Research Article

Field Evaluation of Host-Parasitoid Scenario in Different Varieties of Cotton

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Abstract | Cotton crop is attacked by several sucking (whitefly, thrips and jassid) and chewing (american bollworm, spotted bollworm, pink bollworm and armyworm) insect pests, which severely affects its quality and quantity. Cotton also contains the populations of parasitoids i.e. *Trichogramma* spps., Braconid wasps and *Encarsia* spps., which act to reduce the population of these notorious insect pests. Cotton plants shows genetic resistance or tolerance against these insect pests. In the current experiment six varieties of cotton *i.e.* CIM-496, CIM-534, NIAB-111, MNH-786 and Bt-121 were sown in the field under sprayed and un-sprayed condition to check the genetic resistance or tolerance against these insect pests and to also check the population of the parasitoids. It was observed that MNH-786 and Bt-121 were the most resistant or tolerant varieties against the insect pests but the pesticide application would still be required to keep their population below the economic threshold level. Population of insect pests and parasitoids significantly reduced using insecticides. In Pakistan, environmental friendly insecticides need to be encouraged to avoid their deleterious effects on beneficial insects.

Received | June 21, 2021; **Accepted** | March 07, 2022; **Published** | July 28, 2022
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Citation | Faheem, U., Q. Ali, M. Hussain, A. Ahmad, T. Nazir, G. Ahmad, I. Ahmad, M. Mobeen, H. Hussnain and N.H. Ahmad. 2022. Field evaluation of host-parasitoid scenario in different varieties of cotton. *Sarhad Journal of Agriculture,* 38(3): 1007-1016.
DOI | https://dx.doi.org/10.17582/journal.sja/2022/38.3.1007.1016
Keywords | Host, Parasitoid, Varieties, Insecticides and Cotton

Introduction

Cotton contributes significantly in foreign earnings being a non-food cash crop. It accounts for 0.8 percent in Gross Domestic Product and 4.1 percent in value added in agriculture. Though, this year the cotton production was 6.9 percent less than the target. This is predominantly due to the shortage of irrigation water, un-favorable weather conditions and heavy flare up of sucking and chewing pest complexes (Anonymous, 2020).

Both sucking and chewing type of insect pest are observed on cotton crop, more than 1346 mites and insect pests have been recorded throughout the world. In Pakistan, 145 insect pests were recorded (Haque, 1994). These insect pests cause significant damage during cotton production. The estimated losses fall within the range of 20-40 percent due to these pests and diseases (Ahmad, 2003).

Many types of natural enemies also exist in cotton crop in addition to these insect pests. It has been observed that populations of these natural enemies alone can noticeably be lower pest populations in cotton. A great number of insect pest eggs are consumed by these natural enemies or destroyed by rain and wind before hatching (Fye, 1979; Mabbett and Nachapong, 1983; Nuessly, 1986).

The most severe limitation to the potential of predators and parasitoids in crops is disturbance through the extensive use of insecticides with broad spectrum toxicity against both insect pests and their natural enemies (Newsom *et al*., 1976; Croft, 1990). The most important example of this is found in the cotton where insecticide use disturbs the control of key insect pests and may cause the outbreak of secondary pests (Leigh *et al*., 1966; Eveleens*et al*., 1973; Stoltz and Stern, 1978). In Pakistan, broad spectrum insecticides have been used, which have the toxicity both to the pests and natural enemies. Over/misuse of these broad-spectrum insecticides can lead to the eradication of population of these natural enemies and give rise to phenomena such as pest resurgence, occurrence of secondary pests, and selection of populations of resistant insects (Ahmed, 1995).

Stern *et al*. (1959) given the concept of Integrated Pest Management (IPM) by using both chemical and biological control in agricultural ecosystem. However, the population of these natural enemies is problematic to maintain when insecticides are applied to control these insect pests. It has been observed that against the insecticides natural enemies are more sensitive as compared to the insect pests. To maintain natural enemies in IPM systems, natural enemies should be resistant or tolerant to several groups of insecticides.

