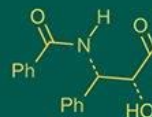


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Population dynamics of pink bollworm in *Bt* cotton at middle Gujarat

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Abstract

The pink bollworm *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) has major pest on *Bt* cotton in India. The population dynamics of pink bollworm larvae and damage on different cotton parts *i.e.*, square, flower and green boll were recorded at AAU, Anand, Gujarat during 2019-20 and 2020-21. The infestation of pink bollworm was first recorded from squares during third week of August (33 SMW). The maximum rosette flowers observed during first week of December (49 SMW). The highest green bolls damage noticed during second week of December (50 SMW). Pink bollworm larval population appeared during third (38 SMW) and fourth (39 SMW) week of September and persist throughout the crop periods, reaching peak activity at third week of December (51 SMW) during 2019-20 and 2020-21. The favourable environment conditions for increased pink bollworm population and damage in cotton were, minimum temperature, low vapour pressure, minimum relative humidity, less rainfall, fewer rainy days, high evaporation, and high bright sunshine hours.

Keywords: *Bt* cotton, pink bollworm, abiotic factor, rosette flowers, square damage

Introduction

The pink bollworm (PBW), *Pectinophora gossypiella* (Saunders), is a major pest of cotton crops worldwide. The insect is indigenous to the Indo-Pak region, and its presence extends to other cotton-cultivating regions, such as Tropical America, Africa, Asia, Australia, Egypt, the United States, and Mexico (Mahalakshmi & Prasad, 2021^[4]; Raju *et al.*, 2021)^[6]. The pink bollworm (PBW) is a stenophagous insect that has co-evolved with Malvaceous food plants such as cotton, okra deccan hemp, and roselle. The introduction of *Bt* cotton has led to changes in the pest status of the Indian cotton ecosystem. However, PBW has emerged as a serious concern in cotton production in India, particularly for *Bt* cotton. The long duration of varieties/hybrids, along with the practice of ratooning, which involves allowing the cotton crop to grow for a second year, extends the cotton season, which also aids in the build-up of PBW. The extended cotton season, along with the provision of supplemental irrigation and fertilizer applications, allows PBW to cause continuous damage to flowers and bolls, ultimately leading to severe cotton seed loss. PBW caused yield losses in cotton of 20-90 per cent. PBW larvae damage cotton plants by feeding on the flowers, buds, bolls, and seeds. This feeding results in rosette flowers, premature opening of bolls, shedding of damaged bolls, decreased fiber length, and staining of the lint, which reduces its quality (Raju *et al.*, 2021)^[6].

Understanding the population dynamics of PBW in *Bt* cotton, particularly the factors influencing its resurgence and temporal variations in infestation levels, is crucial for developing and implementing effective IPM strategies to mitigate yield losses and ensure the long-term sustainability of *Bt* cotton technology.

Methodology

To determine the population dynamics of pink bollworm, *Bt* cotton variety Ajeet 155 was sown at Regional Research Station, Anand Agricultural University, Anand during 2019-20 and 2020-21. The crop was raised in 24 x 24 m plot size with a spacing 120 x 60 cm. The plot was kept free from any plant protection measures. The plot was divided into six equal sectors *i.e.*, 7.2 x 12 m. From each sector, five plants were randomly observed. For pink bollworm infestation, total square(s) as well as damaged square(s), total flower(s) and

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rosetted flower were recorded on each plant at weekly interval from square formation to till harvest of crop.

To record the pink bollworm larva(e) and green boll damage, 20 green bolls were plucked randomly from the plots and brought to the laboratory for further observations at weekly interval. In laboratory, each green boll was cut opened along with ridges of the locule with the help of sharp knife carefully and number of live pink bollworm larvae from each boll recorded. Then total number of pink bollworm larvae and green boll damage per 20 bolls was recorded. The data thus obtained were summarized and used for interpretation of the results.

