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Influence of weather parameters on insect-pests and associated natural enemies in cotton ecosystem of Anand, Gujarat

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Abstract
A comprehensive study was conducted during *kharif-rabi*, 2024-25 at Biological Control Research Farm, ICAR Unit-9, Anand Agricultural University, Anand to monitor the population dynamics of key insect-pests and their natural enemies on cotton and the influence of weather parameters. Aphid population started appearing in late July, attained peak during 51st SMW, with populations negatively correlated with minimum temperature, humidity, rainfall and wind speed, but positively associated with bright sunshine hours. Jassids activity was recorded from July to November, showing a significant positive correlation with maximum temperature. However, thrips incidence remained below economic threshold levels with showing no significant correlation with weather parameters. While, whitefly population attained peak in 42nd SMW, exhibited a strong positive correlation with maximum temperature. Pink bollworm infestation was maximum in 51st SMW, exhibiting a significant negative correlation with temperature and rainfall. Among natural enemies, green lacewing, both eggs and larvae were observed from September to January, eggs and larvae negatively correlated with humidity, and minimum temperature and larvae positively influenced by sunshine hours. Coccinellid beetles showed negative correlations with humidity and positive trends with temperature and sunshine hours. Spiders were active during the same period, negatively affected by humidity, wind and rainfall, but positively influenced by sunshine hours. The study clearly showed that weather play a crucial role in shaping the population of pests and their natural enemies in cotton fields. Understanding these relationships helps farmers to anticipate pest outbreaks and implement better, more timely strategies that are tailored to seasonal changes, ultimately leading to healthier crops and more effective pest control.

Keywords: Green lacewing, population dynamics, natural enemies, *Bt* cotton, correlation

Introduction
Cotton (*Gossypium* spp.), often called the "King of natural fibres," is of great commercial importance worldwide and is cultivated in more than 111 countries. It forms the backbone for many developing nations, including India, where it contributes significantly to employment and foreign exchange earnings (WTO, 2020). However, cotton cultivation faces persistent threats from insect-pests, leading to severe yield losses and reduced fibre quality.

Globally, around 326 insect-pest species are known to affect cotton, with 130 species reported in India (Sohi, 1964) [25]. Among these, sucking pests and the bollworm complex are significant insect-pests of cotton crops that cause significant losses. Aphid (*Aphis gossypii* Glover), jassid (*Amrasca biguttula biguttula* Ishida), thrips (*Thrips tabaci* Lindeman), whiteflies (*Bemisia tabaci* Gennadius) and mealybug (*Phenacoccus solenopsis* Tinsley) causing damage during the early stages of the cotton plant and can cause significant damage if not controlled. The bollworm complex, particularly *Helicoverpa armigera* (Hübner) Hardwick, spotted bollworm (*Earias vittella* Fabricius) and pink bollworm (*Pectinophora gossypiella* Saunders) are destructive during reproductive phase of crop, impacting both yield and lint quality.

To overcome this menace, *Bt* cotton, a genetically modified variety was developed. This cotton expresses proteins from *Bacillus thuringiensis* that specifically target bollworm pests, resulting in reduced crop damage and lower pesticide use (Lu *et al*., 2012) [14]. However, it does not control sucking pests. Moreover, its performance can be affected by several factors, such as pest behaviour and weather patterns (Krishna and Qaim, 2012) [13].

Cotton ecosystems also attract many natural enemies that help to control pest populations (Chi *et al*., 2021) [5]. These include ladybird beetles *Coccinella septempunctata* and *Cheilomenes sexmaculatus*, green lacewing *Chrysoperla carnea* and several species of spiders (Kannan *et al*., 2004) [11]. These natural enemies are particularly effective against aphids and other sucking pests, playing a key role in supporting the natural balance of the ecosystem and limiting the need for chemical interventions. Ladybird beetle and green lacewing are the dominant predators of aphids in the cotton agroecosystem (Pervez and Omkar, 2003) [21].

This study focuses on better understanding how insect-pests and their natural predators behave in *Bt* cotton fields, especially in response to weather conditions in the Anand region. By exploring these relationships, the research aims to create smart, weather-informed pest management strategies that help farmers grow cotton in a healthier and more sustainable way. Knowing how these factors interact allows for pest control methods tailored to each season and location, benefiting both farmers' livelihoods and the environment.