Host Plant Resistance (HPR) plays a significant role in managing insect pest population and protection of predators and parasitoid in an agricultural ecosystem (Farid *et al*., 1998; Francis *et al*., 2001; Messina and Sorenson, 2001; Giles *et al*., 2002). Use of varieties that resist or tolerate the attack of insect pests has been a major tool in reducing the use of insecticides and in developing IPM strategies. The HPR provides management of insect pests without any additional cost. It is also economical and environmentally safe (Pedigo, 1989; Khan and Sexena, 1998).

In Pakistan, resistance in several cultivars of cotton was monitored against sucking insect pest (Arif *et al*., 2004; Pathan *et al*., 2007; Amjad *et al*., 2009; Khan, 2011; Karar *et al*., 2020) as well as against chewing bollworms (Ahmad *et al*., 2003; Aslam *et al*., 2004; Razaq *et al*., 2004; Nasreen *et al*., 2004; Jamshed *et al*., 2008; Din *et al*., 2016).

The objectives of the following study was to check the population fluctuation of insect pests and their parasitoids on various varieties of cotton throughout the season, under sprayed and un-sprayed conditions and to screen out the most tolerant variety of cotton against different insect pests.

Materials and Methods

Study site

The trial was performed at the Agricultural Research Area of Cotton Research Institute, Multan, Punjab, Pakistan during the year 2018.

Varieties

There were six cotton varieties were sown in the trial, which were CIM-496, CIM-534, NIAB-111, MNH-786 and Bt-121.

Experimental design

The trial was laid out in a split plot design. In the first main plot insecticides were applied to manage the insect pest population and the second plot was left unsprayed. Six varieties of cotton were sown in the subplots. There were four replications of each treatment. The plot size was maintained at 10x15 feet.

Agronomic practices

For seed bed preparation two cultivations followed by planking was done. One bag of DAP was applied at the time of seed bed preparation and two bags of Urea was applied at the time of flowering. The varieties were sown on 16.05.2018 and seeds were sown manually with plant-to-plant distance 12 inches. The row-row distance was maintained at 30 inches.

Insecticides

The common and trade names of insecticides along with spray dates are given in the Table 1.

Table 1: *Trade and common names of insecticides along with spray dates of insecticidal applications.*

Trade Name	Common Name	Spray Dates
Mospilon®	acetamiprid 20SP	19.06.2018
Confidor®	imidachloprid 200 SL	17.07.2018
Dimmer®	acephate 40 EC	14.08.2018
Match®	leufenuron 50 EC	04.09.2018

Table 2: *Fortnightly mean population of whitefly per leaf in different varieties of cotton under sprayed and unsprayed conditions during 2018 cropping season.*

Date	CIM-496		MNH-786		Bt-121		NIAB-111		CIM-534		
	S	US	S	US	S	US	S	US	S	US	Mean
Mid-June	5.75	6.00	4.75	5.00	5.25	4.75	5.00	5.75	5.50	5.75	5.35a
July	2.50	4.50	2.00	3.50	2.25	3.75	2.25	4.00	2.25	4.75	3.17cd
Mid-July	4.75	5.00	4.50	3.50	4.50	3.75	4.50	4.75	4.25	4.50	4.40b
August	1.75	3.50	1.50	2.50	1.75	2.75	1.75	2.50	1.50	3.50	2.30de
Mid-Aug	1.25	3.50	1.00	3.00	1.25	3.00	1.25	3.00	1.00	2.75	2.10e
September	2.50	4.25	2.00	3.50	2.25	3.00	2.25	4.25	2.25	4.00	3.02 de
Mid-Sept.	3.25	5.75	2.75	5.00	2.75	4.50	3.00	5.75	2.75	5.00	4.05bc
October	3.75	5.50	3.25	4.75	3.25	4.00	3.50	5.00	3.50	4.50	4.10bc
Mid-Oct.	2.50	4.50	2.00	3.50	2.00	4.00	2.25	4.25	2.00	4.25	3.12cd
Mean	3.11b	4.72a	2.64b	3.81ab	2.81b	3.72ab	2.86b	4.36a	2.78b	4.33a	
LSD for varieties	1.17										
LSD for date	0.92										

(Means were separated by DMR test at the 0.05% level of significance. Values sharing the same alphabets were not significantly different from each other), S= Sprayed plot, US= Unsprayed plot.

