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Influence of weather factors on population trends of pink bollworm (*Pectinophora gossypiella*) infesting *Bt* cotton

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ABSTRACT

Pink bollworm [*Pectinophora gossypiella* (Saunders)] continues to threaten cotton (*Gossypium* spp.) farming in India, as its larvae are concealed within bolls, making them difficult to control. The present study was carried out during rainy (*kharif*) season of 2020 and 2021 at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra to examine the population dynamics of pink bollworm in *Bt* cotton, focusing on its occurrence and the factors driving its infestation. Cotton variety used for the study was Ajeet-199. The data revealed that in *kharif* 2020, the number of adult moths captured/week were ranged from 1.00–185.00, with the highest moths catches during the 50th standard meteorological week (SMW) (185 moths/week). In 2021, the trap catches showed a gradual increase, reaching its peak during the 49th SMW (153 moths/week). Rosette flower incidence varied from 2.27–32.84% in 2020 and 2.38–41.67% in 2021. The peaks of rosette flowers were detected during 37th SMW during both the years. During 2020, the extent of green boll damage caused by *Pectinophora gossypiella* varied from 2.56–63.49%, while in 2021, it was ranged from 4.35–3.49%. The population of pink ballworm (PBW) larvae/20 green bolls ranged from 0.45–38.55 in 2020 and from 1.30–32.50 in 2021, with peak occurrences observed in the 46th and 47th SMW for both the years.

Keywords: *Bt* cotton, Correlation, *Pectinophora gossypiella*, Pink bollworm, Population dynamics, Weather factors

Cotton (*Gossypium* spp.), commonly known as the "king of natural fibres," holds global commercial significance. Cultivated in over 111 countries, it dominates the fibre market, contributing significantly to the global economy. Despite occupying just 2% of arable land and comprising 6% of global trade, cotton is vital for the trillion-dollar textile and fashion industry. Additionally, it serves as an economic backbone for many developing nations, including India, where it plays a pivotal role in driving economic growth (WTO 2020). Cotton, a cornerstone of economic progress worldwide, faces a formidable adversary, insect pests. Unlike most crops, indeterminate growth of cotton fosters a hospitable environment for a wide range of insects, posing a significant challenge both directly and indirectly (Manjunatha 2004). The pink bollworm (PBW) (*Pectinophora gossypiella*) presents a significant challenge in cotton farming, particularly in its larval stage hidden within the cotton fruiting bodies. Traditional control methods, such as insecticidal sprays are often ineffective (Nagaraj *et al*. 2024). This pest inflicts substantial damage with 37.5% on non-*Bt* cotton and 13.58% on *Bt* cotton at 160 days post planting, leading to substantial losses in cotton production (Naik *et al*. 2014, Birah *et al.* 2023). Environmental conditions, including temperature, humidity and precipitation, significantly influence the insect pests activity in cotton crop (Skendzic *et al.* 2021, Deshmukh and Bhamare 2024). Studying pink bollworm population dynamics is pivotal for effective pest management in agriculture. It allows precise timing of interventions, optimal resource allocation and aids in combating resistance. This knowledge informs policies and drives innovation for sustainable crop protection. The current study aims to establish a correlation between the seasonal occurrence of PBW and weather conditions.

MATERIALS AND METHODS

The present study was carried out during rainy (*kharif*) season of 2020 and 2021 at the research farm Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. The *Bt* cotton variety Ajeet-199 was used for the study. The experiment utilized an unprotected plot measuring 25 m × 20 m. The cotton crop was cultivated in accordance with recommended agronomic practices and subsequent observations were duly recorded.

Per cent rosette flowers: The rosette flowers were monitored on a weekly schedule. Five randomly selected

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tagged plants were counted for total and rosette flowers each week after initiation.

Pink bollworm larval population and per cent green boll damage: Twenty green bolls were collected from five randomly tagged plants. Using a precise cutter, each boll was carefully opened along the locule ridges and the count of live PBW larvae was recorded. This process was repeated weekly to monitor the incidence of PBW in green bolls. Furthermore, 20 green bolls were collected from the same set of plants in each subplot and brought to the laboratory. In this setting, the count of impaired bolls was registered and the findings were presented as the percentage of green boll damage.

Per cent open boll damage: At harvest, both the total count of intact, opened bolls and the ones damaged by pink bollworm were tallied from five plants chosen at random. Subsequently, the percentage of opened boll damage was computed.