Materials and Methods

To determine the population dynamics of various insect-pests and natural enemies, *Bt* cotton variety G. Cot. Hybrid 10 (BG-II) was sown at Biological Control Research Farm, ICAR Unit-9, Anand Agricultural University, Anand during *kharif-rabi*, 2024-25. The crop was raised in 24×18 m plot size with a spacing 120×45 cm. The plot was kept free from any plant protection measures. The plot was divided into eight equal sectors each of 6×9 m. From each sector, five plants were randomly observed.

Method of recording observations

To record observations of aphids, jassids, thrips and whiteflies, three leaves (top, middle and bottom leaves) per plant were recorded. Observations of pink bollworm larvae were counted from rosette flowers, green bolls and locules per plant. However, egg(s), larva (e) and adult(s) of green lacewing; grubs and adult population of coccinellids and spider were noted from five plants. The observations were recorded at weekly intervals throughout the crop period.

Correlation study

In order to study the influence of weather parameters on incidence, fluctuation of insect-pests and natural enemies, the data on abiotic parameters were correlated. Data on weather parameters were obtained from the Agrometeorological Observatory, Department of Agricultural Meteorology, B. A. College of Agriculture, AAU, Anand were utilized. The relationship between weather parameters and insect-pests and natural enemies was calculated by using simple correlation-coefficient (r) analysis.

Results and Discussion

The presence of insect pests on cotton was monitored from July, 2024 until the crop was harvested. The main pests observed during this period included aphid, jassid, thrips, whitefly and pink bollworm. Alongside these pests, predators such as green lacewings, ladybird beetles (coccinellids), and spiders were also observed. The detailed information on the population trends of these pests on *Bt* cotton during the *kharif*, 2024-25 represented in Table 1.

Population of insect-pests

Aphid, *Aphis gossypii* Glover

Aphids were present throughout the entire *kharif-rabi* season of 2024-25 as shown in Table 1. Their infestation began in the last week of July (31st SMW) and continued all the way until the cotton was harvested in mid-January (2nd SMW). The number of aphids per leaf varied between 0.48 and 19.51. An initial rise was observed until early August, then steady decline and increased till early October. A sharp rise occurred from late October, reaching a peak of 19.51 aphids per leaf in mid-December (49th SMW). Following this peak, their numbers gradually decreased to around 5.04 aphids per leaf by the time the crop was harvested. These findings are consistent with previous research of Kengegowda *et al.* (2005) [12], who observed aphid peak around 48th SMW in *Bt* cotton grown in Karnataka. Similarly, Makwana and Dulera (2018) [15] reported a peak of 74.6 aphids per three leaves during 49th SMW.

Jassid, *Amarsca biguttula biguttula* (Ishida)

The infestation of jassid was recorded from the third week of July (30th SMW) to third week of November (46th SMW), with population levels ranging from 0.11 to 0.81 jassid per leaf. The population showed a gradual increase, peaking first at 0.48 jassid per leaf during the fourth week of August (34th SMW). A slight decline followed until mid-September, after which the population rose again, reaching a second peak of 0.81 jassid per leaf in the fourth week of October (43rd SMW). Thereafter, a steady decline was observed and the population disappeared completely by the third week of November. These findings agree with Makwana and Dulera (2018) [15] and Patel and Radadia (2018) [18], who reported peak jassid population around 42nd-43rd SMW ranging from 14.5 to 37.2 per three leaves.

Thrips, *Thrips tabaci* Lindeman

The data on incidence of thrips, presented in Table 2 showed that infestation started in fourth week of July (31st SMW) with a low population of 0.12 thrips per leaf and continued until the fourth week of September (39th SMW), declining to 0.02 thrips per leaf. The population attained peak at 0.43 thrips per three leaves in the second week of August (33rd SMW), then slightly declined to 0.39 per leaf by fourth week of August (35th SMW). A second peak of 0.41 thrips per plant occurred in first week of September (36th SMW), after which the population steadily declined to 0.02 per leaf by the end of September (39th SMW). Thrips infestation remained below the economic threshold level (ETL) throughout the period. Desai *et al.* (2009) [6] reported thrips presence from 31st to 41st SMW on RCH 2 *Bt* cotton at Surat. Janu *et al.* (2017) [9] observed thrips starting from 27th SMW, with a peak in 33rd SMW. Similarly, Pawar *et al.* (2017) [20] documented thrips infestation from 32nd to 41st SMW, supporting the current findings.

