4.56-7.22%), thrips (1.36-6.22%), pink bollworm (0.99-5.42%) and armyworm (2.77-4.23%). The population of dusky cotton bug, spotted bollworm and American bollworm were negligible with 1.22% hot spots of dusky cotton bug and 0.02% of spotted bollworm during 2020. CLCuV hot spots ranged from 15.66-22.74% during 2018-2020. Correlation matrix revealed that population fluctuations of whitefly, mealybug, pink bollworm and armyworm were negatively correlated with maximum and minimum temperature and positively correlated with jassid and thrips. Relative humidity exhibited a positive association with all the insect pests and CLCuV incidence. Multiple regression analysis was used to estimate the combined as well as individual impact of maximum and minimum temperature and relative humidity on population fluctuation of insect pests. The R^2 values indicated that maximum and minimum temperature were the most influential factors and played a significant role in the population fluctuation of the studied insect pests as well as CLCuV. The results of the study may be helpful to the pest managers as a pest forecasting tool for initiating management strategies at appropriate time during the cotton season.

Received | April 22, 2021; **Accepted** | August 05, 2021; **Published** | August 25, 2021
***Correspondence** | Muhammad Usman Asif, Plant Protection Division, Nuclear Institute of Agriculture, Tandojam, Pakistan; **Email:** uakhan1987@hotmail.com
Citation | Nasir, M., M.U. Asif, A.H. Abid, Q-u-A. Haneef and M. Awais. 2021. Spatial survey of cotton (*gossypium hirsutum* L.) insect pests and leaf curl virus (CLCuV) in relation to weather parameters in Muzaffargarh, Punjab, Pakistan. *Pakistan Journal of Agricultural Research,* 34(4): 713-724.
DOI | https://dx.doi.org/10.17582/journal.pjar/2021/34.4.713.724
Keywords | Population dynamics, CLCuV, Relative humidity, Temperature, Multiple regression, Correlation

Introduction

Cotton, *Gossypium hirsutum* L. is a major fiber and cash crop of Pakistan and is considered as the main strength of the country's economy (Tayyib *et al.*, 2005). Pakistan ranks 4th among all the cotton producing countries (Anonymous, 2013); however, per acre yield of cotton is comparatively meager.

Links Researchers

Various restraints contribute to this fact. Insect pests are one of the primary menaces to cotton production (Ahmad *et al*., 2011). Worldwide, 162 insect pest species have been documented that feed on different cotton growth stages (Kannan *et al*., 2004). Generally, insect pest composite on the cotton crop is divided into two groups; sucking and chewing insect pest complex. Jassid (*Amrasca devastans* Distant), whitefly (*Bemesia tabaci* Gennadius) and thrips (*Thrips tabaci* Lindeman) are the most precarious sucking pests that suck cell sap of leaves and ultimately damage the food producing unit, while dusky cotton bug (*Oxacarenus laetus* Kirby) and red cotton bug (*Dysdercus cingulatus* Fabricius) cause the reduction in seed germination and lint quality. Among chewing pests, pink (*Pectinophora gossypiella* Saunders), American (*Helicoverpa armigera* Hubner) and spotted bollworm (*Earis insulana* and *E. vitella*.) are boll feeders (Babar *et al*., 2013). On average, these insect pests cause 5-10% yield loss, increasing up to 40-50% in severe situations (Chaudhary, 1976). In addition to these pests, the cotton leaf curl virus (CLCuV) is another serious threat liable for massive losses to cotton crop (Farooq *et al*., 2011).

To protect the cotton crop from these menaces, growers primarily depend on synthetic insecticides. Cotton is the topmost receiver of pesticides in Pakistan, receiving for almost 62% of the total pesticide consumption (Khan *et al*., 2010). Insecticides usage not only creates health risks and environmental contamination but also leads to insecticidal resistance and disruption of the natural equilibrium in agroecosystems (Ahmad and Khan, 1991; Hamburg and Guest, 1997; Sorejani, 1998). Therefore, only proper pest monitoring and their prediction can mitigate the situations of high pest pressure owing to timely management.

Pest monitoring is a prime step in developing an appropriate Integrated Pest Management (IPM) program. Insect pests can be monitored through various tools, i.e., light traps, colored sticky traps, pheromone traps, suction traps and pitfall traps. The data generated from pest monitoring could then be used for ecological investigations, studying the timing of pest influx into agroecosystem, tracing insect migration, initiating sampling procedures and field scouting, determining proper timing for insecticide applications, and the prediction of future generations depending upon the size of previous generations (Lewis, 1981; Crummay and Atkinson 1997; Drake *et al*., 2002; Zalucki and Furlong, 2005; Hirao *et al*., 2008; Klueken *et al*., 2009; Merril *et al*., 2010). Forecast for pests is an important constituent of any IPM strategy. Pest forecasts and timely warnings depending on biophysical techniques provide time for managing future pest attacks and can thus reduce yield losses, optimize pest control and minimize the cultivation costs.

Abiotic factors such as relative humidity, temperature, and rainfall play a significant role in the population fluctuation of insect pests. These climatic parameters severely affect spatial distribution, behavioral and physiological features (Kingsolver, 1989). Theoretical ecologists primarily focused on climatic factors to develop a pest forecasting model (Wallner, 1987). These models are formulated to make farmers aware of future insect pests outbreaks for effective preventive measures to counter pest attack (Hameed *et al*., 2014). General and anticipated weather information can help plan crops, developing spray schedules and managing farm activities to increase crop returns and yields. The development of long term monitoring spatial data on crop–pest–weather relationships will narrow the gaps in knowledge required for reliable forecasts.

Therefore, the present study was initiated to investigate and monitor the population fluctuation of cotton insect pests and CLCuV incidence with respect to the abiotic factors in district Muzaffargarh of Punjab, Pakistan.

Materials and Methods

The study on spatial survey of sucking and chewing insect pests of cotton as well as CLCuV was conducted for three years (2018-2020) in four tehsils (Alipur, Jatoi, Kot Addu and Muzaffargarh) of district Muzaffargarh. The latitude of Muzaffargarh, Punjab, Pakistan is 30.074377, and the longitude is 71.184654. The aim of the investigation was to determine the population trend of different insect pests and disease throughout the cotton crop season. In each tehsil pest scouting was conducted at 40-50 spots per week (five acres each) on a weekly basis starting from 1st June to 30th October each year.

Sampling of sucking insects and CLCuV

Jassid (*Amrasca devastans*), whitefly (*Bemesia tabaci*) and thrips (*Thrips tabaci*) population were recorded on 20 leaves randomly selected from 20 plants per block; upper, middle and lower leaves, one from each plant.