Pheromone trap catches: To monitor pink bollworm activity, three pheromone traps were set up in the cotton field at All India Coordinated Research Project on Cotton, Mahatama Phule Krishi Vidyapeeth, Rahuri, Maharashtra and Pectino Lure septa were replaced after every 20 days. The pink bollworm moth collections from each standard meteorological week (SMW) were aggregated on a weekly basis and the weekly average of catches was calculated.

Relationship between weather parameters: Weekly meteorological data for the *kharif* seasons of 2020 and 2021 were sourced from the meteorological observatory at Mahatama Phule Krishi Vidyapeeth, Rahuri, Maharashtra. This information was then juxtaposed with the population dynamics of pink bollworm. The research delved into the correlation between environmental factors and PBW in *Bt* cotton.

RESULTS AND DISCUSSION

During *kharif* 2020, the occurrence of rosette flowers varied from 2.27–32.84% (Table 1). This incidence was first observed in the 37th SMW with the highest incidence recorded during the 47th week (32.84%). Subsequently, it exhibited a gradual decline to 9.80% by the 51st SMW. Meanwhile, in *kharif* 2021, it was ranged from 2.38–41.67% throughout the cropping period. The incidence began to be seen in the second fortnight of September (37th SMW) and grew steadily as crop growth progressed, peaking during the 46th SMW (41.67%). Thereafter, the incidence of rosette flowers gradually declined. However, the results of present investigations are more or less similar with the findings of Yalawar and Patel (2019) who reported that the per cent rosette flowers was found to vary between 2.25–15.45% with seasonal mean of 9.05%. Sarode *et al.* (2020) reported that the per cent rosette flowers were highest during 41st SMW. Patel (2020) reported that the peak per cent rosette flowers (14.35%) was observed during 51st SMW.

In *kharif* 2020, the damage to green bolls by *Pectinophora gossypiella* in *Bt* cotton ranged from 2.56–43.88%, starting from the 38th SMW (Table 1). The highest occurrence was noticed during 48th SMW, reaching 43.88%. Subsequently, the damage gradually decreased. In *kharif* 2021, the green boll damage (GBD) ranged from 4.35–63.49%. The incidence began in the 38th SMW and peaked at 63.49% in the 48th SMW. These results are in line with the earlier reports. Yalawar and Patil (2019) observed GBD starting in the first half of September (37th SMW), which increased steadily and reached its highest point in the second half of December (48th SMW). Similarly, Sarode *et al.* (2020) noticed that the highest percentage of green boll infestation occurred in the 48th SMW. Additionally, Dake *et al.* (2021) stated that during *kharif* 2018, GBD ranged from 5.00–40.00%, while in *kharif* 2019, it ranged from 1.67–85.00%. The pinnacle of GBD was observed in the 47th and 48th SMW for 2018 and 2019, respectively.

During *kharif* 2020, the larval infestation in green bolls varied from 0.45–38.55 larvae/20 bolls (Table 1). The infestation began in the 38th SMW with 0.45 larvae/20 bolls and reached its first peak of 21.50 larvae during the 46th SMW. The highest incidence of larvae, 38.55 larvae/20 bolls, was noticed in the 47th SMW. In the following year (*kharif* 2021), larval infestation ranged from 1.30–32.50 larvae/20 bolls. The infestation began at 11.30 larvae/20 bolls in the 38th SMW and peaked at 32.50 larvae in the 48th SMW. The current findings corroborate with those of Sarode *et al.* (2020) who observed the highest larval population in the 48th SMW (25 larvae/20 green bolls). Similarly, Divya *et al.* (2020) reported that PBW incidence initiated in the 32nd SMW and peaked in severity during the 46th SMW (15 larvae/20 green bolls). Similarly, Vora *et al.* (2024) observed that larval populations peaked in the 43rd and 46th SMW, which corresponds to late October and November. Consistent results were also revealed by Dake *et al.* (2021) and Seram *et al.* (2022).

During *kharif* 2020, locule damage in green bolls varied from 1.25–52.70% (Table 1). The highest damage, 43.88%, occurred during the peak boll development period. In the following year (*kharif* 2021), a similar trend was observed with the highest locule damage at 48.38% during the 48th SMW. The range of locule damage was from 1.65–48.38% in *Bt* cotton. The current findings are similar to those of Yalawar and Patil (2019) who reported locule damage in green bolls ranging from 24.71–39.35%, with a mean of 39.05%. Shinde *et al.* (2018) documented locule damage ranging from 1.77–15.73%.