Whitefly, *Bemisia tabaci* (Gennadius)

The incidence of whiteflies commenced in third week of August (34th SMW) with a low population of 0.18 whitefly per leaf (Table 1). The population showed a rising trend, with the first peak observed during first week of October (40th SMW), reaching 2.38 whiteflies per leaf. This was followed by a slight drop with the second and highest peak recorded in third week of October (42nd SMW), with 2.43 whiteflies per leaf. These findings agree with Chauhan *et al.*

(2017) [4] and Makwana and Dulera (2018) [15], who reported whitefly onset around 32nd - 33rd SMW and peak activity between 42nd - 44th SMW.

Table 1: Population dynamics of insect-pests and their natural enemies in *Bt* cotton (2024-25)

Months	Week	SMW	WAS	Number of sucking pests per leaf				No. of pink bollworm larva(e)/ Plant	No. of natural enemies/plant				
				Aphids	Jassids	Thrips	Whitefly		Coccinellids	Spider	Lacewing eggs	Lacewing larvae	Lacewing adults
July, 2024	II	28	1	0	0	0	0	0	0	0	0	0	0
	III	29	2	0	0	0	0	0	0	0	0	0	0
	IV	30	3	0	0.15	0	0	0	0	0	0	0	0
	V	31	4	0.48	0.26	0.12	0	0	0	0	0	0	0
August, 2024	I	32	5	1.33	0.42	0.22	0	0	0	0	0	0	0
	II	33	6	2.50	0.43	0.43	0	0	0	0	0	0	0
	III	34	7	1.58	0.48	0.42	0.18	0	0	0	0	0	0
	IV	35	8	1.18	0.44	0.39	0.48	0	0.35	0	0	0	0
September, 2024	I	36	9	2.40	0.39	0.41	0.60	0	0.50	0.33	0	0	0
	II	37	10	2.98	0.21	0.31	1.04	0	0.85	0.48	0.08	0	0.03
	III	38	11	4.34	0.35	0.15	1.33	0	1.03	0.55	0.48	0.08	0.03
	IV	39	12	4.47	0.44	0.02	1.90	0	1.48	0.65	0.60	0.25	0.13
October, 2024	I	40	13	5.93	0.58	0	2.38	0.28	1.30	0.80	0.85	0.30	0.20
	II	41	14	5.41	0.49	0	2.33	0.63	1.63	0.83	1.20	0.80	0.18
	III	42	15	5.12	0.78	0	2.43	0.75	1.40	0.98	1.00	1.03	0.18
	IV	43	16	6.95	0.81	0	2.37	1.13	1.28	1.08	1.45	1.33	0.23
November, 2024	I	44	17	7.88	0.79	0	2.23	1.63	1.25	1.15	2.53	1.25	0.23
	II	45	18	9.92	0.33	0	1.94	2.50	1.53	1.10	2.63	1.13	0.20
	III	46	19	10.13	0.11	0	1.13	2.58	1.88	1.20	3.25	1.00	0.18
	IV	47	20	10.11	0	0	0.45	3.18	1.93	1.33	4.40	1.10	0.20
December, 2024	I	48	21	17.21	0	0	0.14	3.85	1.95	1.35	5.28	1.18	0.13
	II	49	22	19.51	0	0	0	3.60	2.35	1.13	3.53	1.43	0.20
	III	50	23	16.82	0	0	0	5.08	1.85	0.93	2.75	1.28	0.10
	IV	51	24	12.75	0	0	0	5.18	1.35	0.80	2.60	1.15	0.20
	V	52	25	10.24	0	0	0	5.15	0.70	0.65	2.20	0.93	0.25
January, 2025	I	1	26	8.33	0	0	0	4.25	0.28	0.35	1.35	0.68	0.23
	II	2	27	5.04	0	0	0	3.90	0.20	0.23	0.53	0.35	0.13

Note: SMW: Standard Meteorological Week; WAS: Week After Sowing

Table 2: Correlation-coefficient (r) between weather parameters and pests as well as their natural enemies in *Bt* cotton