Cotton mealybug *(Phenacoccus solenopsis)* population was recorded on 20 cm twig from 15 plants. Dusky cotton bug (*Oxacarenus laetus*) population was estimated from 25 randomly selected plants by recording the number of bugs from five bolls of each plant. Cotton leaf curl virus incidence was noted by observing symptoms from 100 plants.

Sampling of chewing insects

American bollworm (*Helicoverpa armigera*) and spotted bollworm (*Earis insulana* and *E. vitella*.) live larvae was recorded on fruiting bodies of randomly selected 25 cotton plants viz., five consecutive plants from five different places per block). Pink bollworm (*Pectinophora gossypiella*) infestation was recorded by dissecting 100 bolls per block and counting the healthy as well as damaged bolls. Percent infestation was calculated by dividing the total and damaged number of bolls. For armyworm (*Spodoptera* spp.) spots were recorded on its appearance.

Data analysis

A place was considered a hot spot where the pest population was found at and above Economic Threshold Level (ETL). Hot spots for each tehsil (Alipur, Jatoi, Kot Addu and Muzaffargarh) were determined on a weekly basis. The spots were numbered as above and below ETL for each pest of each tehsil. Then, the combined infestation of insect pests and CLCuV was calculated at the district level. To evaluate the influence of weather factors on the cotton insect pests population and CLCuV incidence meteorological data, i.e., minimum temperature, maximum temperature and relative humidity (%), were obtained from the weather record of the Agriculture Extension Department of District Muzzafargarh (Table 1). Correlation of hot spots number, insect pests population and CLCuV with individual abiotic factors was computed with Statistica by StatSoft. The relationship between weather factors, i.e., maximum and minimum temperature (°C) and relative humidity (%) with insect pests and CLCuV hot spots were evaluated using multiple regression analysis.

Results and Discussion

Whitefly (Bemesia tabaci)

The mean percentage of whitefly hot spots ranged from 8.36-24.14% during 2018-2020. The whitefly population was highest in 2020 with 24.14% of hot spots followed by 2018 (12.47%), while the lowest hot spots were recorded in 2019 with 8.36% hot spots (Table 2). An increasing trend in whitefly hot spots was observed after the first week of July up to September with maximum temperature ranging from 34-41°C, minimum temperature 31-36°C and relative humidity 55-70% during all the years of study. However, the population was recorded at its peak with the highest number of hot spots during September favored by relative humidity ranging from 55-65 % and maximum temperature 35-39°C. The population started declining afterwards rapidly due to the decrease in relative humidity (Table 1; Figure 1). The correlation analysis revealed that the whitefly population had a non-significant correlation with maximum and minimum temperature, while it exhibited a positive relationship with relative humidity during the three years of study (Table 3). Multivariate regression analysis indicated that cumulatively weather factors exhibited 22.3, 24.2 and 18.4% impact on the fluctuation of whitefly population during the years 2018, 2019 and 2020, respectively. The maximum temperature was the most influential factor with 15.3 and 16.4% role during 2018 and 2020, whereas during 2019, the minimum temperature was the most dominant factor with 13% impact on population fluctuation. Relative humidity showed a nugatory influence on the population of whitefly by having only 0-1.4% impact during 2018-20 (Table 4).

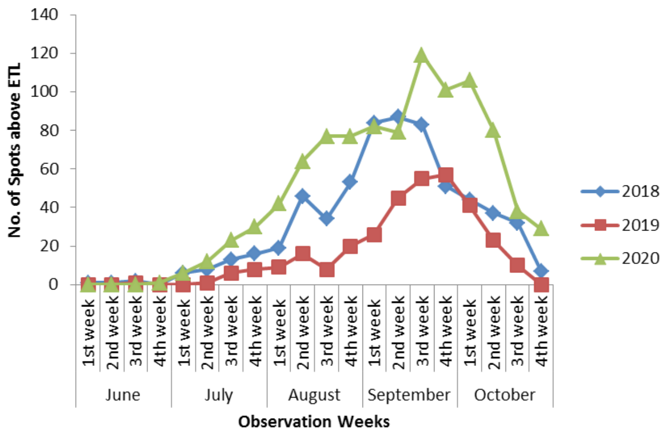

Figure 1: *Whitefly hotspots observed in different weeks during 2018-2020.*

Jassid (Amrasca devastans)

The results revealed that the mean percentage of jassid hot spots ranged 4.56-7.22% during 2018-2020. The population of jassid was highest in 2020 with 7.22% of hot spots followed by 2018 (6.29%), while the lowest hot spots were recorded in 2019 with 4.56% hot spots (Table 2).

Table 1: *Weekly meteorological data of weather factors during 2018 -2020.*

Months	Weeks	2018			2019			2020		
		Max Temp	Min Temp	RH	Max Temp	Min Temp	RH	Max Temp	Min Temp	RH
June	1st week	44.2	31.0	33.9	42.2	31.4	29.8	37.4	25.9	48.9
	2nd week	40.6	28.9	49.3	42.9	30.2	35	42.8	30.9	44.3
	3rd week	39.9	27.6	48.5	36.7	26.1	56.1	40.9	31.4	50.1
	4th week	36.4	27.6	55.5	39.5	27.7	52.9	40.5	30.3	64.0
July	1st week	37.7	27.7	57.3	40.3	30.1	54.9	40.0	28.6	52.8
	2nd week	41.0	31.5	51.1	37.5	30.7	58.9	40.1	29.9	57.4
	3rd week	37.2	28.4	59.4	38.9	29.8	58.5	37.9	28.6	67.4
	4th week	37.6	30.0	59.3	37.3	28.9	64	38.3	30.3	59.8
August	1st week	36.3	28.7	60.5	37.4	28.6	63	38.9	30.6	59.7
	2nd week	37.0	29.3	62.2	36.8	27.6	67.7	38.9	30.1	63.0
	3rd week	37.7	28.6	61.1	37.8	27.5	60.7	38.0	30.0	63.7
	4th week	37.6	29	56.4	38.4	29.7	61.0	35.3	27.4	81.1
September	1st week	37.0	27.3	57.6	38.4	30.2	60.3	33.8	26.1	76.2
	2nd week	35.8	27.4	60.9	39.5	29.7	56.1	38.0	28.0	62.4
	3rd week	34.7	25.3	56.7	36.8	28.0	59.6	38.3	27.8	52.6
	4th week	36.2	24.7	52	34.8	26.0	63.2	36.5	24.2	53.3
October	1st week	36.5	22.9	47.5	31.4	21.3	67	36.5	21.8	49.3
	2nd week	32.6	20.6	48.1	34.9	22.6	52.3	35.8	21.1	51.3
	3rd week	32.1	18.7	50.2	31.9	20.0	52.0	34.0	17.6	48.6
	4th week	32.7	19.2	51.5	32.9	18.8	58.1	30.4	17.3	55.3

Max Temp: Maximum Temperature (°C); Min Temp: Minimum Temperature (°C); RH: Relative Humidity (%).