In order to study the instantaneous effect of weather parameters on incidence fluctuation of pink bollworm, the data abiotic parameters viz., bright sunshine (BSS), rainfall (RF), wind speed (WS), maximum (MaxT) and minimum (MinT) temperature, morning (RH1), evening (RH2) relative humidity, morning vapour pressure (VP1), evening vapour pressure (VP2) and evaporation (EP) were correlated. Week-wise data on various weather parameters recorded at Department of Agril. Meteorology, B. A. College of Agriculture, Anand Agricultural University, Anand during 2019-20 and 2020-21 were utilized.

Results

The data presented in Table 1 to 3, the incidence of pink bollworm on *Bt* cotton highlights a correlation between the increasing presence of larvae and damage on various parts of the cotton plants viz., square, flower and green boll.

Square Damage

During the 2019-2020 period, square damage due to pink bollworm data presented on Table 1 which are indicated that the number of damaged squares per plant, began to appear in third week of August (33 standard metrological week, SMW), reaching 0.20 by the end of the month. This damage rapidly escalated in fourth week of September (39 SMW) and first week of October (40 SMW), peaking at 2.37 square damage per plant. A declining trend began in after first week of November (45 SMW), but damage levels remained relatively high compared to December. In the 2020-2021 period, square damage followed a similar pattern but with slightly lower values, starting in August and peaking at 2.50 in second week of October (41 SMW). However, the decline in damage was more pronounced in November and December compared to the previous year (Table 2).

Square damage shows a significant negative correlation with maximum temperature in both 2019-20 ($r = -0.520^*$) and 2020-21 ($r = -0.320$). This indicates that as maximum temperatures increase, the number of squares damaged per plant tends to decrease (Table 3).

Rosette Flower Damage

In 2019-2020, rosette flower was not observed until September, remaining at low levels until October, Pink bollworm peak damage on flower was reported in first week of December (49 SMW) when it reached 2.73 rosette flower pr plant (Table 1). The 2020-2021 period exhibited a different trend. While rosette flower damage began in September, similar to the previous year, it remained at much lower levels throughout the season. The pink bollworm peak damage on flower in first week of December (2.34 rosette flower, 49 SMW), notably lower than the peak observed in the 2019-2020 period (Table 2).

Rosette flower damage has significant negative correlations with several weather parameters. Evaporation shows a strong negative correlation in both years (2019-20: $r = -0.730^*$, 2020-21: $r = -0.606^{**}$), suggesting that higher evaporation rates are associated with lower rosette flower damage. Rainfall also demonstrates a strong negative correlation in both years (2019-20: $r = -0.606^*$, 2020-21: $r = -0.219$). Minimum temperature shows a very strong negative correlation in both years (2019-20: $r = -0.776^{**}$, 2020-21: $r = -0.568^{**}$), indicating a likely relationship between lower minimum temperatures and reduced rosette flower damage. Morning vapor pressure also exhibits a very strong negative correlation in both years (2019-20: $r = -0.809^{**}$, 2020-21: $r = -0.553^*$). Evening vapor pressure shows a similar strong negative correlation (2019-20: $r = -0.780^{**}$, 2020-21: $r = -0.686^{**}$). Rainy days are also negatively correlated with rosette flower damage (2019-20: $r = -0.674^{**}$, 2020-21: $r = -0.175$) (Table 3). These findings suggest that lower rainfall, fewer rainy days, and lower vapor pressure, often associated with drier conditions, might lead to increased rosette flower damage due to pink bollworm.

Green Boll Damage

Green boll damage, represented as a percentage, was not observed until third week of September (38 SMW) of the 2019-2020 period, starting at 2.50 per cent. This damage escalated rapidly, reaching 14.17 per cent by the first week of October (40 SMW) and exceeding 45 per cent by the end of the month (fifth week of October, 44 SMW). The upward trend continued in November and December, with damage peaking at 62.50 per cent in first week of December (49 SMW) before declining to 49.17 per cent at the end of the period (Table 1). The 2020-2021 period showed a similar pattern of green boll damage; however, the percentage remained consistently lower than the previous year throughout the entire period. Damage began in September and rose consistently, reaching its peak in third week of November at 47.50 per cent (Table 2).