Sampling of host-parasitoid population

For the sampling of sucking insects (whitefly, thrips and jassid), five plants were observed randomly from each plot. From each plant three leaves (top, middle and bottom) were selected, and the population of the sucking insects was counted. The mean value was calculated to represent their population per leaf. For the sampling of chewing insects (american bollworm, armyworm, pink bollworm and spotted bollworm) and parasitoids (*Trichogramma* spps., Braconid wasps and *Encarsia* spps.) five plants were selected from each plot and mean population of chewing insects and parasitoids per plant were determined. Population of parasitoids were calculated as per international guidelines.

Sampling frequency

Samplings were conducted on fortnight basis.

Statistical analysis

The data was analyzed by using MSTATC, computer software (MSU, 1982). The means of populations of insect pests and parasitoids on different varieties were separated by Least Significant Difference (LSD) Test at α= 0.05%.

Sucking insect pest scenario

Whitefly: In all varieties of cotton, the population of whitefly was significantly ($P<0.05$) reduced due to the application of insecticides. The population of whitefly was similar ($P>0.05$) on CIM-496, NIAB-111 and CIM-534. On un-sprayed field, the mean population of whitefly on MNH-786 and Bt-121 were 3.81 and 3.72, respectively as these varieties shown some sort of tolerance. The highest mean population of whitefly was observed during the 1st week of August where, the mean population per leaf was 4.50. On the other hand, the minimum population was observed during 1st week of July where the mean population was only 0.12 per leaf (Table 2).

Thrips: Table 3 indicates that the varieties MNH-786 and Bt-121 were found less susceptible against thrips. CIM-496, NIAB-111 and CIM-534 were found to be equally susceptible against thrips as in case of whitefly. Application of insecticides had significantly ($P<0.05$) reduced the population of thrips. The maximum population of thrips was observed during the mid-June and mid-August while the minimum population was observed during the start of July.

Jassid: It has been observed in Table 4 that the average population of jassid was above the ETL under un-sprayed conditions, while the application of insecticides managed the population of jassid. The most susceptible varieties of cotton against jassid were found to be CIM-496 and MNH-786. CIM-496 was found significantly ($P<0.05$) more susceptible than MNH-786. All other varieties were found similar ($P>0.05$) in susceptibility against the infestation of jassid. The highest population of jassid was found during the mid of June and the mid of July.

Table 3: *Fortnightly mean population of thrips per leaf in different varieties of cotton under sprayed and unsprayed conditions during 2018 cropping season.*

Date	CIM-496		MNH-786		Bt-121		NIAB-111		CIM-534		
	S	US	S	US	S	US	S	US	S	US	Mean
Mid-June	9.25	10.00	4.25	5.25	4.50	5.00	7.50	9.25	7.25	9.00	7.12a
July	4.25	8.75	2.00	4.75	2.75	5.50	4.00	8.75	3.75	8.00	5.25bcd
Mid-July	3.50	9.75	2.50	5.50	3.00	6.00	3.50	9.50	3.25	8.25	5.47bc
August	5.50	9.25	3.00	6.75	3.25	7.00	5.25	7.75	5.00	7.75	6.05ab
Mid-Aug	3.75	5.00	2.75	3.75	3.25	4.50	3.50	5.00	3.25	4.75	3.95d
September	4.50	6.25	1.25	2.00	1.75	2.75	4.50	6.25	4.25	6.00	3.95d
Mid-Sept.	3.00	6.50	2.00	4.75	2.00	5.25	3.75	6.75	2.75	6.25	4.30cd
October	3.25	7.75	2.50	5.50	2.75	5.75	3.25	7.50	2.75	7.25	4.82bcd
Mid-Oct.	2.50	7.50	2.75	5.25	3.50	5.75	4.00	7.75	3.00	7.25	4.92bcd
Mean	4.39bc	7.86a	2.56d	4.83b	2.97cd	5.78b	4.36bc	7.61a	3.92bcd	7.17a	
LSD for varieties	1.65										
LSD for date	1.29										

(Means were separated by DMR test at the 0.05% level of significance. Values sharing the same alphabets were not significantly different from each other), S= Sprayed plot, US= Unsprayed plot.