Table 2: *Mean percentage of hot spots per year of different insect pests and CLCuV during 2018-2020.*

Pests	Hot Spots (%) per year		
	2018	2019	2020
Whitefly	12.47	8.36	24.14
Jassid	6.29	4.56	7.22
Thrips	1.71	1.36	6.22
Mealybug	6.71	9.55	11.79
Dusky cotton bug	0	0	1.22
Pink Bollworm	0.99	2.43	5.42
Spotted Bollworm	0	0	0.024
American Bollworm	0	0	0
Armyworm	4.23	2.77	3.47
CLCuV	18.87	15.66	22.74

An increasing trend in jassid population was observed after the second week of June due to an increase in temperature and relative humidity and gained its peak with the highest number of hotspots in the July favored by maximum temperature ranging from 37-41°C, minimum temperature 27-31°C and high relative humidity 55-65%. The hot spots number remained high in August; however, the population declined rapidly with the lowest number of hot spots in September and October due to the gradual decrease in the temperature as well as relative humidity during all the years of study (Table 1, Figure 2). Correlation analysis showed that the population of jassid exhibited positive relationships with all the studied weather factors, i.e., maximum and minimum temperature and relative humidity. Significant association of jassid population was observed with minimum temperature as well as with relative humidity (Table 3). Multivariate analysis revealed that cumulatively weather factors recorded 65.6, 55.2 and 34.5% impact on the fluctuation of jassid population during the years 2018, 2019 and 2020, respectively. The minimum temperature was the most prominent factor with 53.7 and 28.1% role during 2018 and 19 whereas during 2020, the maximum temperature was the most dominant parameter with an 18.5 % impact on population fluctuation. Relative humidity had 2.9-20.5% influence on the jassid population fluctuation during 2018-20 (Table 4).

Table 3: *Correlation (r) values of weather factors with cotton insect pests and CLCuV.*

Pests	2018			2019			2020		
	Max Temp	Min Temp	RH	Max Temp	Min Temp	RH	Max Temp	Min Temp	RH
Whitefly	-0.39	-0.17	0.37	-0.33	-0.12	0.39	-0.40	-0.29	0.22
Jassid	0.30	0.66*	0.57*	0.25	0.47*	0.42	0.43	0.54*	0.28
Thrips	0.03	0.40	0.63*	0.09	0.27	0.42	0.13	0.43	0.41
Mealybug	-0.47*	-0.38	0.24	-0.32	-0.10	0.50*	-0.43	-0.16	0.54*
Pink Bollworm	-0.40	-0.38	0.05	-0.54*	-0.38	0.33	-0.71	-0.88*	-0.29
Armyworm	-0.55*	-0.38	0.32	-0.55*	-0.36	0.48*	-0.18	0.08	0.39
CLCuV	-0.27	-0.01	0.45*	-0.007	0.25	0.53*	-0.55	-0.50	0.16

*Significant * = $p < 0.05$; Max Temp: Maximum Temperature (°C); Min Temp: Minimum Temperature (°C); RH: Relative Humidity (%).*

Table 4: *Multivariate regression model between weather factors and cotton insect pests and CLCuV.*

Pests	Factor	2018		2019		2020	
		R^2	Impact %	R^2	Impact %	R^2	Impact %
Whitefly	Max Temp	15.3	15.3	11.2	11.2	16.4	16.4
	Min Temp	22.3	7.0	24.2	13.0	17.0	0.6
	RH	22.3	0	24.2	0	18.4	1.4
Jassid	Max Temp	9.0	9.0	6.6	6.6	18.5	18.5
	Min Temp	62.7	53.7	34.7	28.1	30.3	11.8
	RH	65.6	2.9	55.2	20.5	34.5	4.2
Thrips	Max Temp	0.2	0.2	1.0	1.0	1.7	1.7
	Min Temp	43.6	43.4	16.1	15.1	35.6	33.9
	RH	48.6	5	34.7	18.6	35.8	0.2
Mealybug	Max Temp	22.3	22.3	10.3	10.3	19.0	19
	Min Temp	22.4	0.1	24.3	14.0	31.3	12.3
	RH	24.8	2.4	27.8	3.5	39.8	8.5
Pink Bollworm	Max Temp	16.6	16.6	29.4	29.4	51.4	51.4
	Min Temp	17.4	0.8	33.1	3.7	78.7	27.3
	RH	17.5	0.1	35.0	1.9	79.4	0.7
Armyworm	Max Temp	30.8	30.8	30.4	30.4	3.4	3.4
	Min Temp	32.2	1.4	36.7	6.3	21.3	17.9
	RH	32.5	0.3	37.0	0.3	21.3	0.0
CLCuV	Max Temp	7.6	7.6	0.0	0.0	31.0	31.0
	Min Temp	22.1	14.5	30.1	30.1	31.6	0.6
	RH	23.0	0.9	43.3	13.2	35.0	3.4

Max Temp: Maximum Temperature (°C); Min Temp: Minimum Temperature (°C); RH: Relative Humidity (%).

Thrips (Thrips tabaci)

The mean percentage of thrips hot spots ranged 1.36-7.22% during 2018-2020. A considerable increase in thrips population was recorded in the year 2020 with 7.22% of hot spots compared to 2018 and 2019 with 1.71 and 1.36% hot spots, respectively (Table 2). The population of thrips started increasing in the 2nd week of July. It gained its peak with the highest number of hot spots in the 2nd and 3rd week of August due to the increase in temperature and relative humidity with maximum temperature ranging from 37-41°C, minimum temperature 27-31°C and relative humidity 51-67% and afterwards declined rapidly in September during all the years of study (Table 1, Figure 3). A population reduction was observed due to a decline in both temperature and relative humidity in September. Correlation analysis results showed that the thrips population exhibited non-significant positive relationships with maximum and minimum temperature, whereas relative humidity correlation was significantly positive during the year 2018 (Table 3). Multivariate analysis revealed that cumulatively weather factors retained 48.6, 34.7 and 35.8 % impact on the fluctuation of thrips population during the years 2018, 2019 and 2020, respectively. The minimum temperature was the most prominent factor with 43.4 and 33.9% influence during 2018 and 2020 whereas, during 2019, relative humidity was the most dominant factor with 18.6% impact on population fluctuation. Maximum temperature showed minimal influence on thrips abundance with 0.2 -1.7% role during 2018-20 (Table 4).

