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Research Article

Seasonal Incidence of Pink Bollworm Pectinophora Gossypiella (Saunders) in Bt Cotton

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ABSTRACT

An investigation was undertaken to study the seasonal incidence of major sucking pests in Bt cotton during Kharif 2018 and 2019 at research farm of Department of Agril. Entomology, College of Agriculture, V NMKV, Parbhani. The results revealed that the The pheromone trap catches ranged from 03.00 to 125.00 male moths per trap per week during Kharif 2018, while it was 01.00 to 86.00 male moths per trap per week during Kharif 2019. The peak of pheromone trap catches was observed during 51st and 47th MW in 2018-19 and 2019-20, respectively. The rosette flowers in Bt cotton ranged from 3.65 to 17.25 per cent in Kharif 2018. Corresponding values during Kharif 2019 was 2.14 to 29.85 per cent. The peaks of rosette flowers due to pink bollworm were detected during 46 th and 44th MW in 2018-19 and 2019-20, respectively. It was found that, 5.00 to 40.00 per cent green boll damage was observed during Kharif 2018. Corresponding values for Kharif 2019 were 1.67 to 85.00 per cent in Bt cotton. The peak of per cent green boll damage was reported during 47th and 48th MW in 2018-19 and 2019-20, respectively. Pink bollworm larval population per 20 green bolls in Bt cotton ranged from 2.00 to 21.00 during Kharif 2018, although during Kharif 2019 it was 2.00 to 40.00. The peak of PBW larval population per 20 green bolls was observed during 46th and 40th MW in 2018-19 and 2019-20, respectively. Per cent locule damage in green bolls ranged from 1.23 to 55.56 per cent during Kharif 2018, however during Kharif 2019 it ranged from 1.25 to 62.50 per cent. The peak of per cent locule damage in green bolls was observed during 46th and 47th MW in 2018-19 and 2019-20, respectively. Seasonal incidence of moth catches, larval population, green boll damage, rosette flowers and locule damage due to pink bollworm was more in 2019 than 2018 due to variation in weather parameters.

Keywords: Bt cotton; pink bollworm Pectinophora gossypiella (Saunders); seasonal incidence; correlation; regression

INTRODUCTION

Cotton is a major fibre crop of global significance, cultivated in more than seventy countries in the world. Cotton crop is playing an important role in economic, political and social affairs of the world. Cotton belongs to the family "Malvaceae" and genus "Gossypium". Cotton crop as commercial commodity plays an important role in industrial activity of nation, in terms of both employment generation and foreign exchange, Hence it is popularly known as "White Gold" and "Friendly Fibre"[1].

The major threat to the continued success of Bt crops is evolution of resistance by pests. While most target pest populations remain susceptible, resistance to Bt crops has been reported in one of the most devastating pests of cotton globally recently, the pink bollworm, evolved resistance to transgenic cotton that produces Bt toxin Cry 1 Ac in western India. Bt cotton is specially developed for the bollworms but sucking pests are emerging as prime insect pests causing severe losses in yield. Among major insect pests of cotton population of sucking pests was higher in Bt hybrids (Meenu) [2].

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There are several reasons attributed to this low yield, losses due to pests assume significant importance as cotton crop is a heaven for insects. A total of 1326 species of insects have been recorded on cotton (Kranti). The pest spectrum of cotton crop is quite complex comprising several species of the insects. Pink bollworm (Pectinophora gossypiella Saunders) account for a considerable yield loss to the extent of 36.2% (Kranti) [3].

In cotton, population buildup of various insects' pests have been found to be influenced by different parameters of climate. The insect being the member of biotic community interacts with other non-living (abiotic) components of the environment. The outcome of these interactions is population dynamics, the positive and negative growth of the population. Hence, the life system and abundance of insect can be understood by study of interaction between insect and abiotic factors. Appropriate manipulation of agro-ecosystem can aid in preventing economic damage by the insects. New technology to be developed in future for the management of insect pests will necessarily depend on knowledge of pertinent agro-ecosystem under particular situation. The determination of effect of different environmental factors on incidence of sucking pests and bollworm complex in cotton is essential for effective pest management. It may be possible to predict their occurrence on the basis of meteorological factors well in advance. This may help in making an effective and most economic use for farmer pest management armory. Timely preventive measures can be undertaken with less use of chemical insecticides and thus reducing harmful side effects on human being. Hence, attempt can be made for development of database useful for pest forecasting. This study will be very useful not only for forecasting the outbreak of bollworms but also in formulating effective management strategies [4].

MATERIAL AND METHODS

The field experiment with Bt cotton crop using variety RCH-659 BG-II was conducted at Research Farm of Department of Agril. Entomology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (MS)-India during Kharif 2018 and Kharif 2019. The experiment was conducted in unprotected plot with 10 m x 10 m size which was non-replicated and the plot was divided in four quadrants. Ten plants were randomly selected from each quadrant for observations. Observations were recorded during morning before 8.00 am in each meteorological week from untreated plot of RCH-2 BG –II cotton hybrid. The observations recorded during the course of investigation are seasonal activity of pink bollworm with different parameters [5].

Pheromone Trap Catch

Five pherosensor sleeve traps were erected at 1-2 m height in plot depending on the crop stage for monitoring the pink bollworm adult emergence from the first week of July, till the end of December during both seasons. Every week adult male moth catches in the pheromone traps were recorded[6].