Table 4: *Fortnightly mean population of jassid per leaf in different varieties of cotton under sprayed and unsprayed conditions during 2018 cropping season.*

Date	CIM-496		MNH-786		Bt-121		NIAB-111		CIM-534		
	S	US	S	US	S	US	S	US	S	US	Mean
Mid-June	1.50	2.75	1.00	1.75	1.50	2.50	1.25	2.25	1.25	1.75	1.75a
July	0.75	2.00	0.50	1.50	0.75	2.00	0.50	1.75	0.50	1.50	1.17b
Mid-July	0.75	4.00	0.00	2.50	0.50	3.75	0.50	3.50	0.50	3.00	1.90a
August	1.00	2.00	0.25	1.75	0.50	2.00	0.75	2.00	0.50	1.75	1.25b
Mid-Aug	1.00	1.25	0.25	1.00	0.75	1.25	0.50	1.00	0.25	1.00	0.82b
September	0.75	1.25	0.50	1.25	0.50	1.00	0.75	1.25	0.50	1.25	0.90b
Mid-Sept.	0.00	2.25	0.00	2.00	0.00	2.25	0.00	2.00	0.00	2.00	1.05b
October	0.00	2.50	0.00	1.75	0.00	2.50	0.00	2.25	0.00	2.00	1.10b
Mid-Oct.	0.75	1.25	0.00	1.00	0.50	1.25	0.25	1.25	0.25	1.25	0.77b
Mean	0.72b	2.13a	0.28b	1.61a	0.55b	2.06a	0.50b	1.91a	0.42b	1.72a	
LSD for varieties	0.60										
LSD for date	0.47										

(Means were separated by DMR test at the 0.05% level of significance. Values sharing the same alphabets were not significantly different from each other), S= Sprayed plot, US= Unsprayed plot.

Chewing pest scenario

American bollworm: Table 5 shows that CIM-496 is the most susceptible against american bollworm attack. MNH-786 and CIM-496 were found equally susceptible (P>0.05) against american bollworm attack. Other varieties were found less susceptible (P<0.05) as compared to MNH-786 and CIM-496 against american bollworm. Highest population of american bollworm was observed during the middle of September to the start of October. There was no incidence of american bollworm during the mid of June.

Armyworm: Against armyworm attack MNH-786 and Bt-121 were found to be the most resistant varieties of cotton. The tolerance level was found to be similar (P>0.05) to each other. Remaining varieties were observed to be susceptible against armyworm. Spray of insecticides significantly (P<0.05) reduced the infestation of armyworm. There was no incidence of armyworm un-till the mid of August. The highest population of armyworm was found from the start of September to the start of October (Table 6).

Table 5: *Fortnightly mean population of American bollworm per plant in different varieties of cotton under sprayed and unsprayed conditions during 2018 cropping season.*