During *kharif* 2020, the open boll damage (OBD) percentage in *Bt* cotton ranged from 41.79–48.15%, with the highest damage (48.15%) occurred during 50th SMW, specifically at the 3rd picking. On an average, the open boll damage was 44.41%. During the following year, *kharif* 2021, a similar pattern emerged with the highest open boll damage recorded during 50th SMW (59.52%). The OBD % ranged from 44.74–59.52% and there was a gradual increase at 3rd picking (59.52%) during the 50th SMW. These findings are in line with those of Verma *et al.* (2017), who observed OBD 29.99%. Yalawar and Patil (2019) reported a range of OBD percentage from 48.36–53.48% with an average of 53.45%.

In *kharif* 2020, PBW adult trap catches commenced in August, ranging from 1.00–185.00 moths/week (Table 1). Subsequently, there was a steady rise in catches with a notable surge in moth emergence from the second week of November, corresponding to the 46th SMW (118 moths/week). The highest trap catches were recorded during the 50th SMW (185 moths/week). In *kharif* 2021, trap catches exhibited a gradual increase, peaking in the first week of December (49th SMW) at 153 moths/week. The current results are in conformity with Rani *et al.* (2010) who found that adult trap catches commenced in September and remained relatively stable until the second week of November. Surwase *et al.* (2017) documented the highest adult catches in the final week of November.

The data revealed that, the moth catches in *Bt* cotton exhibited negatively significant relationship to minimum temperature (r =-0.446*), morning relative humidity (RH) (r =-0.480*) and evening RH (r =-0.520*), respectively (Table 2). The pheromone trap catches in relation to maximum temperature (r =-0.085) and rainfall (r =-0.308) were negatively non-significant. While, wind speed showed positive non-significant relation with adult moth catches. Whereas, during *kharif* 2021, moth trap catches showed negatively significant relationship with minimum temperature (r =-0.583**) and maximum temperature (r =-0.451*) while, evening RH (r =-0.322) and rainfall (r =-0.229) were negatively non-significant. The current findings are in line with those of Babu and Meghwal (2014) who noticed a significant negative correlation between trap catches of PBW and minimum temperature. According to Ali *et al.* (2016), both maximum and minimum temp had a significant negative effect on adult moth catches, while morning and evening RH had a non-significant negative effect. Similarly, Seram *et al.* (2022) observed a non-significant negative relationship between trap catches and rainfall and a significant negative relationship with maximum temperature.

The data indicated that in both *kharif* 2020 and 2021, rosette flowers in *Bt* cotton had no significant correlations with weather parameters (Table 2). The current findings are corroborated with those of Yalawar and Patil (2019), who found that rosette flower damage percentage had a non-significant association with rainfall and negative significant correlation with maximum temp.

The data on correlation between weather parameters and PBW larvae per 20 green bolls revealed that, during *kharif* 2020, the larval population of PBW exhibited a significant negative relation with minimum temperature (r = -0.701**), evening RH (r = -0.719**), morning RH (r = -0.597*) and rainfall (r = -0.517*). The present findings are similar to those of Verma *et al.* (2017) who reported that PBW larval population exhibited negative correlations with maximum and minimum temperatures as well as rainfall, while showing positive correlations with morning

Table 1 Population dynamics of pink bollworm in *Bt* cotton during *kharif* 2020 and 2021