Weather parameters Pest	Temperature		Relative humidity		Bright sunshine	Rainfall	Wind speed	Evaporation
	Maximum (Max. T)	Minimum (Min. T)	Morning (RH_1)	Evening (RH_2)				
Aphids (n = 24)	-0.324	-0.796**	-0.811**	-0.784**	0.648**	-0.562**	-0.433*	0.125
Jassids (n = 17)	0.543*	0.018	-0.155	-0.255	0.355	-0.069	-0.478	0.211
Thrips (n = 10)	0.276	0.138	-0.125	-0.348	0.433	0.301	0.178	0.089
Whiteflies (n = 15)	0.749**	0.291	0.120	-0.147	0.210	-0.416	-0.569*	0.188
Pink bollworm (n = 15)	-0.848**	-0.932**	-0.375	-0.361	0.162	-0.436*	0.522*	-0.304
Coccinellids (n = 20)	0.202	-0.184	-0.577**	-0.451*	0.277	-0.362	-0.442	0.210
Spider (n = 20)	0.341	-0.255	-0.482**	-0.649**	0.501**	-0.555*	-0.701**	0.042
Green lacewing eggs (n = 20)	-0.189	-0.586*	-0.563*	-0.686**	0.405	-0.324	-0.339	-0.214
Green lacewing larvae (n = 20)	-0.001	-0.474*	-0.490*	-0.691**	0.422	-0.277	-0.606**	-0.246
Green lacewing adults (n = 20)	0.055	-0.239	0.120	-0.265	0.090	-0.126	-0.804**	-0.703**

Note: **Correlation is significant at 0.01 % level
*Correlation is significant at 0.05 % level

Pink bollworm, *Pectinophora gossypiella* (Saunders)

Pink bollworm infestation started in the first week of October (41st SMW) with 0.28 larva per plant and continued until the second week of January (2nd SMW), ending at 3.90 larvae per plant. The population gradually increased, peaking at 3.85 larvae in the first week of December (48th SMW) and reaching the highest level of 5.18 larvae per plant in the fourth week of December (51st SMW), followed by a steady decline until crop termination. Muchhadiya *et al*. (2014) [16] reported the incidence of pink bollworm during 47-52nd SMW with peak infestation observed during 51st SMW (0.26 larva per plant). Pawar *et al*. (2017) [20] recorded the highest larval population of pink bollworm (8 larvae per 20 green bolls) during 6th SMW. Nagrare *et al.* (2025) [17] reported pink bollworm infestation above ETL from 49th to 4th SMW, aligning with the present findings.

Correlation between weather parameters and various insect-pests

The data on insect-pests were correlated separately with weather parameters and the correlation coefficients analysis was presented in Table 2. Correlation analysis revealed a highly significant negative correlation between aphid (*A. gossypii*) population and minimum temperature (r = -0.796), morning relative humidity (r = -0.811), evening relative humidity (r = -0.784), rainfall (r = -0.562) and wind speed (r = -0.433). Bright sunshine hours showed a highly significant positive correlation (r = 0.648), while evaporation (r = 0.125) and maximum temperature (r = -0.324) had non-significant correlations. These findings agree with Patel (2010) [19], Prasad *et al.* (2008) [22], Bhute *et al.* (2012) [2] and Muchhadiya *et al.* (2014) [16], who reported similar weather influences on aphid populations.

Correlation analysis showed jassid population had a highly significant positive correlation with maximum temperature (r = 0.543). Minimum temperature (r = 0.018), sunshine hours (r = 0.355) and evaporation (r = 0.211) had non-significant positive correlations. Negative non-significant correlations were observed with morning RH (r = -0.155), evening RH (r = -0.255), wind speed (r = -0.478) and rainfall (r = -0.069). These findings align with previous studies by Patel (2010) [19], Bhute *et al.* (2012) [2] and Patel and Radadia (2018), all of which reported a positive correlation between leafhopper populations and maximum temperature.

Thrips incidence showed no significant correlation with most weather parameters. Positive but non-significant correlations were found with maximum temperature, rainfall, wind speed, sunshine hours, evaporation and minimum temperature. Negative non-significant correlations observed with morning and evening relative humidity. Prasad *et al.* (2008) [22] and Janu *et al.* (2017) [9] also reported that none of the weather parameters significantly affected the thrips population.

Whitefly population showed a highly significant positive correlation with maximum temperature (r = 0.749) and a significant negative correlation with wind speed (r = -0.569). Minimum temperature, morning relative humidity, sunshine hours and evaporation showed positive but non-significant correlations, while evening relative humidity and rainfall had negative non-significant associations. These results align with Patel (2010) [19] and Pawar *et al.* (2017) [20], who all confirmed that maximum temperature significantly promotes whitefly population growth.