Date	CIM-496		MNH-786		Bt-121		NIAB-111		CIM-534		
	S	US	S	US	S	US	S	US	S	US	Mean
Mid-June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00d
July	0.00	0.50	0.00	0.50	0.00	0.50	0.00	0.50	0.00	0.50	0.25cd
Mid-July	0.25	1.25	0.25	1.25	0.25	1.25	0.25	1.25	0.25	1.25	0.75bc
August	0.00	0.25	0.00	0.25	0.00	0.25	0.00	0.25	0.00	0.25	0.12cd
Mid-Aug	0.25	0.75	0.75	0.75	0.50	0.50	0.25	0.75	0.25	0.75	0.55bcd
September	0.25	1.25	0.25	1.25	0.25	1.25	0.25	0.75	0.25	1.25	0.70bcd
Mid-Sept.	1.50	5.00	0.25	3.00	0.25	2.25	1.50	4.25	1.25	4.25	2.35a
October	2.00	4.7	0.50	2.25	0.50	1.50	1.25	1.75	0.75	3.25	1.85a
Mid-Oct.	1.00	3.25	0.00	2.25	0.00	1.25	0.50	1.25	0.00	2.25	1.17b
Mean	0.58cd	1.89a	0.22d	1.28abc	0.19d	0.97bcd	0.44cd	1.19abc	0.30d	1.53ab	
LSD for varieties	0.82										
LSD for date	0.65										

(Means were separated by DMR test at the 0.05% level of significance. Values sharing the same alphabets were not significantly different from each other), S= Sprayed plot, US= Unsprayed plot.

Table 6: *Fortnightly mean population of armyworm per plant in different varieties of cotton under sprayed and un-sprayed conditions during 2018 cropping season.*

Date	CIM-496		MNH-786		Bt-121		NIAB-111		CIM-534		
	S	US	S	US	S	US	S	US	S	US	Mean
Mid-June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00d
July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00d
Mid-July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00d
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00d
Mid-Aug	1.00	3.50	0.25	2.00	0.50	2.50	0.50	2.75	1.00	3.50	1.75c
September	4.75	10.75	1.75	6.00	1.75	6.50	1.75	7.25	4.00	8.75	5.32a
Mid-Sept.	5.50	7.50	2.50	4.25	2.50	6.00	4.75	7.50	4.75	7.50	5.27a
October	4.00	9.75	0.75	4.50	1.50	5.25	3.50	9.25	3.50	9.25	5.12a
Mid-Oct.	2.00	5.25	0.50	3.00	1.25	4.50	1.25	4.50	1.25	4.50	2.80b
Mean	1.92cd	4.08a	0.64f	2.19bc	0.83ef	2.75b	1.31de	3.47a	1.61cd	3.72a	
LSD for varieties	0.65										
LSD for date	0.51										

(Means were separated by DMR test at the 0.05% level of significance. Values sharing the same alphabets were not significantly different from each other), S= Sprayed plot, US= Unsprayed plot.

Pink bollworm: CIM-496 and NIAB-111 were found to be the most susceptible varieties of cotton against pink bollworm attack.1.22 and 0.93 larvae per plant were their average population, respectively. Again the spray of insecticides had significant (P<0.05) reduced pink bollworm population. The highest population of pink bollworm was found in the middle of September (Table 7).

Spotted bollworm: Bt-121 and MNH-786 were the most resistantor tolerant varieties against spotted bollworm attack. Spray application during the of experiment significantly (P<0.05) lowers the population of spotted bollworm in different varieties of cotton. Most infestation of spotted bollworm was observed during the start of September. There was no incidence of spotted bollworm from mid-June to start of August (Table 8).

Parasitoid's scenario

***Trichogramma* spps.:** It can be seen from Table 9 that under un-sprayed conditions MNH-786 contains the

Table 7: *Fortnightly mean population of pink bollworm per plant in different varieties of cotton under sprayed and unsprayed conditions during 2018 cropping season.*

Date	CIM-496		MNH-786		Bt-121		NIAB-111		CIM-534		
	S	US	S	US	S	US	S	US	S	US	Mean
Mid-June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00d
July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00d
Mid-July	0.25	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.05d
August	0.00	0.50	0.00	0.25	0.00	0.25	0.00	0.25	0.00	0.25	0.15d
Mid-Aug	0.25	0.75	0.00	0.25	0.00	0.25	0.25	0.50	0.00	0.25	0.25cd
September	1.75	1.25	0.25	0.75	0.25	0.75	0.25	0.75	0.25	0.75	0.55c
Mid-Sept.	1.00	3.75	0.00	1.25	0.00	0.50	0.50	3.50	0.00	2.75	1.40a
October	1.00	3.25	0.25	1.00	0.25	0.00	0.25	2.25	0.25	1.25	0.97b
Mid-Oct.	1.00	2.75	0.25	1.25	0.25	0.00	0.50	2.25	0.50	1.75	1.05b
Mean	0.50cde	1.36a	0.08e	0.53cd	0.08e	0.19de	0.22de	1.06ab	0.11de	0.78bc	
LSD for varieties	0.41										
LSD for date	0.32										