Green boll damage shows significant correlations with multiple weather factors. Bright sunshine hours have a strong positive correlation with damage in 2019-20 ($r = 0.575^{**}$) but not in 2020-21. Rainfall shows a consistent strong negative correlation across both years (2019-20: $r = -0.739^{**}$, 2020-21: $r = -0.595^{**}$). Maximum temperature also shows a strong negative correlation (2019-20: $r = -0.818^{**}$, 2020-21: $r = -0.662^{**}$), indicating that higher maximum temperatures might lead to lower damage to green bolls. Minimum temperature exhibits a very strong negative correlation (2019-20: $r = -0.919^{**}$, 2020-21: $r = -0.861^{**}$). Morning vapor pressure has a very strong negative correlation in both years (2019-20: $r = -0.853^{**}$, 2020-21: $r = -0.906^{**}$). Evening vapor pressure also shows a very strong negative correlation (2019-20: $r = -0.708^{**}$, 2020-21: $r = -0.830^{**}$). Rainy days are negatively correlated with green boll damage in both years (2019-20: $r = -0.687^{**}$, 2020-21: $r = -0.544^*$) (Table 3). These correlations suggest that drier conditions, characterized by lower rainfall, fewer rainy days, and lower vapor pressure, could potentially lead to increased green boll damage.

Larvae

The pink bollworm larvae observed as the number of larvae per 20 bolls, was first observed in third week of September (38 SMW) 2019 at 0.50 larva per plant (Table 1). The larval population increased throughout September and October, reaching 6.50 larvae per plant by the fifth week of October

(44 SMW). The increasing trend continued, with the number of larvae peaking at 12.50 in second and third week of December before gradually decreasing throughout January. The 2020-2021 period displayed a similar pattern of larvae damage, with a gradual increase from fourth week of September (39 SMW) to fourth week of November (48 SMW), reaching 9.50 larvae per plant. The peak larvae count, however, was slightly lower than the previous year, reaching 11.00 in third week of December (51 SMW) before gradually declining (Table 2).

The pink bollworm larvae population also reveals significant correlations with several weather parameters. Bright sunshine hours show a strong positive correlation with larvae damage in both years (2019-20: $r = 0.584^{**}$, 2020-21: $r = 0.286$). Evening relative humidity displays a negative correlation in 2020-21 ($r = -0.485^{*}$). Morning vapor pressure shows a very strong negative correlation (2019-20: $r = -0.958^{**}$, 2020-21: $r = -0.919^{**}$), suggesting a strong link between higher morning vapor pressure and lower larvae numbers. Evening vapor pressure also exhibits a very strong negative correlation (2019-20: $r = -0.909^{**}$, 2020-21: $r = -0.823^{**}$). Rainy days show a strong negative correlation with larvae damage in both years (2019-20: $r = -0.681^{**}$, 2020-21: $r = -0.554^{*}$), implying that more rainy days might be associated with reduced larvae numbers (Table 3).

Discussion

The observation that rosette flower damage was not observed until September in both 2019-2020 and 2020-2021 aligns with previous research. Nadaf and Basavana (2006)

[10] found that rosette flowers were observed from the third week of September onwards, peaking in November. This pattern suggests a consistent timeline for PBW infestation in cotton fields, with damage becoming apparent as the cotton plant enters its flowering and boll formation stage. This period coincides with the findings in (Vora *et al.*, 2024) [9], which states that the peak activity window for *Helicoverpa armigera* adults on cotton is from September to the end of November, a time when the crop is in peak flowering and boll formation stage.

While this study found a negative correlation between rosette flower damage and various weather parameters, some sources present conflicting findings. For example, Vora *et al.* (2024) [9] found that maximum temperature and bright sunshine hours were significantly positively correlated with rosette flower damage. This discrepancy highlights the complex interplay of factors influencing PBW infestation and suggests that regional variations in climate and other environmental factors might play a role.