Per Cent Rosette Flowers

The observations on rosette flowers due to pink bollworm infestation were recorded at weekly interval. In each week, after the initiation of flowers, ten plants were randomly selected for counting the total number of flowers and number of rosette flowers. Finally, per cent rosette flowers were worked out by using the following formula,

$$\text{Per cent Rosette flowers (\%)} = \frac{\text{Number of Rosette flowers}}{\text{Total number of flowers}} \times 100$$

Per Cent Green Boll Damage

Observations on the incidence of pink bollworm in green bolls were made at weekly intervals. For this purpose, 20 green bolls of three-week old, 20 green bolls from plot were plucked randomly
and brought to the laboratory. In laboratory, the number of da maged bolls was counted and expressed in terms of per cent green boll damage using formula,

$$\text{Per cent green boll damage} = \frac{\text{No. of damaged green bolls}}{\text{Total No. of green bolls observed}} \times 100$$

Pink bollworm larval population in green bolls

Observations on the incidence of pink bollworm in green bolls were made at weekly interval. For this purpose, 20 cotton green bolls were collected for estimating green boll damage and these bolls were cut opened along with ridges of the locules with the help of sharp cutter carefully and pink bollworm larvae of all the age groups were counted. Then total number of pink bollworm larvae per 20 bolls was worked out [7].

Per cent locule damage in green bolls

Observations on the locule damage in green bolls by pink bollworm were made at weekly interval. For this purpose, 20 cotton green bolls collected were cut opened along with ridges of the locules with the help of sharp cutter carefully and then total number of locules and damaged locules were counted and expressed in terms of per cent locule damage using formula [8].

$$\text{Per cent locule damage (\%)} = \frac{\text{Damaged locules}}{\text{Total number of locules}} \times 100$$

Meteorological data on weekly basis for Kharif seasons during the year 2018 and 2019 were obtained from meteorological observatory, Department of Agril. Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani from the same campus.

The data pertaining to seasonal activity of major insect pests was correlated with various weather factors. The relation between weather parameters and major insect pests in Bt cotton was studied. Simple correlation, simple regression and multiple regression studies were carried out [9].

RESULTS AND DISCUSSION

The data on moths trapped per trap, percent rosette flower, percent green boll damage, larval population per twenty bolls and percent locule damage in twenty green bolls during Kharif 2018 and Kharif 2019 in Bt cotton are presented in Table 1.

Pheromone trap moth catch

Pheromone sleeve traps were placed in a plot to observe the seasonal incidence of pink bollworm from the end of July, till the mid-January during both Kharif 2018 and Kharif 2019. The moth catches were recorded and presented meteorological week wise in table 1.

During the Kharif 2018, the adult trap catch of pink bollworm started from the month of July and it's ranged from 03.00 to 125.00 moths/trap/week. Thereafter, there was gradual increase in adult trap catches and a sudden sprut in moth emergence was observed from first week of November, corresponding to 44th MW (85.00 moths/trap/week) and continued at high level till the end of December corresponding to 52nd MW (57.00 moths/trap/week). First peak of moth catch was observed in 45th MW (123.00 moths/trap/week). Second peak with the highest trap catch was observed during 51st MW (125.00 moths/trap/week) then onwards the pink bollworm population gradually declined.

During Kharif 2019 the adult trap catch of pink bollworm started from the month of August and it's ranged from 01.00 to 86.00 moths/trap/week. The adult trap catch of pink bollworm increased gradually reaching to its first peak with the highest trap catch in the last week of November (47th MW) (86.00 moths/trap/week) and thereafter gradually declined till the end of season.

The findings of earlier workers are more or less in the line of present work Khan et al. (2002) who reported that the pink bollworm infestation during October. Monitoring with the pheromone traps indicated that the activity of PBW advanced to as early as August month (2004-2005). However, the peak activity of the pest was consistently high during end of the season (Radhika and Reddy, 2006). Sandhya et al. (2010) reported the adult trap catches of pink bollworm was started from the month of September and its build up was more or less steady till the second week of November. While, Ramesh Babu and Meghwal (2014) reported that the peaks of moth populations of pink bollworm were recorded during 41-52nd MW corresponding with larval population in field. Surwase (2017) reported maximum trapped moths were in the last week of November.

Rosette flowers due to pink bollworm P. gossypiella (Saunders)

During Kharif 2018 the data on rosette flowers due to pink bollworm in Bt cotton (Table 1) ranged from 3.65 to 17.25 per cent occurring from 38th MW. The rosette flowers were noticed from the period 38th MW to 02nd MW. The highest incidence was noticed in 46th MW (17.25 per cent). Thereafter it gradually declined to 3.27 per cent in 02nd MW and become nil at 3rd MW.

The rosette flowers during Kharif 2016 (Table 1) in Bt cotton ranged between 7.14 to 38.18 per cent. The rosette flowers started from 38th MW (7.14 per cent). The first peak with highest incidence was recorded in 44th MW (38.18 per cent). The second peak incidence was observed in 52nd MW (28.57 per cent).