(Means were separated by DMR test at the 0.05% level of significance. Values sharing the same alphabets were not significantly different from each other), S= Sprayed plot, US= Unsprayed plot.

Table 8: *Fortnightly mean population of spotted bollworm per plant in different varieties of cotton under sprayed and unsprayed conditions during 2018 cropping season.*

Date	CIM-496		MNH-786		Bt-121		NIAB-111		CIM-534		
	S	US	S	US	S	US	S	US	S	US	Mean
Mid-June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00e
July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00e
Mid-July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00e
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00e
Mid-Aug	1.00	2.75	0.50	1.25	0.25	1.00	1.00	1.75	0.50	1.25	1.12d
September	4.25	6.50	1.00	3.75	0.75	2.75	3.25	5.50	2.50	4.50	3.47a
Mid-Sept.	2.50	4.75	0.75	2.75	0.50	1.75	1.75	3.75	1.50	3.50	2.35b
October	1.75	5.00	0.25	1.50	0.25	0.75	1.00	3.75	0.25	2.25	1.67c
Mid-Oct.	1.00	4.50	0.25	1.50	0.25	0.50	0.50	3.25	0.50	2.25	1.45cd
Mean	1.17cd	2.61a	0.31ef	1.19cd	0.22f	0.75def	0.83de	2.00b	0.58ef	1.53bc	
LSD for varieties	0.56										
LSD for date	0.44										

(Means were separated by DMR test at the 0.05% level of significance. Values sharing the same alphabets were not significantly different from each other), S= Sprayed plot, US= Unsprayed plot.

highest population ($P<0.05$) of *Trichogramma spps.* as compared to the other varieties. Application of insecticides significantly ($P<0.05$) lowers the population of these Lepidopterous egg parasitoids. There was no seasonal fluctuation in the population of *Trichogramma spps.*

Braconid wasps: The population of braconid wasps was also found similar throughout the season. The highest population of this parasitoid was observed on Bt-121, NIAB-111 and CIM-534. The population was similar to each other. It was, however, determined that application of insecticides had no significant ($P>0.05$) effect on braconid population (Table 10).

***Encarsia* spps.:** Table 11 indicates that the population of *Encarsia* spps. was similar ($P>0.05$)in different varieties of cotton. Spray of the insecticides significantly ($P<0.05$) reduced the population of *Encarsia* spps. There were no significant differences in the population of *Encarsia* spps. during the course of the present study.

Table 9: *Fortnightly mean population of Trichogramma spps. per plant in different varieties of cotton under sprayed and unsprayed conditions during 2018 cropping season.*

Date	CIM-496		MNH-786		Bt-121		NIAB-111		CIM-534		
	S	US	S	US	S	US	S	US	S	US	Mean
Mid-June	0.50	1.50	1.75	1.75	1.75	1.25	0.50	1.50	1.00	1.75	1.32a
July	0.25	2.00	0.25	2.75	0.50	2.75	0.25	2.00	0.25	2.25	1.32a
Mid-July	1.00	1.25	1.50	2.00	1.50	1.50	1.00	1.25	1.50	1.50	1.40a
August	0.25	1.50	0.50	2.25	1.25	2.50	0.50	1.50	0.50	2.00	1.27a
Mid-Aug	1.50	1.00	1.25	2.00	1.25	2.25	1.00	1.25	1.25	1.25	1.40a
September	0.00	1.50	0.00	2.25	0.25	2.25	0.00	1.50	0.00	2.00	0.97a
Mid-Sept.	0.00	1.75	0.50	5.25	0.50	1.00	0.50	1.00	0.50	1.00	1.20a
October	0.25	2.25	0.50	3.00	0.50	3.00	0.25	2.25	0.50	2.25	1.47a
Mid-Oct.	0.25	1.50	0.25	2.25	0.50	2.50	0.25	1.25	0.25	1.00	1.00a
Mean	0.44d	1.58bc	0.72d	2.61a	0.89cd	2.11ab	0.47d	1.50bc	0.64d	1.67b	
LSD for varieties	0.748										
LSD for date	0.587										