SMW	Duration	Moths/ Trap		Rosette flower (%)		PBW larvae/20 green bolls		Green boll damage (%)		Locule damage/20 green bolls	
		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
33	13–19 Aug	0	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	20–26 Aug	1	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	27–02 Sept	15	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	03–09 Sept	4	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	10–16 Sept	7	5	2.27	2.38	0.00	0.00	0.00	0.00	0.00	0.00
38	17–23 Sept	5	6	5.66	7.14	0.45	1.30	2.56	4.35	1.25	1.65
39	24–30 Sept	8	8	8.62	8.47	0.95	2.00	3.51	5.26	3.40	2.80
40	01–07 Oct	13	4	11.59	9.86	1.65	3.75	5.80	6.94	4.30	3.65
41	08–14 Oct	26	15	13.33	16.67	3.45	4.55	8.89	10.47	6.50	7.32
42	15–21 Oct	67	21	19.70	19.12	5.35	5.65	14.93	24.66	7.35	9.84
43	22–28 Oct	47	35	24.32	21.88	9.50	10.15	24.66	27.50	14.70	12.70
44	29–04 Nov	54	47	25.56	25.81	13.70	13.90	27.78	34.62	27.20	17.55
45	05–11 Nov	78	59	26.67	31.82	19.35	16.65	29.21	37.50	37.30	28.15
46	12–18 Nov	118	108	29.67	41.67	21.50	18.85	30.47	41.75	44.65	36.70
47	19–25 Nov	137	124	32.84	39.68	38.55	21.65	32.46	48.81	49.31	42.15
48	26–02 Dec	153	139	22.95	36.76	23.70	32.50	43.88	63.49	52.70	48.38
49	03–09 Dec	172	153	19.72	28.32	22.15	20.40	32.39	53.89	25.15	34.80
50	10–16 Dec	185	142	12.86	26.79	21.45	15.45	28.38	45.44	22.65	26.32
51	17–23 Dec	161	128	9.80	13.16	18.60	13.22	26.83	34.88	18.55	20.21
52	24–31 Dec	126	112	14.52	9.68	16.60	11.30	23.64	26.36	14.65	18.28

SMW, Standard meterological week.

and evening RH. Additionally, Patel (2020) reported a significant negative correlation between PBW population and maximum temperature, minimum temperature, wind velocity and rainfall.

During *kharif* 2020, GBD exhibited significant positive correlation with wind speed (r = 0.618**) and significant negative correlations with minimum temperature (r = -0.666**), evening RH (r = -0.711**), rainfall (r = -0.607**) and morning RH (r = -0.529*). In *Kharif* 2021, conversely, maximum temperature (r = -0.561*) and minimum temperature (r = -0.810**) exhibited significant negative correlations. The present findings are more or less similar with the reports of Yalawar and Patil (2019) who observed a negative and significant relationship between GBD and both maximum and minimum temperatures. Seram *et al.* (2022) found that GBD had a non-significant negative relationship with max temperature (r = -0.401), morning RH (r = -0.034), evening RH (r = -0.073) and rainfall (r = -0.346). Additionally, it had a significant negative relationship with min temperature (r = -0.601*).

During *kharif* 2020, locule damage displayed significant negative correlations with evening RH (r = -0.627**), morning RH (r = -0.557*) and minimum temperature (r = -0.521*). During *kharif* 2021, locule damage exhibited a significant negative correlation with min temperature (r = -0.732**). The results regarding locule damage in green bolls caused by *Pectinophora gossypiella* are in concurrence with Rawal *et al.* (2018) who reported that the percentage of locule damage had a negative correlation with max temperature, min temperature and rainfall. In contrast, they found a positive correlation with morning and afternoon RH.

The (R^2) coefficient of determination reveals the shared variability between weather parameters and various aspects of *Bt* cotton cultivation. By pooling data from *kharif* 2020 and 2021 the model's predictive accuracy was significantly improved with weather variables accounting for 76% of the variation in pink bollworm moth trap catches, 74% in rosette flowers, 65% in pink bollworm larval populations, 79% in GBD severity and 62% in locule damage. These results demonstrated the enhanced reliability of weather factors in forecasting pest occurrences in *Bt* cotton, providing a stronger basis for understanding the influence of climatic conditions on cotton cultivation.

In the present study, results obtained on the reliability of weather factors in forecasting pink bollworm's occurrence and its damage in *Bt* cotton highlighted the significant role of weather factors in influencing *Bt* cotton pests, with high R^2 values indicating strong correlations. These results were consistent with Kadam *et al.* (2022) who found that weather parameters, particularly temperature and BSS were key drivers of pest population fluctuations. Our model also emphasized the importance of these factors in predicting pest occurrence, supporting the use of weather-based strategies for effective pest management in cotton agroecosystems.