However, the results of present findings are in contrast with (Arshad). who reported that the maximum numbers of rosette flowers observed on 30 July. As per Verma. (2017) the pink bollworm, P. gossypiella infestation on flowers found higher in 2nd week of September with intensity of 7 larvae per 30 flowers. According to Shinde et al. (2018) the peak of flower resetting was observed during 47th. In the same way, Sarode. (2020) reported that the percent rosette flowers due to P. gossypiella were highest in 41st MW.

Green boll damage by pink bollworm P. gossypiella (Saunders)

The data on per cent green boll damage due to P. gossypiella in Bt cotton during Kharif 2018 (Table 1) ranged between 5.00 to 40.00 per twenty bolls occurring from 39th MW (5.00 per cent per twenty bolls). The peak incidence was noticed in second forth night of November (46th and 47th MW) i.e. 40.00 per cent per twenty bolls. Thereafter per cent green boll damage gradually declined with second peak in 52nd MW 30 per cent per twenty bolls.

During Kharif 2019 per cent green boll damage due to P. gossypiella in Bt cotton ranged between 10.00 to 70.00 per cent per twenty bolls. The incidence was observed from second week of October 38th MW with 10.00 per cent per twenty bolls. The peak incidence was noticed in 48th MW with 70.00 per cent per twenty bolls and gradually declined till end of the season.

The findings of earlier workers are more or less in the line of present work. Laxman. who reported that infestation of pink bollworm was recorded on Bt-cotton in September (12th week) of crop. According to Shinde. (2018) the peak green boll damage was observed in 46th, 47th and 48th MW. As per Yalawar and Patil (2019) the incidence in green bolls was noticed from the first fortnight of September (34th SMW) and rose gradually to reach its zenith during the second fortnight of December (48th SMW). Sarode. (2020) reported that per cent green boll infestation due to P. gossypiella is highest (125%) in 48th MW.

Larval population of pink bollworm P. gossypiella (Saunders) in green bolls

The number of pink bollworm larva in green bolls were recorded at weekly interval starting from first week of September to third week of January and data are presented in table 2.

During Kharif 2018, the larval incidence on green bolls in Bt cotton varied from 2.00 to 21.00 larvae per twenty green bolls. The incidence started from last week of September (39th MW) 2.00 larvae per twenty green bolls and later, the larval population increased gradually with first peak of 21.00 larvae

per twenty bolls during 46th MW. The second peak was recorded 52nd MW (11.00 larvae per twenty green bolls).

During the succeeding year (Kharif) the larval incidence on green bolls in Bt cotton documented ranged from 2.00 to 40.00 larvae per twenty green bolls. The incidence noticed from first week of October (40th MW) to till the end of season (03rd MW) 2.00 larvae per twenty green bolls. The highest occurrence recorded in 47th MW 40 larvae per twenty green bolls and later on gradually declined.

Table1: Seasonal incidence of pink bollworm in Bt cotton.

Weeks	Duration	Moths trapped/ trap		Rosette flower (%)	Green boll damage (%)		
		2018	2019	2018	2019	2018	2019
30	23-29 July	3.00	0.00	0.00	0.00	0.00	0.00
31	30-05 Aug	4.00	0.00	0.00	0.00	0.00	0.00
32	06-12 Aug.	4.00	0.00	0.00	0.00	0.00	0.00
33	13-19 Aug.	4.00	0.00	0.00	0.00	0.00	0.00
34	20-26 Aug.	6.00	1.00	0.00	0.00	0.00	0.00
35	27-02 Sept.	5.00	1.00	0.00	0.00	0.00	0.00
36	03-09 Sept	6.00	2.00	0.00	0.00	0.00	0.00
37	10-16 Sept.	3.00	3.00	0.00	0.00	0.00	0.00
38	17-23 Sept.	3.00	4.00	3.65	7.14	0.00	0.00
39	24-30 Sept.	7.00	9.00	5.54	14.29	5.00	0.00
40	01-07 Oct.	8.00	6.00	6.68	18.75	5.00	0.00
41	08-14 Oct.	17.00	7.00	9.87	26.67	10.00	10.00
42	15-21 Oct.	21.00	18.00	11.25	31.67	15.00	15.00
43	22-28 Oct.	25.00	27.00	12.68	36.36	20.00	25.00
44	29-04 Nov.	85.00	32.00	14.58	38.18	30.00	35.00
45	05-11 Nov.	123.00	48.00	16.92	37.50	35.00	45.00
46	12-18 Nov	103.00	74.00	17.25	28.57	40.00	50.00
47	19-25 Nov.	46.00	86.00	16.27	21.43	40.00	60.00
48	26-02 Dec.	46.00	65.00	15.35	11.54	35.00	70.00
49	03-09 Dec.	38.00	54.00	10.24	8.57	30.00	65.00
50	10-16 Dec.	82.00	46.00	9.68	14.29	25.00	60.00
51	17-23 Dec.	125.00	38.00	8.27	18.75	25.00	55.00
52	24-31 Dec.	54.00	31.00	7.68	28.57	30.00	30.00
1	01-07 Jan	23.00	23.00	6.87	16.67	15.00	20.00
2	08-14 Jan	0.00	2.00	3.27	10.71	10.00	10.00
3	15-21 Jan	5.00	3.00	0.00	0.00	10.00	10.00

The present findings are in agreement with those of earlier workers like Arshad. (2015) who reported that the larval number increased in Bt cotton in September and October. As per Verma . (2017) the pink bollworm, P. gossypiella peak larval population on bolls was recorded in 3rd week of September. According to Shinde. (2018) the peak of pink bollworm larval population per 20 green bolls 46th.