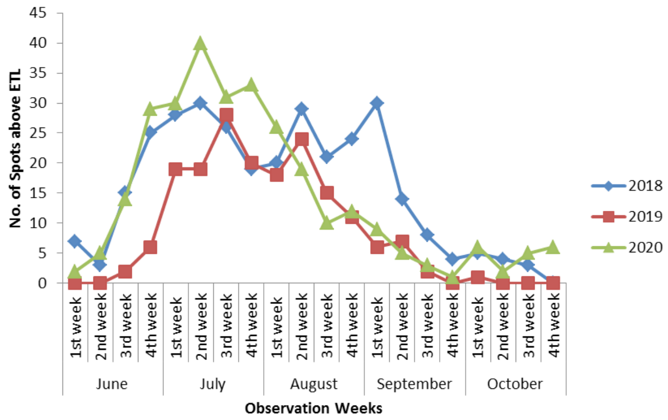

Figure 2: *Jassid hotspots observed in different weeks during 2018-2020.*

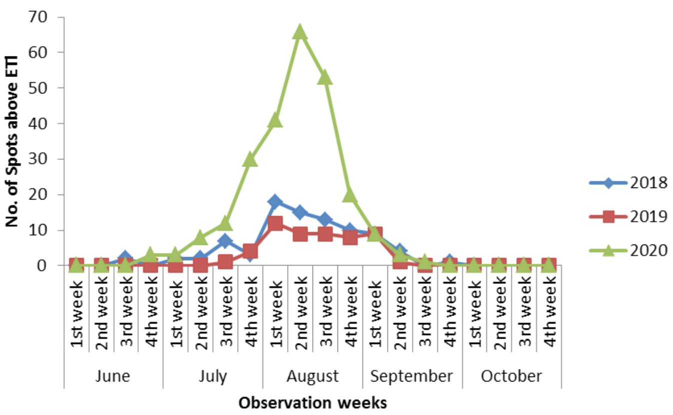

Figure 3: *Thrips hotspots observed in different weeks during 2018-2020.*

Mealybug (Phenacoccus solenopsis)

The results showed that the mean percentage of mealybug hot spots ranged from 6.71–11.79% during 2018-2020. The population of mealybug was highest in 2020 with 11.79% of hot spots followed by 2019 (9.55%), while the lowest hot spots were recorded in 2018 with 6.71% hot spots (Table 2). An increasing trend in mealybug population was observed at the end of July and gained its peak in the 3rd and 4th week of August with the highest number of hot spots due to a decline in maximum and minimum temperature with maximum temperature ranging from 33-39°C, minimum temperature 24-30°C and relative humidity 56-80%. The number of hot spots remained high in the month of September; however, the population started declining in the month of October due to the decrease in relative humidity with the lowest number of hot spots during all the years of study (Table 1, Figure 4). The maximum temperature 35-38°C, minimum temperature 27-30°C and relative humidity 55-60% favored the peak population development. The correlation analysis showed that the mealybug population had a significantly positive correlation with relative humidity, significantly negative correlation with maximum temperature whereas non-significant and negative results were observed with minimum temperature (Table 3). Multivariate regression analysis showed that cumulatively weather factors had 24.8, 27.8 and 39.8% impact on the fluctuation of the mealybug population during the years 2018, 2019 and 2020, respectively. The maximum temperature was the most influential factor with 22.3 and 19% role during 2018 and 2020, whereas during 2019, the minimum temperature was the most dominant parameter with 14% impact on population fluctuation. The influence of relative humidity on mealybug population fluctuation was 2.4, 3.5 and 8.5% during 2018, 2019 and 2020, respectively (Table 4).

Pink bollworm (Pectinophora gossypiella)

The results showed that the mean percentage of pink bollworm hot spots ranged from 0.99–5.42% during 2018-2020. The population of pink bollworm was highest in 2020 with 5.42% of hot spots followed by 2019 (2.43%), while the lowest hot spots were recorded in 2018 (0.99% hot spots; Table 2). The population of pink bollworm started increasing in the month of August and gained its peak with the highest number of hot spots in the month of September during 2018 and 2019, and in October during 2020 due to a decrease in temperature with maximum temperature ranging from 30-39°C and minimum temperature varying from 17-27°C. However, the population started declining in the month of October gradually during the first two years of study (Table 1, Figure 5). Peak infestation was favored by maximum temperature 32-34 °C, minimum temperature 20-25°C and relative humidity 50-60%. Correlation analysis showed that pink bollworm infestation had a significantly negative correlation with maximum temperature during 2019 and 2020 whereas significant and negative correlation with minimum temperature during 2020. Relative humidity had a non-significant positive correlation with pink bollworm infestation during the first two years of study (2018 and 19), while the correlation was negative during 2020 (Table 3). Multivariate regression analysis revealed that cumulatively weather factors illustrated 17.5, 35 and 79.4% impact on the fluctuation of pink bollworm infestation during the years 2018, 2019 and 2020, respectively. The maximum temperature was the most influential factor with 16.6, 29.4 and 51.4% role in the pink bollworm fluctuation during the years 2018, 19 and 20, respectively. The role of minimum temperature was 0.8-27.3%, whereas relative humidity showed 0.1-1.9% influence on the pink bollworm infestation during 2018-20 (Table 4).

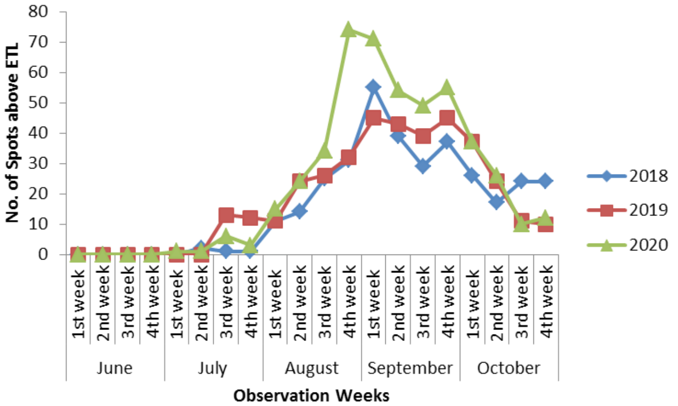

Figure 4: *Mealybug hotspots observed in different weeks during 2018-2020.*

Armyworm (Spodoptera spp.)