(Means were separated by DMR test at the 0.05% level of significance. Values sharing the same alphabets were not significantly different from each other), S= Sprayed plot, US= Unsprayed plot.

Table 10: *Fortnightly mean population of Braconid wasps per plant in different varieties of cotton under sprayed and unsprayed conditions during 2018 cropping season.*

Date	CIM-496		MNH-786		Bt-121		NIAB-111		CIM-534		
	S	US	S	US	S	US	S	US	S	US	Mean
Mid-June	1.75	1.25	3.00	1.25	3.25	3.75	1.75	3.75	2.50	3.75	2.60a
July	1.25	1.50	2.50	1.00	2.75	4.00	1.25	3.50	2.00	3.50	2.32a
Mid-July	1.50	1.50	1.00	1.00	4.50	6.50	3.50	4.50	4.50	5.50	3.40a
August	1.75	1.00	1.75	1.00	3.25	5.50	2.00	5.25	2.00	5.50	2.90a
Mid-Aug	1.50	1.00	1.75	1.00	3.25	5.00	2.25	4.50	3.50	4.50	2.82a
September	1.25	1.50	2.25	1.00	3.50	6.00	1.50	4.50	3.00	5.00	2.95a
Mid-Sept.	2.00	2.50	1.00	1.00	2.75	3.50	2.00	3.25	2.75	3.25	2.40a
October	1.75	1.25	2.25	2.00	2.75	4.25	2.00	3.75	2.00	4.00	2.60a
Mid-Oct.	1.00	1.50	2.25	1.00	2.75	3.75	1.75	3.25	1.75	3.75	2.25a
Mean	1.53c	1.44c	1.97bc	1.14c	3.19abc	4.69a	1.97bc	4.03ab	2.67abc	4.31a	
LSD for varieties	2.106										
LSD for date	1.653										

(Means were separated by DMR test at the 0.05% level of significance. Values sharing the same alphabets were not significantly different from each other), S= Sprayed plot, US= Unsprayed plot.

Result and Discussion

Cotton is the main cash crop in Pakistan and the successful production of this crop needs heavy sprays of insecticides which resulted in high cost of production. These heavy applications of insecticides are mainly due to the reason that insecticide resistance has been developed by the insect pests. Due to this main reason the number and doses of insecticides had been increased to control these insect pests. Cotton production can be made profitable by adopting Integrated Pest Management (IPM). By utilizing all the management techniques in a compatible manner we could be able to reduce the population beneath the economic threshold level (ETL).

In the present work, on different varieties of cotton significant variation in population of insect pest has been observed. This variation in pest population has also been reported by the earlier scientists (Bughio*et al*., 1984; Mohan *et al*., 1996; Ali *et al*., 1999; Fairbanks *et al*., 2000; Nath *et al*., 2000; Jackson *et al*., 2000).

Table 11: *Fortnightly mean population of Encarsia spps. per leaf in different varieties of cotton under sprayed and unsprayed conditions during 2018 cropping season.*