Table2: Seasonal incidence of pink bollworm in Bt cotton.

Weeks	Duration	PBW larval population / 20 green bolls		Locule damage in 20 green bolls (%)	
		2018	2019	2018	2019
30	23-29 July	0.00	0.00	0.00	0.00
31	30-05 Aug	0.00	0.00	0.00	0.00
32	06-12 Aug.	0.00	0.00	0.00	0.00
33	13-19 Aug.	0.00	0.00	0.00	0.00
34	20-26 Aug.	0.00	0.00	0.00	0.00

35	27-02 Sept.	0.00	0.00	0.00	0.00
36	03-09 Sept	0.00	0.00	0.00	0.00
37	10-16 Sept.	0.00	0.00	0.00	0.00
38	17-23 Sept.	0.00	0.00	0.00	0.00
39	24-30 Sept.	2.00	0.00	1.23	0.00
40	01-07 Oct.	3.00	2.00	5.00	1.25
41	08-14 Oct.	5.00	5.00	7.32	7.32
42	15-21 Oct.	8.00	7.00	14.81	9.88
43	22-28 Oct.	10.00	11.00	22.50	18.75
44	29-04 Nov.	13.00	20.00	29.27	30.49
45	05-11 Nov.	18.00	25.00	43.90	36.59
46	12-18 Nov	21.00	31.00	55.56	49.38
47	19-25 Nov.	19.00	40.00	42.50	62.50
48	26-02 Dec.	13.00	26.00	34.57	43.21
49	03-09 Dec.	12.00	22.00	29.27	34.15
50	10-16 Dec.	12.00	19.00	24.69	25.93
51	17-23 Dec.	9.00	9.00	18.75	17.50
52	24-31 Dec.	11.00	6.00	17.28	12.35
1	01-07 Jan	7.00	4.00	12.20	7.32
2	08-14 Jan	4.00	2.00	7.41	6.17
3	15-21 Jan	3.00	2.00	3.75	2.50

Locule damage in green bolls due to pink bollworm P. gossypiella (Saunders)

The per cent locule damage in green bolls made by pink bollworm larvae was recorded from twenty green bolls and the data are presented in During Kharif 2018 of investigation, the per cent locule damage in green bolls ranged from 1.23 to 55.56 in Bt cotton. Maximum of 55.56 per cent locule damage in green bolls were noticed during peak boll developmental period (upto November). Whereas, highest locule damage in green bolls also registered in the same period (46th MW). Followed byNovember per cent locule damage decreased upto the end of season.

In the second year (Kharif) of study, similar trend in the highest locule damage was noticed with 62.50 per cent locule damage in developmental period (upto November). The per cent locule damage in green bolls ranged from 1.25 to 62.50 in Bt cotton. The per cent locule damage in green bolls gradually increased up to 47th MW and gradually declined to the till the end of season.

The findings of earlier workers are more or less in the line of present work. Shinde who reported that the locule damage in green bolls were observed during 47th MW. As per Yalawar and Patil locule damage ranged from (24.71 to 39.35 %) with a mean of (39.05 %).

RELATIONSHIP BETWEEN WEATHER PARAMETERS AND PINK BOLLWORM IN BT COTTON

Pheromone trap catch

Simple correlation studies

The data on correlation between weather parameters and pheromone trap catch during Kharif 2018 and Kharif 2019 presented in Table 3.

The pheromone trap catch in Bt cotton were positively significant and non- significant relationship to bright sun shine (r = 0.388*) and evaporation (r = 0.168), respectively. The pheromone trap catch in relation to minimum temperature (r = -0.512**), morning RH (r = -0.570**) and evening RH (r = -0.455*) were negatively significant. The pheromone trap catch negatively non- significant in relationship to maximum temperature (r = -0.079), rainfall (r = -0.224) and wind speed (r = -0.231) during Kharif 2018.

Although, during Kharif 2019, the pheromone trap catch in Bt cotton were positively significant relationship to bright sun shine (r = 0.563**). The pheromone trap catch in relation to minimum temperature (r = -0.655**), evening RH (r = -0.670**), rainfall (r = -0.398*) and wind speed (r = -0.655**) were negatively significant. The pheromone trap catch were negatively non- significant in relationship to maximum temperature (r = -0.186), morning RH (r = -0.347) and evaporation (r = -0.072)

Multiple regression studies

The partial regression coefficients for different weather paramet ers and pheromone trap catch during Kharif 2018 and Kharif 2019 were worked out and presented in Table 4 and 5. The multiple regression equation fitted with weather parameters in order to predict pheromone trap catch in Bt cotton was as below

Kharif 2018: Y=-725.62 + 0.255 X1 – 7.259 X2 – 10.280 X3 + 3.945 X4 + 0.206 X5 + 5.766 X6 + 1.322 X7 + 3.560 X8 with coefficient of determination (R2) 0.55.

Kharif 2019: Y= -95.59 + 4.216 X1 – 2.976 X2 – 0.555 X3 - 0.972 X4 + 0.042 X5 - 0.435 X6 - 3.345 X7 - 7.983 X8 with coefficient of determination (R2) 0.60.