Pink bollworm infestation showed highly significant negative correlations with maximum (r = -0.848) and minimum temperature (r = -0.932) and a significant negative correlation with rainfall (r = -0.436). Wind speed had a significant positive effect (r = 0.522). Other weather factors showed non-significant correlations. These results agree with Muchhadiya *et al.* (2014) [16], Rakhesh *et al.* (2023) [24] and Deshmukh *et al.* (2025) [7].

Population of natural enemies

Green lacewing

Different stages of green lacewing were observed from the second week of September (37th SMW) until mid-January. Egg laying started from 0.08 egg per plant, peaking twice, 1.20 eggs in mid-October (41st SMW) and 5.28 eggs in early December (48th SMW). Larvae appeared from late September, peaking at 1.43 larvae per plant in mid-December (49th SMW), then declined to 0.35 by mid-January. Adults were first seen in mid-September, with a peak of 0.25 per plant in late December (51st SMW). Kengegowda *et al.* (2005) [12] reported peak green lacewing activity in 49th SMW. Chakraborty (2009) [3] noted three oviposition peaks, with major peaks in early October and December. Larval populations attained peak in 50th SMW. Badgujar *et al.* (2017) [1] observed lacewing activity from 33rd SMW, peaking in 46th SMW. Similarly, Patel and Radadia (2018) [18] recorded presence from 37th to 2nd SMW, with a peak in mid-November.

Coccinellids

Coccinellid (grub + adult) activity began in late August (35th SMW) and continued until crop termination, with populations ranging from 0.35 to 2.35 per plant (Table 2). The peak (2.35/plant) was recorded in second week of December (49th SMW). These results align with earlier findings by Kengegowda *et al.* (2005) [12], Badgujar *et al.* (2017) [1] and Patel and Radadia (2018) [18], who also reported peak activity during the later crop stages.

Spider

Spider activity commenced from first week of September (36th SMW) with 0.33 spider per plant and continued until second week of January (2nd SMW), peaking at 1.35 in early December (48th SMW). These findings align with Kengegowda *et al.* (2005) [12], Badgujar *et al.* (2017) [1], Patel and Radadia (2018) [18] and Ramzan *et al.* (2019) [23], who reported similar seasonal trends and peak population between October and December.

Population of natural enemies and its correlation with weather parameters

Green lacewing eggs showed a highly significant negative correlation with evening RH (r = -0.686) and significant negative correlations with morning RH (r = -0.563) and minimum temperature (r = -0.586). Larvae showed highly significant negative correlations with evening RH (r = -0.691) and wind speed (r = -0.606) and significant negative correlations with morning RH (r = -0.490) and minimum temperature (r = -0.474), while bright sunshine hours had a significant positive effect (r = 0.422). Adults showed highly significant negative correlations with evaporation (r = -0.703) and rainfall (r = -0.804). Dhaka and Pareek (2007) [8], Chakraborty (2009) [3], Muchhadiya *et al.* (2014) [16] and Pawar *et al.* (2017) [20] all reported significant negative effects of temperature and relative humidity on green lacewing stages, which closely align with the present findings.

Coccinellid beetles showed a highly significant negative correlation with morning relative humidity (r = -0.577) and a significant negative relation with evening relative humidity (r = -0.451). Coccinellid population showed non-significant correlations with other parameters. These findings align with Pawar *et al.* (2017) [20] and Patel and Radadia (2018) [18], who reported significant negative effects of temperature, humidity and wind speed on coccinellids and a positive influence of sunshine hours. Jat *et al.* (2023) [10] also noted a positive association with relative humidity.

Spider population showed highly significant negative correlations with morning relative humidity (r = -0.482), evening relative humidity (r = -0.649) and wind speed (r = -0.701) and a significant negative correlation with rainfall (r = -0.555). A highly significant positive correlation was observed with bright sunshine hours (r = 0.501), while maximum temperature and evaporation showed non-significant positive effects. These findings agree with Pawar *et al.* (2017) [20], who reported strong negative correlations with temperature and humidity and a positive correlation with sunshine hours. Patel and Radadia (2018) [18] also found a positive correlation with evaporation and a negative one with wind speed.

Conclusion

The study highlights the population dynamics of key insect-pests and their natural enemies on cotton during *kharif-rabi*, 2024-25 season. Weather parameters significantly influenced pest and predator populations, with temperature, humidity, rainfall, wind speed and sunshine hours playing crucial roles. Understanding these relationships can aid in developing effective, weather-informed pest management strategies, enhancing the sustainability of cotton cultivation through better timing and deployment of control measures.

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