However, the negative correlations this study observed between rosette flower damage and minimum temperature, rainfall, and vapor pressure are consistent with the general understanding that drier conditions favor PBW infestation. These findings are in partial agreement with Laxman *et al.* (2014) [3], who found that PBW infestation showed a negative correlation with maximum and minimum temperatures and rainfall. Drier conditions might enhance larval survival and development, leading to increased damage.

Table 1: Larval population and Fruiting body damage due to pink bollworm, *P. gossypiella* in Bt cotton during 2019-20

Months	Week	Standard Metrological Weeks (SMW)	No. of damage square per plant	No. of rosette flowers per plant	Green boll damage (%)	No. of larva (e)/20 bolls
July	1	27	0.00	0.00	0.00	0.00
	2	28	0.00	0.00	0.00	0.00
	3	29	0.00	0.00	0.00	0.00
	4	30	0.00	0.00	0.00	0.00
August	1	31	0.00	0.00	0.00	0.00
	2	32	0.00	0.00	0.00	0.00
	3	33	0.03	0.00	0.00	0.00
	4	34	0.07	0.00	0.00	0.00
	5	35	0.20	0.00	0.00	0.00
September	1	36	0.37	0.00	0.00	0.00
	2	37	2.13	0.17	0.00	0.00
	3	38	2.17	0.17	2.50	0.50
	4	39	2.37	0.23	4.17	0.83
October	1	40	2.37	0.43	14.17	2.83
	2	41	2.20	0.53	26.67	5.33
	3	42	1.93	0.93	26.67	5.00
	4	43	1.80	0.97	32.50	5.50
	5	44	1.30	1.53	45.00	6.50
November	1	45	2.00	1.90	48.33	9.00
	2	46	1.67	1.57	50.00	9.67
	3	47	1.73	2.10	53.33	10.50
	4	48	1.93	2.37	56.67	11.00
December	1	49	1.57	2.73	62.50	11.50
	2	50	0.83	1.97	61.67	12.50
	3	51	0.57	1.73	55.83	12.50
	4	52	0.00	0.00	49.17	12.00
January	1	1	0.00	0.00	0.00	9.83
	2	2	-	0.00		

Table 2: Larval population and Fruiting body damage due to pink bollworm, *P. gossypiella* in *Bt* cotton during 2020-21

Months	Weeks	Standard Metrological Weeks (SMW)	No. of damage square per plant	No. of rosette flowers per plant	Green boll damage (%)	No. of larva (e)/20 bolls
July	2	28	0.00	0.00	0.00	0.00
	3	29	0.00	0.00	0.00	0.00
	4	30	0.00	0.00	0.00	0.00
August	1	31	0.00	0.00	0.00	0.00
	2	32	0.00	0.00	0.00	0.00
	3	33	0.00	0.00	0.00	0.00
	4	34	0.03	0.00	0.00	0.00
	5	35	0.13	0.00	0.00	0.00
September	1	36	0.47	0.00	0.00	0.00
	2	37	1.63	0.00	0.00	0.00
	3	38	1.87	0.05	0.00	0.00
	4	39	2.00	0.26	5.83	1.17
October	1	40	2.27	0.23	10.00	2.00
	2	41	2.50	0.17	21.67	4.33
	3	42	1.87	0.12	33.33	5.17
	4	43	1.47	0.13	38.33	5.67
	5	44	0.97	0.18	40.83	6.67
November	1	45	1.23	0.27	41.67	7.67
	2	46	1.47	0.32	46.67	8.17
	3	47	1.57	1.16	47.50	9.33
	4	48	1.50	1.30	40.83	9.50
December	1	49	1.33	2.34	45.83	9.83
	2	50	0.33	1.81	53.33	10.17
	3	51	0.30	1.94	45.83	11.00
	4	52	0.00	0.58	41.67	10.00
January	1	1	0.00	0.00	45.83	9.50
	2	2	0.00	0.00	0.00	9.17

Table 3: Correlation coefficient between incidence of pink bollworm and weather parameters