Where, X1= maximum temperature, X2= minimum temperature, X3= morning RH, X4= evening RH, X5= rainfall, X6= bright sun shine, X7= wind speed, X8= evaporation and R2= Coefficient of determination.

The coefficient of determination (R2) represents the proportion of common variation in the two variables. The present investigations shown that the weather parameters contributed for 55.00 and 60.00 per cent of total variation in the pheromone trap catch in Bt cotton during Kharif 2018 and 2019 and of both years, respectively indicating that the predictions of the pheromone trap catch by using weather parameters were reliable.

Rosette flowers due to pink bollworm P. gossypiella (Saunders)

Simple correlation studies

The data on correlation between weather parameters and rosette flowers during Kharif 2018 and Kharif 2019 presented in Table 3.

The rosette flowers in Bt cotton in relation to bright sun shine (r = 0.573**) was positively significant. The rosette flowers negatively non-significant in relationship to maximum temperature (r = 0.345) and evaporation (r = 0.362). The rosette flowers in relation to minimum temperature (r = -0.498**), morning RH (r = -0.742**) and evening RH (r = -0.693**) and wind speed (r = -0.524**) were negatively significant and rainfall (r = -0.346) negatively non-significant during Kharif 2018.

Whereas, during Kharif 2019, the rosette flowers in Bt cotton negatively significant relationship to wind speed (r = -0.624**). The rosette flowers in relation to bright sun shine (r = 0.374) was positively non-significant. The rosette flowers negatively non- significant in relationship to maximum temperature (r = -0.113), minimum temperature (r = -0.283), morning RH (r = -0.055), evening RH (r = -0.342), rainfall (r = -0.069) and evaporation (r = -0.272).

Multiple regression studies

The partial regression coefficients for different weather parameters and rosette flowers during Kharif 2018 and Kharif 2019 were worked out and presented in Table 6 and 7. The multiple regression equation fitted with weather parameters in order to predict rosette flowers in Bt cotton was as below

Kharif 2018: Y= 66.21 + 0.797 X1 - 0.091 X2 - 1.000 X3 + 0.001 X4 + 0.053 X5 + 0.301 X6 + 0.191 X7 - 1.663 X8 with coefficient of determination (R2) 0.62.

Kharif 2019: Y= -333.91 – 10.75 X1 + 6.414 X2 - 1.030 X3 – 0.137 X4 + 0.103 X5 + 3.369 X6 - 13.000 X7 + 1.639 X8 with coefficient of determination (R2) 0.69.

Where, X1= maximum temperature, X2= minimum temperature, X3= morning RH, X4= evening RH, X5= rainfall, X6= bright sun shine, X7= wind speed, X8= evaporation and R2= Coefficient of determination.

The coefficient of determination (R2) represents the proportion of common variation in the two variables. The present investigations shown that the

Table3: Correlation between weather parameters and pink bollworm in Bt cotton.

Pests	Year	Correlation coefficient (r)							
		Max. Temp.	Min. Temp.	RH-I	RH-II	Rainfall	BSS	WS	EVP
TRAP	2018	-0.079	-0.512**	-0.570**	-0.455*	-0.224	0.388*	-0.231	0.168
	2019	-0.186	-0.655**	-0.347	-0.670**	-0.398*	0.563**	-0.655**	-0.072
Rosette flower (%)	2018	0.345	-0.498**	-0.742**	-0.693**	-0.346	0.573**	-0.524**	0.362
	2019	-0.113	-0.283	-0.055	-0.342	-0.069	0.374	-0.624**	-0.272
% Green boll damage	2018	0.017	-0.682**	-0.694**	-0.692**	-0.321	0.542**	-0.513**	0.123
	2019	-0.115	-0.610**	-0.372	-0.632**	-0.367	0.603*	-0.677**	-0.038
PBW larval population / 20 green bolls	2018	0.127	-0.602**	-0.699**	-0.665**	-0.311	0.534**	-0.512**	0.166
	2019	-0.045	-0.573**	-0.346	-0.603**	-0.388*	0.619**	-0.650**	-0.024
Locule damage in green	2018	0.137	-0.535**	0.137	-0.585**	-0.275	0.475*	-0.485*	0.118
	2019	-0.093	-0.602**	-0.093	-0.599**	-0.395*	0.602**	-0.644**	-0.041

bolls (%)				

Table4: Multiple correlation and regression between weather parameters and moth catches (Trap) of pink bollworm during 2018.

Sr. No.	Parameters	Regression Coefficient (b)	S.E. (b)	't' values
(X1)	Max. Temp.	0.255	9.924	0.026
(X2)	Min. Temp.	-7.259	8.187	-0.887
(X3)	RH-I	-10.275	3.434	-2.992
(X4)	RH-II	3.945	2.441	1.616
(X5)	Rainfall	0.206	0.265	0.775
(X6)	BSS	5.766	6.487	0.889
(X7)	WS	1.322	11.177	0.118
(X8)	EVP	3.560	15.791	0.225
Intercept (a) = 725.62, N=26, F value = 2.68, R2 = 0.55				

Table5: Multiple correlation and regression between weather parameters and moth catches (Trap) of pink bollworm during 2019.