It was observed that the mean percentage of armyworm hot spots ranged from 2.77–4.23% during 2018-2020. The population of armyworm was highest in 2018 with 4.23% of hot spots followed by 2020 (3.47%), while the lowest hot spots were recorded in 2019 with 2.77% hot spots (Table 2). The population of armyworm started increasing in the middle of July and remained high in the month of August and September due to decrease in temperature with maximum temperature ranging from 33-38°C and minimum temperature 24-30°C. However, the population started declining in the start of October gradually during all the years of study (Table 1, Figure 6). Correlation analysis showed that armyworm population fluctuation had significant negative correlation with maximum temperature, positive with relative humidity whereas non-significant results were observed with minimum temperature (Table 3). Multivariate regression analysis revealed that cumulatively weather factors exhibited 32.5, 37 and 21.3% impact on the fluctuation of armyworm population during the years 2018, 2019 and 2020, respectively. The maximum temperature was the most prominent factor with 30.8 and 30.4% role during 2018 and 2019, whereas during 2020, the minimum temperature was the most dominant factor with 17.9 % impact on population fluctuation. Relative humidity showed nugatory influence on the armyworm population fluctuation (Table 4).

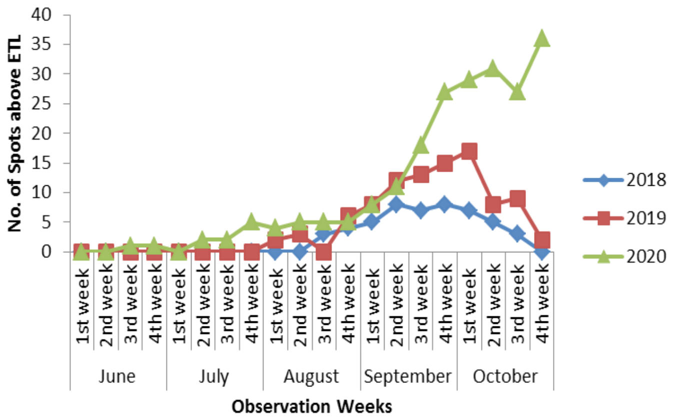

Figure 5: *Pink bollworm hotspots observed in different weeks during 2018-2020.*

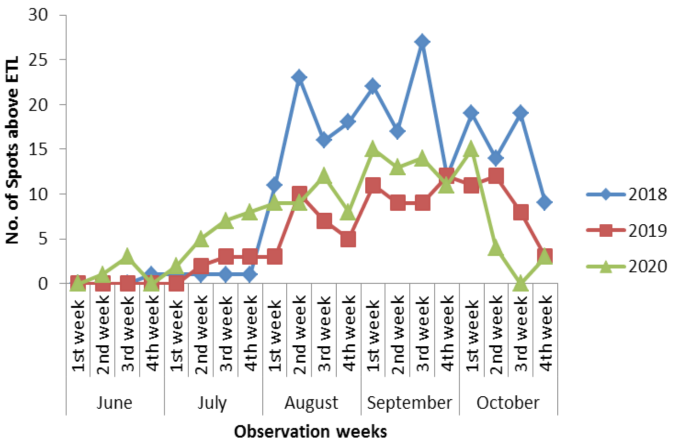

Figure 6: *Armyworm hotspots observed in different weeks during 2018-2020.*

Dusky cotton bug (Oxacarenus laetus)

The results indicated that the population of the dusky cotton bug was negligible and no hot spots were found during the years 2018 and 2019, whereas in 2020, its population was above ETL at few locations with hot spots percent of 1.22 % (Table 2).

Spotted bollworm (Earis insulana and E. vitella.)

Table 1 shows that that infestation of spotted bollworm was negligible and no hot spots were found during the years 2018 and 2019 where as in 2020 its population was above ETL at only one location with hot spot percent of 0.024 % (Table 2).

American bollworm (Helicoverpa armigera)

American bollworm population was also negligible and no hot spots were recorded during all the years of study (Table 2).

Cotton leaf curl virus

Cotton leaf curl virus data during 2018-2020 clearly indicated that CLCuV incidence was highest in 2020 with hot spots of 22.74%, followed by 2018 with 18.87% hot spots, while the lowest incidence was recorded in 2019 with 15.66% hotspots (Table 2). The results indicated that the incidence of CLCuV started increasing at the end of July and gained its momentum in the 1st week of September due to decrease in temperature with maximum temperature ranging from 33-40°C, minimum temperature 25-30°C and high humidity 52-80% during all the years of study. However, rapid decline was observed in the month of October (Table 1, Figure 7). Correlation analysis showed that the correlation between CLCuV incidence and maximum and minimum temperature was significantly negative and positive and significant with relative humidity (Table 3). Multivariate regression analysis showed that cumulatively weather factors had 23.0, 43.3 and 35% impact on the incidence of CLCuV during the years 2018, 2019 and 2020, respectively. The minimum temperature was the most influential factor with 14.5 and 30.1% role during 2018 and 19, whereas during 2020, the maximum temperature was most dominant factor with 31% impact on CLCuV incidence. Relative humidity had 0.9-13.2% impact on the CLCuV incidence (Table 4).

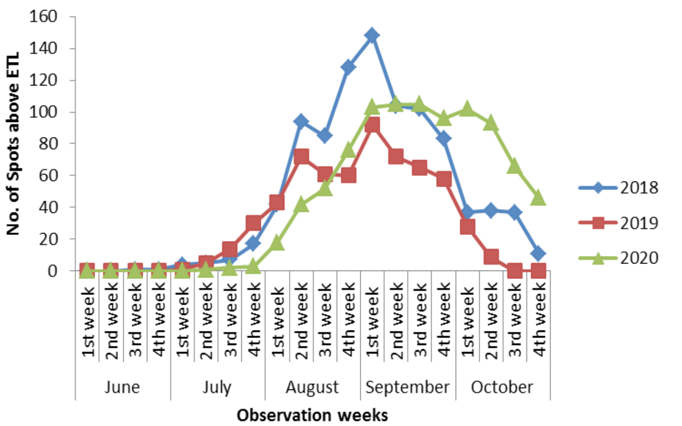

Figure 7: *CLCuV hotspots observed in different weeks during 2018-2020.*

Cotton whitefly is a notorious insect pests of cotton. Weather conditions greatly influence its incidence and development (Chaudhari *et al*., 1999; Arif *et al*., 2006). It is essential to determine the extent of the relationship between weather factors and the whitefly population to help the entomologists devise the best integrated pest management strategy for whitefly control (Umar *et al*., 2003). The present studies indicated the peak population of whitefly during the September due to high relative humidity ranging from 55-65% and maximum temperature 35-39°C. Whitefly population was found to have positive correlation with relative humidity and negative with maximum and minimum temperature. Similarly, Gahfoor *et al*. (2011), Sahito *et al*. (2012) and Anjali *et al*. (2012) reported positive relationship of whitefly population with relative humidity and negative association with temperature. Shah *et al*. (2017) reported significantly enhanced whitefly population on USDA accessions with high relative humidity whereas non-significant positive effect on local varieties. These results are partially in line with Ahmad *et al*. (2018) who reported positive relationship of average temperature and relative humidity with the abundance of whitefly. Contrarily, positive correlation with temperature and negative correlation with relative humidity has also been reported (Arif *et al*., 2006; Ashfaq *et al*., 2010; Kalkal *et al*., 2013). These anomalies in results may be due to the differences in climatic conditions of the locations where studies were conducted.