Sr. No.	Particular	Correlation coefficient (r)							
		No. of squares damage per plant		No. of rosette flowers per plant		Green boll damage (%)		No. of larva per 20 bolls	
		2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
1	Evaporation (mm per day)	0.05	0.353	-0.730*	-0.606**	-0.315	-0.426	-0.320	-0.469*
2	Bright sunshine hours (hr.)	0.293	0.223	-0.300	-0.216	0.575**	0.298	0.584**	0.286
3	Rainfall (mm)	-0.068	-0.368	-0.606*	-0.219	-0.739**	-0.595**	-0.733**	-0.595**
4	Wind speed (km/hr.)	-0.072	-0.270	0.080	0.123	0.197	-0.384	0.200	-0.343
5	Temperature (°C)	Maximum	-0.520*	-0.320	-0.577**	-0.803**	-0.818**	-0.662**	-0.829**
		Minimum	-0.290	-0.056	-0.776**	-0.568**	-0.919**	-0.861**	-0.930**
6	Relative humidity (%)	Morning	0.185	0.356	-0.308	-0.079	-0.312	-0.369	-0.605**
		Evening	0.086	0.315	-0.363	0.068	-0.289	-0.485*	-0.683**
7	Vapour Pressure (kPa)	Morning	0.006	0.056	-0.809**	-0.553*	-0.853**	-0.906**	-0.958**
		Evening	0.101	0.132	-0.780**	-0.686**	-0.708**	-0.830**	-0.909**
8	Rainy Day	0.09	-0.329	-0.674**	-0.175	-0.687**	-0.544*	-0.681**	-0.554*

Note: * Significant at 5 per cent, ** Significant at 1 per cent (n: 16 all parameters except square damage n: 21)

The present findings show that pink bollworm larval populations generally increase from September to a peak in December, then decline. This pattern aligns with existing research. Prasad *et al.* (2008) [5] found that peak pink bollworm activity occurs from November to January. Similarly, Vora *et al.* observed that larval populations peaked in the 43rd and 46th Standard Meteorological Week (SMW), which corresponds to late October and November. The findings that bright sunshine hours positively correlate with larval damage are supported by Vora *et al.* (2024) [9] research. Vora *et al.* also found a significant positive correlation between bright sunshine hours and larval population. The negative correlation between evening relative humidity and larval damage is consistent with the findings of Prasad *et al.* (2008) [5]. They found that evening relative humidity negatively influenced the pheromone trap catch of pink bollworm, suggesting a link between higher

humidity and reduced activity. While the provided findings highlight correlations with vapor pressure, the sources primarily focus on relative humidity as a key weather factor influencing pink bollworm. More research is needed to explore the relationship between vapor pressure and pink bollworm infestation.

The strong negative correlation between rainy days and larval damage is supported by several sources. Prasad *et al.* (2008) [5] found that rainfall had a significant negative impact on pink bollworm trap catches. Similarly, Vora *et al.* (2024) [9] reported a positive correlation between rainfall and rosette flower damage, but this correlation was not statistically significant. This suggests that while rainfall might not directly impact flower damage, it could influence larval populations and, therefore, overall infestation levels. Other studies have also reported a negative correlation between rainfall and pink bollworm incidence.

The findings presented align with existing research on pink bollworm seasonality and the influence of weather parameters. Notably, bright sunshine hours and rainfall appear to be significant factors influencing pink bollworm populations, and further investigation into the role of vapor pressure is warranted.

Conclusion

The infestation of pink bollworm was first recorded from squares during third week of August (33 SMW). The maximum rosette flowers observed during first week of December (49 SMW). The highest green bolls damage noticed during second week of December (50 SMW). Pink bollworm larval population appeared during third (38 SMW) and fourth (39 SMW) week of September and persist throughout the crop periods, reaching peak activity at third week of December (51 SMW) during 2019-20 and 2020-21. The favourable environment conditions for increased pink bollworm population and damage in cotton were, minimum temperature, low vapour pressure, minimum relative humidity, less rainfall, fewer rainy days, high evaporation, and high bright sunshine hours.

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