Sr. No.	Parameters	Regression Coefficient (b)	S.E. (b)	't' values
(X1)	Max. Temp.	4.216	8.467	0.498
(X2)	Min. Temp.	-2.976	4.516	-0.659
(X3)	RH-I	-0.555	1.158	-0.480
(X4)	RH-II	-0.972	0.647	-1.501
(X5)	Rainfall	0.042	0.142	0.293
(X6)	BSS	-0.435	5.408	-0.080
(X7)	WS	-3.345	7.844	-0.426
(X8)	EVP	-7.983	10.312	-0.774
Intercept (a) = -95.59, N=26, F value = 3.27, R2 = 0.60				

Table6: Multiple correlation and regression between weather parameters and Rosette flower during 2018.

Sr. No.	Parameters	Regression Coefficient (b)	S.E. (b)	't' values
(X1)	Max. Temp.	0.797	1.438	0.554
(X2)	Min. Temp.	-0.091	1.186	-0.077
(X3)	RH-I	-1.000	0.498	-2.010
(X4)	RH-II	0.001	0.354	0.004
(X5)	Rainfall	0.053	0.038	1.389
(X6)	BSS	0.301	0.940	0.320
(X7)	WS	0.191	1.619	0.118
(X8)	EVP	-1.663	2.288	-0.727
Intercept (a) = 66.21, N=26, F value = 3.58, R2 = 0.62				

Table7: Multiple correlation and regression between weather par ameters and Rosette flower during 2019.

Sr. No.	Parameters	Regression Coefficient (b)	S.E. (b)	't' values
(X1)	Max. Temp.	-10.748	3.876	-2.773
(X2)	Min. Temp.	6.414	2.068	3.102
(X3)	RH-I	-1.030	0.530	-1.944
(X4)	RH-II	-0.137	0.296	-0.463
(X5)	Rainfall	0.103	0.065	1.584
(X6)	BSS	3.369	2.476	1.360
(X7)	WS	-13.004	3.592	-3.621
(X8)	EVP	1.639	4.722	0.347
Intercept (a) = 333.91, N=26, F value = 4.80, R2 = 0.69				

Table8: Multiple correlation and regression between weather parameters and Green boll damage during 2018.

Sr. No.	Parameters	Regression Coefficient (b)	S.E. (b)	't' values
(X1)	Max. Temp.	-0.849	3.332	-0.255
(X2)	Min. Temp.	0.387	2.749	0.141
(X3)	RH-I	-2.411	1.153	-2.092
(X4)	RH-II	-0.068	0.819	-0.083
(X5)	Rainfall	0.090	0.089	1.010
(X6)	BSS	1.784	2.178	0.819

(X7)	WS	-0.037	3.752	-0.010
(X8)	EVP	-6.106	5.301	-1.152
Intercept (a) = 243.36, N=26, F value = 3.67, R2 = 0.63				

Table9: Multiple correlation and regression between weather parameters and Green boll damage during 2019.

Sr. No.	Parameters	Regression Coefficient (b)	S.E. (b)	't' values
(X1)	Max. Temp.	1.602	8.187	0.196
(X2)	Min. Temp.	-0.888	4.367	-0.203
(X3)	RH-I	-1.198	1.119	-1.070
(X4)	RH-II	-0.601	0.626	-0.960
(X5)	Rainfall	0.079	0.138	0.575
(X6)	BSS	1.147	5.230	0.219
(X7)	WS	-7.102	7.586	-0.936
(X8)	EVP	-5.340	9.972	-0.536
Intercept (a) = -139.59, N=25, F value = 7.47, R2 = 0.79				

Table10: Multiple correlation and regression between weather parameters and larval population pink bollworm during 2018.

Sr. No.	Parameters	Regression Coefficient (b)	S.E. (b)	't' values
(X1)	Max. Temp.	0.021	0.079	0.261
(X2)	Min. Temp.	-0.005	0.065	-0.081
(X3)	RH-I	-0.064	0.027	-2.354
(X4)	RH-II	0.005	0.019	0.273
(X5)	Rainfall	0.002	0.002	1.160
(X6)	BSS	0.048	0.052	0.924
(X7)	WS	0.008	0.089	0.089
(X8)	EVP	-0.169	0.125	-1.345
Intercept (a) = 5.02, N=26, F value = 3.40, R2 = 0.61				

Table11: Multiple correlation and regression between weather parameters and larval population pink bollworm during 2019.

Sr. No.	Parameters	Regression Coefficient (b)	S.E. (b)	't' values
(X1)	Max. Temp.	0.165	0.200	0.826
(X2)	Min. Temp.	-0.065	0.107	-0.609
(X3)	RH-I	-0.023	0.027	-0.848
(X4)	RH-II	-0.015	0.015	-0.974
(X5)	Rainfall	0.001	0.003	0.167
(X6)	BSS	0.045	0.128	0.356
(X7)	WS	-0.032	0.185	-0.174
(X8)	EVP	-0.277	0.243	-1.138
Intercept (a) = 0.31, N=26, F value = 2.80, R2 = 0.56				

Table12: Multiple correlation and regression between weather p arameters and Locule damage in green bolls during 2018.