Date	CIM-496		MNH-786		Bt-121		NIAB-111		CIM-534		
	S	US	S	US	S	US	S	US	S	US	Mean
Mid-June	0.75	1.75	2.25	2.00	1.25	1.00	0.50	1.25	0.50	1.50	1.27a
July	1.00	1.75	2.25	1.75	2.00	1.25	0.75	1.75	1.50	1.75	1.57a
Mid-July	0.25	1.50	3.25	4.25	2.00	1.75	1.00	1.50	1.50	4.00	2.10a
August	0.25	1.50	3.75	5.50	3.00	3.00	0.75	3.25	0.75	4.00	2.57a
Mid-Aug	0.50	2.25	1.50	3.00	1.00	2.00	0.50	2.00	0.75	3.00	1.65a
September	0.75	2.00	0.75	2.25	0.75	3.50	0.50	2.00	0.50	3.50	1.65a
Mid-Sept.	0.50	2.50	1.75	1.00	1.25	3.00	0.50	2.25	0.50	2.75	1.60a
October	0.50	2.00	2.75	1.75	1.75	2.00	1.00	2.75	1.00	3.00	1.85a
Mid-Oct.	0.50	2.50	2.50	1.25	1.75	1.00	0.75	2.00	1.25	3.00	1.65a
Mean	0.55c	1.97abc	2.31abc	2.53ab	1.64abc	2.06abc	0.69c	2.08abc	0.92bc	2.94a	
LSD for varieties	1.78										
LSD for date	1.39										

(Means were separated by DMR test at the 0.05% level of significance. Values sharing the same alphabets were not significantly different from each other), S= Sprayed plot, US= Unsprayed plot.

Non-significant differences were observed among the varieties against sucking insect pests. Bt-121 and MNH-786 had shown some sort of resistance as matched to other varieties against both sucking and chewing insect pests. Their resistance was significantly higher as compared to other observed varieties. Transgenic varieties possessing *Bacillus thuringiensis* (Bt) have become a vital part of IPM program, particularly against the bollworms in cotton (Torres and Ruberson, 2005). In the present work, Bt-121 was the only *Bt*. Variety against the chewing insect pests, which interestingly did not show complete resistance. Jamshed*et al*. (2008) observed the same results during the evaluation of chewing pest infestation in *Bt* and non-*Bt* cotton varieties.

Parasitoids can play a vital role in the reduction of host species abundance within and across generations (Hawkins, 1994). Commercial pesticide use within a region can have a dramatic impact on the temporal abundance patterns of predators and parasitoids (Scholz *et al*., 1998). Interestingly, during the current study there was no temporal population fluctuation was observed of any of the studied parasitoid. But a significant variation in the population of parasitoids in different varieties of cotton. Application of insecticides significantly reduced the population of parasitoids in sprayed plots.

Spray of insecticides significantly maintained the population of insect pests below the ETL. Our results showed that the spray of insecticides may still be essential to keep the population of insect pest in check for inexpensive cotton production.

In unsprayed field the average population of whitefly and thrips was below the economic threshold level but the average population of jassid was above it. Similar, condition was found by Pathan *et al*. (2007) during his work on sucking insect pests at cotton. It may be due to the fact that the population built up of one species may suppress the population built up of other species. To keep the population of chewing insect pests and jassid below the economic threshold level application of insecticides would still be required. Effective pest resistant variety has been therefore described as reducing or maintaining pest population below threshold damage (Aslam *et al*., 2004).

Conclusions and Recommendations

From the present study it can be inferred that Bt-121 and MNH-786 were the most tolerant varieties against sucking and chewing insect pests but the application of environmentally friendly insecticides would still be required to keep the population of insect pests below the economic threshold level. Population of insect pests and parasitoids significantly reduced using insecticides.

Acknowledgments

The first Author is highly thankful to Mr. Muhammad Ashraf, Mr. Zamir Hussain and Mr. Zamir Ahmad, Entomological Research Sub Station, Multan for their kind support during the work.

Novelty Statement

This esearch work is novel in focusing on how different varieties and environmental factors affect the population of insect pests and their natural enemies.

Author's Contributions

Umair Faheem: Manuscript writing, data analysis and conduct of experiment.
Qurban Ali, Mussurrat Hussain, Abrar Ahmad, Tamsila Nazir, Ghayour Ahmad, Idrees Ahmad, Madiha Mobeen, Hammad Hussnain and Nadia Hussain Ahmad: Conducted experiment.

Conflict of Interest
The Authors have no conflict of interest regarding the publication of manuscript.

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