Cotton jassid, a key insect pest inflicting substantial loss to cotton production. The results of the present studies suggested that peak population occurred in July favored by maximum temperature 37-41°C, minimum temperature 27-31°C and high relative humidity 55-65%. These results are in line with Aheer *et al*. (2006), Salman *et al*. (2011) and Asif *et al*. (2019), who reported high population of jassid above threshold level during the month of July. Correlation analysis showed significant and positive relation of jassid population with relative humidity and minimum temperature and non-significantly positive correlation with maximum temperature. These are consistent with other previous studies (Gogoi and Dutta, 2000; Arif *et al*., 2006; Babu and Meghwal, 2014). Wahla *et al*. (1996) and Chandani *et al*. (2015) also reported positive correlation of maximum and minimum temperature with the population change of jassid.

Thrips feed on different hosts and cause considerable yield loss to various economically important crops. Climatic factors play a vital part in the population dynamics of sucking pests (Panickar and Patel, 2001; Murugan and Uthamasamay, 2001). The present results showed peak population in the middle of August favored by maximum temperature 36-38°C, minimum temperature 27-30°C and high relative humidity (60%). Similarly, Hameed *et al.* (2014) also reported peak abundance of thrips during the month of August. Contrary to this, Abro *et al.* (2004) recorded high abundance of thrips in the early season as compared to the late season. Correlation studies showed positive relationship of the thrips population with weather factors. Previous studies also reported positive influence of temperature on thrips population abundance (Arif *et al*., 2006; Akram *et al*., 2013; Patel *et al*., 2013). These results are partially in line with Shah *et al.* (2017) and Asif *et al.* (2020), who reported positive relationship between thrips population fluctuation and maximum and minimum temperature but negative correlation with relative humidity.

The present results showed peak population of mealybug in the end of August that remained high in September. Maximum temperature ranging between 35-38°C, minimum temperature 27-30°C and relative humidity 55-60% favored the development of the population. In agreement with our results, Hameed *et al.* (2014) reported high population of mealybug in last week of August during 2007, 2nd and 3rd week of September during 2009 and 2010. Dhawan *et al.* (2009) also reported the highest population in the middle of September. Correlation results showed positive and significant relationship with relative humidity and negative correlation with maximum and minimum temperature. These results are partially in line with Hachinal *et al.* (2010) who observed positive association of mealybug fluctuation with relative humidity as well as with maximum temperature. Contrarily, Shivanna *et al.* (2009) reported negative correlation with relative humidity and positive relationship with maximum temperature. The difference in weather conditions of the locality in which the experiments were conducted might be the possible reason for the conflicting results.

Pink bollworm is one of the most devastating pests of cotton, causing 20-30% loss of bolls. The results indicated peak infestation in the month of September and October when the crop is fully matured and large number of fruiting bodies are present. The high infestation was favored with low maximum temperature ranging from 32-34°C, minimum temperature 20-25 °C and relative humidity 50-60%. Similarly, Shah *et al.* (2011) reported that high infestation of the pink bollworm population occurred from August to September and reached its peak in the month of September during the two year study. The present findings are in accordance with the work of Khuhro *et al.* (2015), who recorded maximum moth catches in the month of September and October during the five year study from 2009-2013. Results also showed positive correlation of pink bollworm with relative humidity and negative relationship with maximum and minimum temperature. Kumar *et al.* (2012) also reported non-significantly positive correlation of trap catches with relative humidity and negative association with rainfall. These results are partially confirmed by Sharma *et al.* (2015) and Shinde *et al.* (2018), who found negative association of maximum and minimum temperature and relative humidity with the pink bollworm adult population.

American bollworm can solely lessen the crop produce from 50-70% if remained unchecked (Chemeune *et al.*, 2007). The present results showed negligible infestation of American bollworm with nil hot spots. Introduction of Bt (*Bacillus thuringiensis*) cotton in Pakistan agroecosystems has entirely destroyed its occurrence on cotton crop, and even its attack on non-Bt varieties is also reduced due to the breaking of the life cycle. Nowadays, this pest mostly appears in the month of April on Crucifers and vegetables (Hameed *et al*., 2014).

Cotton leaf curl virus is a crucial disease of cotton and its presence is increasing day by day in Pakistan due to the varying and supportive climatic conditions. The present studies showed peak incidence of ClCuV in the 1st week of September with maximum temperature ranging from 33-40°C, minimum temperature 25-30°C and high humidity 52-80%. The correlation results showed a significant and positive relationship with relative humidity and negative association with maximum and minimum temperature. Hameed *et al.* (2014) observed the peak of cotton leaf curl virus in the 1st week of September during 2006, whereas in 2nd week of July in 2007 with similar correlation results.

Conclusions and Recommendations

The current study gives a brief account of how the population of different insect pests varies in relationship with abiotic factors (over three consecutive growing seasons). It was noticed that maximum and minimum temperatures are the main factors that have a significant influence on the population fluctuation of insect pests. This study would be helpful in timely initiating various control tactics to maximize efficacy and minimize yield losses due to insect pests.

Acknowledgements

The authors are highly thankful to the Agriculture Department, Pest Warning and Quality Control of Pesticides, Punjab, for facilitating this research work.

Novelty Statement

In current scenario of climate change and its impact on the abundance of different insect pests, it is highly important to have relevant data on the population fluctuation of different insect pests from time to time. This paper provide novel data on the population trend of different insect pests of cotton and CLCuV incidence with respect to environmental factors in Muzaffargarh district. This study would be helpful in timely initiating various control tactics for the management of insect pests and to minimize yield losses.

Author's Contribution

Muhammad Nasir: Developed basic idea of the study; and discussed and finalized the idea with co-authors. Additionally, he planned and conducted the experiment.
Muhammad Usman Asif: Did statistical analysis of the data, interpret the results and wrote the manuscript.
Abdul Hayee Abid: Finalizes the experimental plan and supervised the project. He also helped in execution of study.
Qurat ul Ain Haneef: Helped in data collection.
Muhammad Awais: Helped in data analysis.

Conflict of interest

The authors have declared no conflict of interest.