Sr. No.	Parameters	Regression Coefficient (b)	S.E. (b)	't' values
(X1)	Max. Temp.	0.032	0.056	0.564
(X2)	Min. Temp.	-0.024	0.047	-0.516
(X3)	RH-I	-0.047	0.020	-2.389
(X4)	RH-II	0.010	0.014	0.722
(X5)	Rainfall	0.002	0.002	1.127
(X6)	BSS	0.028	0.037	0.772
(X7)	WS	0.003	0.064	0.049
(X8)	EVP	-0.091	0.090	-1.014
Intercept (a) = 3.07, N=26, F value = 3.11, R2 = 0.59				

Table13: Multiple correlation and regression between weather parameters and Locule damage in green bolls during 2019.

Sr. No.	Parameters	Regression Coefficient (b)	S.E. (b)	't' values
(X1)	Max. Temp.	4.426	6.238	0.709
(X2)	Min. Temp.	-2.024	3.328	-0.608
(X3)	RH-I	-0.786	0.853	-0.922
(X4)	RH-II	-0.412	0.477	-0.864

(X5)	Rainfall	0.016	0.105	0.151
(X6)	BSS	1.161	3.985	0.291
(X7)	WS	-1.487	5.780	-0.257
(X8)	EVP	-7.815	7.599	-1.029
Intercept (a) = 34.48, N=26, F value = 2.78, R2 = 0.57				

Weather parameters contributed for 62.00 and 69.00 per cent of total variation in the rosette flowers in Bt cotton during Kharif 2018 and 2019 and of both years, respectively indicating that the predictions of the rosette flowers by using weather parameters were reliable.

Green boll damage by pink bollworm P. gossypiella (Saunders)

Simple correlation studies

The data on correlation between weather parameters and green boll damage during Kharif 2018 and Kharif 2019 presented in Table 3.

The green boll damage positively significant in relationship to bright sun shine (r = 0.542**). The green boll damage positively non-significant in relationship to maximum temperature (r = 0.017) and evaporation (r = 0.123). The green boll damage in relation to minimum temperature (r = -0.682**), morning RH (r = -0.694**) and evening RH (r = -0.692**) and wind speed (r = -0.513**) were negatively significant and rainfall (r = -0.321) negatively non-significant during Kharif 2018.

While, during Kharif 2019, the green boll damage in relation to bright sun shine (r = 0.603**) was positively significant. The green boll damage negatively significant in relationship to minimum temperature (r = -0.610**), evening RH (r = -0.632**) and wind speed (r = -0.677**). The green boll damage in relation to maximum temperature (r = -0.115), morning RH (r = -0.372), rainfall (r = -0.367) and evaporation (r = -0.038) were negatively non-significant.

Multiple regression studies

The partial regression coefficients for different weather parameters and green boll damage during Kharif 2018 and Kharif 2019 were worked out and presented in Table 8 and 9. The multiple regression equation fitted with weather parameters in order to predict green boll damage in Bt cotton was as below

Kharif 2018: Y= 243.36 – 0.849 X1 + 0.387 X2 - 2.411 X3 – 0.068 X4 + 0.090 X5 + 1.784 X6 - 0.037 X7 - 6.106 X8 with coefficient of determination (R2) 0.63.

Kharif 2019: Y= -139.59 + 0.1602 X1 – 0.888 X2 - 1.198 X3 – 0.601 X4 + 0.079 X5 + 1.147 X6 - 7.102 X7 - 5.34 X8 with coefficient of determination (R2) 0.79.

Where, X1= maximum temperature, X2= minimum temperature, X3= morning RH, X4= evening RH, X5= rainfall, X6= bright sun shine, X7= wind speed, X8= evaporation and R2= Coefficient of determination.

The coefficient of determination (R2) represents the proportion of common variation in the two variables. The present investigations shown that the weather parameters contributed for 63.00 and 79.00 per cent of total variation in the green boll damage in Bt cotton during Kharif 2018 and 2019 and of both years, respectively indicating that the predictions of the green boll damage by using weather parameters were reliable.

Larval population of pink bollworm P. gossypiella (Saunders) in green bolls

Simple correlation studies

The data on correlation between weather parameters and larval population of pink bollworm during Kharif 2018 and Kharif 2019 presented in Table 3.

The larval population of pink bollworm in Bt cotton positively significant in relationship to bright sun shine (r = 0.534**). The population of pink bollworm larvae positively non-significant in relationship to maximum temperature (r = 0.127) and evaporation (r = 0.166). The larval population of pink bollworm in relation to minimum temperature (r = -0.602**), morning RH (r = -0.699**), evening RH (r = -0.665**) and wind speed (r = -0.512**) were negatively significant and rainfall (r = -0.311) negatively non-significant during Kharif 2018.

Whereas, during Kharif 2019, the larval population of pink bollworm in relation to bright sun shine (r = 0.619**) was positively significant. The larval population of pink bollworm negatively significant in relationship to minimum temperature (r = -0.573**), evening RH (r = -0.602**), rainfall (r = -0.388*) and wind speed (r = -0.650**). The larval population of pink bollworm in relation to maximum temperature (r = -0.045), morning RH (r = -0.346) and evaporation (r = -0.024) were negatively non-significant.