In the present investigation the data from *kharif* 2020 and 2021 showed varying incidences of pink bollworm and associated damages in *Bt* cotton. The first incidence of pink bollworm larvae in *Bt* cotton was recorded in the 37th MW of both *kharif* 2020 and 2021, with peak larval population reaching 38.55 larvae/20 green bolls in 2020 and 32.50 larvae in 2021. Rosette flower, fruiting bodies and green boll damage peaked around the 46th–48th MW in both years. Pheromone traps effectively monitored PBW moth activity with the highest catches recorded in the 50th MW of 2020 (185 moths/week) and the 49th MW of 2021 (153 moths/week). Consistent results were also revealed by Kadam *et al.* (2022), Seram *et al.* (2022) and Vora *et al.* (2024).

The current study affirms that pink bollworm prevails as a prominent threat in cotton crop, maintaining its dominance year-round. The increase in population and damage caused by pink bollworm were associated with favourable environmental conditions such as minimum

Table 2 Simple correlation between weather parameters and pink bollworm in *Bt* cotton

Pests	Year	Correlation coefficient (r)							
		Max. Temp.	Min. Temp.	RH-1	RH-2	Rainfall	BSS	WS	EVP
Trap catches	2020	-0.085	-0.446*	-0.480*	-0.520*	-0.308	-0.259	0.386	-0.132
	2021	-0.451*	-0.583**	-0.348	-0.322	-0.229	-0.338	0.061	-0.387
Rosette flower (%)	2020	0.077	-0.327	-0.389	-0.473	-0.565*	-0.173	0.509*	0.151
	2021	-0.149	-0.276	-0.220	-0.383	-0.082	-0.289	0.156	-0.041
PBW/20 green bolls	2020	-0.216	-0.701**	-0.597*	-0.719**	-0.517*	-0.145	0.542*	-0.192
	2021	-0.149	-0.276	-0.220	-0.383	-0.082	-0.289	0.156	-0.041
Green boll damage (%)	2020	-0.088	-0.666**	-0.529*	-0.711**	-0.607**	-0.326	0.618**	-0.057
	2021	-0.561*	-0.810**	-0.047	-0.480	-0.469	-0.481	0.115	-0.328
Locule damage/20 green bolls	2020	0.014	-0.521*	-0.557*	-0.627**	-0.478	-0.130	0.578*	-0.176
	2021	-0.093	-0.732**	-0.011	-0.304	-0.307	-0.342	-0.057	-0.438

*Significant at 5 % level ** Significant at 1% level.

Max. Temp, Maximum temperature; Min. Temp, Minimum temperature; RH-1, Morning relative humidity; RH-2; Evening relative humidity; BSS, Bright sunshine; WS, Wind speed; EVP, Evaporation; SMW, Standard meteorological week.

Table 3 Multiple regression equations for PBW and meteorological conditions in *kharif* 2020 and 2021 (Pooled)

Particulars	Regression equation (Pooled 2020–2021)	R^2
PBW trap catches	$Y = 300.83 - 3.52X_1 - 14.23X_2 - 0.42X_3 + 0.65X_4 + 0.01X_5 - 10.81X_6 - 0.98X_7 + 21.92X_8$	0.76
Rosette flowers	$Y = 240.41 - 1.94X_1 + 2.24X_2 - 1.66X_3 - 1.00X_4 - 0.02X_5 - 9.03X_6 - 1.71X_7 + 2.57X_8$	0.74
PBW larvae/20 green bolls	$Y = 130.44 - 2.21X_1 - 0.26X_2 - 0.57X_3 - 0.24X_4 + 0.02X_5 - 4.12X_6 + 0.35X_7 + 3.95X_8$	0.65
GBD	$Y = 314.31 - 3.98X_1 + 0.26X_2 - 1.69X_3 - 0.77X_4 + 0.05X_5 - 9.23X6 - 0.53X_7 + 5.50X_8$	0.79
Locule damage	$Y = 309.01 - 4.23X_1 + 0.72X_2 - 1.99X_3 - 0.48X_4 + 0.09X_5 - 7.48X_6 + 0.68X_7 + 5.83X_8$	0.62

PBW, Pink boll worm; Y, Particulars; X_1, Maximum temperature; X_2, Minimum temperature; X_3, Morning relative humidity; X_4, Evening relative humidity; X_5, Rainfall; X_6, Wind speed; X_7, Bright sunshine; X_8, Evaporation and R^2, Coefficient of determination.

temperature and humidity. The correlation studies provide clear evidence of the significance of weather parameters in forecasting pink bollworm infestations. These findings will undoubtedly be valuable for farmers and extension workers in devising more effective pest management strategies to enhance cotton production.

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