References

Abro, G.H., T.S. Syed, G.M. Tunio and M.A. Khuhro. 2004. Performance of transgenic Bt cotton against insect pest infestation. J. Biotech., 3: 75-81. https://doi.org/10.3923/biotech.2004.75.81

Aheer, G.M., A. Ali and S. Hussain. 2006. Varietal resistance against jassid, *Amrasca devastans* (Dist.) in cotton and role of abiotic factors in population fluctuation. J. Agric. Res., 44: 299-305.

Ahmad, F., M.W. Sanjrani, S.N. Khuhro, A. Sajjad, A. Ali, R.R. Khan, F. Ahmed and J. Liu. 2018. Spatial field survey of cotton whitefly and its pupal parasitism in relation to temperature and humidity in southern Pakistan. Pak. J. Zool., 50(4): 1231-1236. https://doi.org/10.17582/journal.pjz/2018.50.4.1231.1236

Ahmad, F., W. Akram, A. Sajjad and A. Imran. 2011. Management practices against mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae). Int. J. Agric. Biol., 13(4): 547-552.

Ahmad, M. and M.R. Khan. 1991. Insecticide resistance management strategies in cotton pests in Pakistan. Pak. Entomol., 13: 1-4.

Akram, M., F. Hafeez, M. Farooq, M. Arshad, M. Hussain, S. Ahmed, K. Zia and H.A.A. Khan. 2013. A case to study population dynamics of *Bemisia tabaci* and *Thrips tabaci* on Bt and non-Bt cotton genotypes. Pak. J. Agric. Sci., 50(4): 617-623.

Anjali, M., N.P., Singh, M. Mahesh and S. Swaroop. 2012. Seasonal incidence and effect of abiotic factors on population dynamics of major insect pests on brinjal crop. J. Environ. Res. Dev., 7: 431-435.

Anonymous, 2013. Economic Survey Pakistan 2012-13, Economic Affairs Division, Islamabad, Pakistan.

Arif, M.J., M.D. Gogi, M. Mirza, K. Zia and F. Hafeez. 2006. Impact of plant spacing and abiotic factors on population dynamics of sucking pests of cotton. Pak. J. Biol. Sci., 9: 1364–1369. https://doi.org/10.3923/pjbs.2006.1364.1369

Ashfaq, M., M. Noor-ul-Ane, K. Zia, A. Nasreen and M. Hasan. 2010. The correlation of abiotic factors and physico-morphic characteristics of (*Bacillus thuringiensis*) Bt transgenic cotton with whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidae) and jassid, *Amrasca devastans* (Homoptera: Jassidae) populations. Afr. J. Agric. Res., 5: 3102-3107.

Asif, M.U., R. Muhammad, M.H. Khan and M. Sohail. 2019. Seasonal population dynamics of cotton jassid (*Amrasca devastans*) in different cotton varieties under field conditions.

J. Ent. Res., 43(3): 315-318. https://doi.org/10.5958/0974-4576.2019.00058.6

Asif, M.U., R. Muhammad, M.H. Khan, M. Sohail and M. Awais. 2020. Incidence and population dynamics of thrips (*Thrips tabaci*) on different cotton varieties in Tandojam, Sindh, Pakistan. Int. J. Biol. Biotech., 17(4): 783-788.

Babar, T.K., H. Karar, M. Hasnain, M.F. Shahzad, M. Saleem and A. Ali. 2013. Performance of some transgenic cotton cultivars against insect pest complex, virus incidence and yield. Pak. J. Agric. Sci., 50(3): 367-372.

Babu, S.R. and M.L. Meghwal. 2014. Population dynamics and monitoring of sucking pests and bollworms on B*t* cotton in humid zone of Southern Rajasthan. Bioscan, 9: 629-632.

Chandani, S., Kamble and T.V. Sathe. 2015. Incidence and host plants for *Amrasca biguttula* (Ishida) from Kolhapur Region, India. Int. J. Dev. Res., 5: 3658–3661.

Chaudhary, G.Q., 1976. Pest control in cotton production. Proc. Cotton Prod. Sem. Org. by ESSO, Pesticide Co. Ltd. Pakistan. pp. 114-118.

Chaudhuri, G.B., T.H. Bharpoda, J.J. Patel, K.I. Patel and J.R. Patel. 1999. Effect of weather on activity of cotton bollworms in middle Gujarat. J. Agrometerol., 1: 137–142.

Chemeune, A., C. Ecole and A. Sidumo. 2007. Effect of strip intercropping for management of American bollworm, *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) on cotton *Gossypium hirsutum* in Morrumbala district. Afr. Crop Sci. Conf. Proc., 8: 1049-1052.

Crummay, F.A. and B.W. Atkinson. 1997. Atmospheric influences on light-trap catches of the brown plant hopper rice pest. Agric. For. Meteorol., 88: 181–197. https://doi.org/10.1016/S0168-1923(97)00040-3

Dhawan, A., K.S.A. Kamaldeep and S. Sarika. 2009. Distribution of mealybug *Phennacoccus solenopsis* Tinsely in cotton with relation to weather factors in south western districts of Punjab. J. Entomol. Res., 33: 59-63.

Drake, V.A., H.K., Wang and I.T. Harman. 2002. Insect monitoring radar: remote and network operation. Comput. Electron. Agric., 35: 77–94. https://doi.org/10.1016/S0168-1699(02)00024-8

Farooq, A., J. Farooq, A. Mahmood, A. Batool, A. Rehman, A. Shakeel, M. Riaz, M.T.H. Shahid and S. Mehboob. 2011. An overview of cotton leaf curl virus disease (CLCuVD) a serious threat to cotton productivity. Aust. J. Crop Sci., 5: 1823–1831.

Ghafoor, A., M. Hassan, Z.H. Alvi and S. Kousar. 2011. Impact of different varieties of stub cotton on population dynamics of whitefly at Faisalabad, Pakistan. Pak. J. Zool., 43: 25-28.

Gogoi, I. and B.C. Dutta. 2000. Seasonal abundance of cotton jassid, *Amrasca biguttula biguttula* (Ishida) on okra. J. Agric. Sci. Soc., 13: 22-26.

Hamburg, H.V. and P.J. Guest. 1997. The impact of insecticide arthropods in cotton agro ecosystem in South Africa. Arch. Environ. Contam. Toxicol., 32: 63–68. https://doi.org/10.1007/s002449900156

Hameed A., M.S. Shahzad, A. Mehmood, S. Ahmad and N. Islam, 2014. Forecasting and modeling of sucking insect complex of cotton under agroecosystem of Multan, Punjab, Pakistan. Pak. J. Agri. Sci., 51(4): 997-1003.