Multiple regression studies

The partial regression coefficients for different weather parameters and larval population of pink bollworm during Kharif 2018 and Kharif 2019 were worked out and presented in Table 10 and 11. The multiple regression equation fitted with weather parameters in order to predict larval population of pink bollworm in Bt cotton was as below

Kharif 2018: Y= 5.02 + 0.021 X1 - 0.005 X2 -0.064 X3 + 0.005 X4 + 0.002 X5 + 0.048 X6 + 0.008 X7 - 0.169 X8 with coefficient of determination (R2) 0.61.

Kharif 2019: Y= -0.31 +0.165 X1 - 0.065 X2 -0.023 X3 – 0.015 X4 + 0.001 X5 + 0.045 X6 - 0.032 X7 - 0.277 X8 with coefficient of determination (R2) 0.56.

Where, X1= maximum temperature, X2= minimum temperature, X3= morning RH, X4= evening RH, X5= rainfall, X6= bright sun shine, X7= wind speed, X8= evaporation and R2= Coefficient of determination.

The coefficient of determination (R2) represents the proportion of common variation in the two variables. The present investigations shown that the weather parameters contributed for 61.00 and 56.00 per cent of total variation in the larval

population of pink bollworm in Bt cotton during Kharif 2018 and 2019 and of both years, respectively indicating that the predictions of the larval population of pink bollworm by using weather parameters were reliable [10-12].

Locule damage due to pink bollworm P. gossypiella (Saunders) in green bolls

Simple correlation studies

The data on correlation between weather parameters and locule damage during Kharif 2018 and Kharif 2019 presented in Table 3.

The locule damage in relation to bright sun shine (r = 0.475**) was positively significant. The locule damage positively non-significant in relationship to maximum temperature (r = 0.137), morning RH (r = 0.137) and evaporation (r = 0.118). The locule damage in relation to minimum temperature (r = -0.535**), evening RH (r = -0.585**) and wind speed (r = -0.485*) were negatively significant and rainfall (r = -0.275) was negatively non-significant during Kharif 2018.

Whereas, during Kharif 2019, the locule damage positively significant in relation to bright sun shine (r = 0.602**). The locule damage in relation to minimum temperature (r = -0.602**), evening RH (r = -0.599**), rainfall (r = -0.395*) and wind speed (r = -0.644**) were negatively significant. The locule damage in relation to maximum temperature (r = -0.093), morning RH (r = -0.093) and evaporation (r = -0.041) were negatively non-significant.

Multiple regression studies

The partial regression coefficients for different weather parameters and locule damage during Kharif 2018 and Kharif 2019 were worked out and presented in Table 12 and 13. The multiple regression equation fitted with weather parameters in order to predict locule damage in Bt cotton was as below

Kharif 2018: Y= 3.07 + 0.032 X1 - 0.024 X2 -0.047 X3 + 0.010 X4 + 0.002 X5 + 0.028 X6 + 0.003 X7 - 0.091 X8 with coefficient of determination (R2) 0.59.

Kharif 2019: Y= 34.48 + 4.426 X1 - 2.024 X2 -0.786 X3 – 0.412 X4 + 0.016 X5 + 1.161 X6 - 1.487 X7 - 7.815 X8 with coefficient of determination (R2) 0.57.

Where, X1= maximum temperature, X2= minimum temperature, X3= morning RH, X4= evening RH, X5= rainfall, X6= bright sun shine, X7= wind speed, X8= evaporation and R2= Coefficient of determination.

The coefficient of determination (R2) represents the proportion of common variation in the two variables. The present investigations shown that the weather parameters contributed for 59.00 and 57.00 per cent of total variation in the locule damage in Bt cotton during Kharif 2018 and 2019 and of both years, respectively indicating that the predictions of the locule damage by using weather parameters were reliable.

(Lingren) who concluded that higher temperatures delayed moth emergence, while lower temperatures resulted in early trap capture. Maximum and minimum temperature thresholds for trap capture were 30.30C and 12.30C, respectively. While, Kumar reported the maximum temperature had negative and significant association with trap catches of pink bollworm, while minimum temperature, morning and afternoon relative humidity were positive and non-significantly correlated with trap catches. Whereas, total rainfall had non-significant negative influence on PBW trap catches. Ramesh Babu and Meghwal reported that the pheromone trap catches of pink bollworm showed negative significant correlation with minimum temperature. However it showed non-significant negative with maximum temperature, morning relative humidity, evening relative humidity, rainfall and rainy days. However, Somaa reported the larval density of pink bollworm had highly significant and negative correlation with changes of the temperature of both seasons. However, the correlation between number of larvae and changes of the relative humidity was insignificant and negative in both seasons. Maximum temperature, minimum temperature and wind shear showed a significantly negative correlation with population of pink bollworm (Shinde).

As per Verma Larval population on flowers shows negative correlation with maximum, minimum (temperatures) and evening relative humidity, while, had positive correlation with morning relative humidity and rainfall. However, larval population on bolls had negative correlation with maximum, minimum (temperatures) and rainfall but had positive correlation with morning, evening relative humidity. The trap catches had a negative and non significant relationship with rainfall and a negative and significant relationship with maximum temperature reported by Yalawar and Patil. While, Sarode reported that the rosette flowers by P. gossypiella showed that positively non-significant with rainfall, minimum temperature, bright sun shine, and wind velocity then negatively significant with maximum temperature. While, negatively non-significant correlation with morning RH and evening RH.

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