Hanchinal, S.G., B.V. Patil, M. Bheemann and A.C. Hoshmani. 2010. Population dynamics of *Phenacoccus solenopsis* Tinsley and its natural enemies on Bt cotton. Karnatka J. Agri. Sci., 23: 137-139.

Hirao, T.M., M. Murakami and A. Kashizaki. 2008. Effects of mobility on daily attraction to light traps: Comparison between lepidopteran and coleopteran communities. Insect Conserv. Div., 1: 32–39. https://doi.org/10.1111/j.1752-4598.2007.00004.x

Kalkal, D., R. Lal, K.K. Dahiya and Y.P. Bharti. 2013. Population dynamics of sucking pest and its correlation with abiotic factors. Agriways, 2: 3-29.

Kannan, M., S. Uthamasamy and S. Mohan. 2004. The impact of insecticides on sucking insect pest and natural enemy complex of transgenic cotton. Curr. Sci., 86(5): 726-729.

Khan, M.J., M.S. Zia and M. Qasim. 2010. Use of pesticides and their role in environmental pollution. Int. J. Environ. Ecol. Eng., 4(12): 621-627.

Khuhro, S.N., F. Ahmad, A.M. Kalroo, K. Abdullah and M.A. Talpur. 2015. Monitoring and population dynamics of pink bollworm on cotton in different cotton growing areas of Sindh-Pakistan. Int. J. Interdiscip. Res. Sci. Soc. Cult., 1(2): 51-60.

Kingsolver, J.G., 1989. Weather and the population dynamics of insects: Integrating physiological

Links Researchers

and population ecology. Physiol. Zool., 62(2): 314–334. https://doi.org/10.1086/physzool.62.2.30156173

Klueken, A.M., B. Hau, B. Ulber and H.M. Poehling. 2009. Forecasting migration of cereal aphids (Hemiptera: Aphididae) in autumn and spring. J. Appl. Entomol., 133: 328–344. https://doi.org/10.1111/j.1439-0418.2009.01387.x

Kumar, K.S., B.K. Shivanna, M. Manjunatha, P.R. Somashekharappa, H.S.I. Khan, S.H. Babu, B.V. Raghunath and B.R. Soumya. 2012. Seasonal incidence of pink bollworm, *Pectinophora gossypiella* (Saunders) in Bt cotton under kharif season. Environ. Ecol., 30(3): 695-698.

Lewis, T., 1981. Pest monitoring to aid insecticide use. Philos. Trans. R. Soc. B, Biol. Sci., 295: 153–162. https://doi.org/10.1098/rstb.1981.0129

Merril, S.C., A. Gebre-Amlak, J.S. Armstrong and F.B. Pearirs. 2010. Nonlinear degree-day models of the sunflower weevil (Curculionidae: Coleoptera). J. Econ. Entomol., 103: 303–307. https://doi.org/10.1603/EC09297

Murugan, M. and S. Uthamasamy. 2001. Dispersal behavior of cotton whitefly, *Bemisia tabaci* under cotton based garden land agro ecosystem of Coimbatore. Madras Agric. J., 88: 1–6.

Panickar, B.K. and J.B. Patel. 2001. Population dynamics of different species of thrips on chilli, cotton and pigeon pea. Ind. J. Ent., 63: 170–175.

Patel, H.V., K.G. Patel, S.K. Chawda and M.R. Siddhapara. 2013. Impact of abiotic factors on population dynamics of insect pest of jatropha in south Gujarat. Bioscan, 8: 91–93.

Sahito, H.A., G.H. Abro, S.A. Memon, B. Mal and R. Mahmood. 2012. Influence of abiotic factors on population development of *Bemisia tabaci* infesting *Abelmoschus esculentus*. Int. Res. J. Pl. Sci., 3: 12-18.

Salman, M., A. Masood, M. Arif, S. Saeed and M. Hamed. 2011. The resistance levels of different cotton varieties against sucking insect pests complex in Pakistan. Pak. J. Agric. Engg. Vet. Sci., 27: 168-75.

Shah, I.A., T.H. Malik, I.R. Khan and Z. Hussain. 2017. Screening of USDA cotton accessions against sucking insect pests complex and cotton leaf curl virus (Clcuv) disease with major emphasis on abiotic factors. Pak. J. Zool., 49(4): 1159-1173. https://doi.org/10.17582/journal.pjz/2017.49.4.1159.1173

Shah, M.A., N. Memon and A.A. Baloch. 2011. Use of sex pheromones and light traps for monitoring the population of adult moths of cotton bollworms in Hyderabad, Sindh, Pakistan. Sarhad J. Agric., 27(3): 435-442.

Sharma, A.S.R., Y. Rama Reddy, K.K. Ashok and Y. Padmalatha. 2015. Seasonal dynamics of insect pests of cotton in scarce rainfall zone, Andhra Pradesh, 4 Congress on Insect Science "Entomology for Sustainable Agriculture, pp. 43.

Shinde, P.R., U.B. Hole and P.V. Patil. 2018. Seasonal population fluctuation of pink bollworm, *Pectinophora gossypiella* (Saund.) as monitored by gossyplure. J. Entomol. Zool. Stud., 6(5): 1998-2000.

Shivanna, B.K., D.N. Nagaraja, M.K. Manjunatha and M.I. Naik. 2009. Seasonal incidence of sucking insect pests on Bt cotton. Karnatka J. Agric. Sci., 22: 666-667.

Sorejani, M., 1998. Current trend in pesticide usage in some Asian countries. Rev. Appl. Ent., 77: 219–234.

Tayyib, M., A. Sohail, Shazia, A. Murtaza and F.F. Jamil. 2005. Efficacy of some new- chemistry insecticides for controlling the sucking insect pests and mites on cotton. Pak. Entomol., 27(1): 63-66.

Umar, M.S., M.J. Arif, M.A. Murtaza, M.D. Gogi and M. Salman. 2003. Effect of abiotic factors on the population fluctuation of whitefly, *Bemisia tabaci* (Gen.) in nectaried and nectariless genotypes of cotton. Int. J. Agric. Biol., 5: 362–363.

Wahla, M.A., J. Arif and M. Afzal. 1996. The impact of physical factors on the population dynamics of sucking pest complex of "FH-87" cotton variety. Pak. Entomol., 18: 566–585.

Wallner, W.E., 1987. Factors affecting insect population dynamics: Differences between outbreak and non out break species. Annu. Rev. Entomol., 32(1): 317–340. https://doi.org/10.1146/annurev.en.32.010187.001533

Zalucki, M.P. and M.J. Furlong. 2005. Forecasting *Helicoverpa* populations in Australia: A comparison of regression based models and a bioclimatic based modeling approach. Insect Sci., 12: 45–46. https://doi.org/10.1111/j.1672-9609.2005.00007.x