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Influence of weather factors on population dynamics of major sucking pests of *Bt* cotton

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Abstract
A field experiment conducted over *Kharif* seasons of 2020 and 2021 at All India Coordinated Cotton Improvement Project, MPKV, Rahuri, examined the impact of weather factors on sucking pest populations in *Bt* cotton. The data reveal that aphids were predominant, ranging from 4.60 to 120.86/3 leaves in 2020 and 0.64 to 63.60/3 leaves in 2021. Jassids ranged from 2.04 to 11.46/3 leaves in 2020 and 0.52 to 5.76/3 leaves in 2021. Thrips ranged from 0.26 to 13.78/3 leaves in 2020 and 0.18 to 57.46/3 leaves in 2021. Whiteflies varied from 0.24 to 8.32/3 leaves in 2020 and 0.04 to 5.82/3 leaves in 2021 with peak activity recorded in the 42nd SMW of 2020 and the 46th SMW of 2021. Natural predators like lady bird beetles, green lace wings and predatory spiders were observed throughout the cropping season, showing peak activity in specific weeks.

Keywords: Population dynamics, *Bt* cotton, sucking pests, aphids, jassid, whitefly, thrips, correlation, natural enemies

Introduction
Cotton, a vital global commodity and cornerstone of the textile industry, plays a pivotal role in the economies of many countries (Nemade *et al*., 2018) [14]. India leads global cotton cultivation with 12.7 million hectares, yielding 28.5 million bales (ICAC, 2021). Despite its vast cultivation area (36% of global cotton area), India's production represents 25 percent of the global total. The average yield, at 510 kg per hectare, lags behind the world average of 808 kg per hectare. India is the top cotton producer, second-largest consumer and fourth-largest raw cotton exporter (ICAC, 2022). Maharashtra leads in cotton cultivation, covering 44.69 lakh hectares, accounting for 34 percent of India's total cotton growing area. Despite its substantial production of 81 lakh bales, the state's productivity at 317 kg per hectare falls below the national average (CCI, 2022).

In Maharashtra, a comprehensive list of 25 pests has been documented to cause damage at various stages of growth (Manjunath, 2004) [12]. Among these, major sucking pests including Aphids, Jassids, Whiteflies, and Thrips are consistently cited as significant threats, posing substantial challenges to cotton cultivation across different regions (Bhamare and Wadnerkar, 2018) [2]. Environmental factors such as temperature, humidity and precipitation play a pivotal role in shaping the behaviour of these pests in cotton fields (Deshmukh *et al*., 2023) [7]. In particular, *Bt* cotton, genetically modified to resist certain pests has become increasingly prevalent in agricultural landscapes. However, despite technological advancements, the menace of sucking pests remains a persistent challenge for cotton growers. Monitoring their incidence throughout the growing season Therefore, monitoring of sucking pest population in *Bt* cotton is imperative for devising effective control measures and crop protection (Santhosh *et al*., 2009) [18]. Monitoring these dynamics helps to assess pest management strategies, identify risks to crop yield and develop targeted and sustainable pest control methods, ensuring the long-term success of cotton farming.

Material and Methods
The present experiment was conducted to study the population dynamics of major sucking pests and activities of natural enemies and their correlation with weather parameters in *Bt* cotton during *Kharif*-2020 and 2021 at All India Coordinated Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (MS). The experiment utilized

an unprotected plot measuring 25 m x 20 m. The hybrid selected for the study was Ajeet-199. The cotton crop was cultivated in accordance with recommended agronomic practices and subsequent observations were duly recorded. Population of aphids, jassids, thrips and whiteflies were recorded at weekly interval from three leaves (Each from top, middle and bottom canopy) on five randomly selected plants from each quadrant. The observation on population of major natural enemies like lady bird beetle, *chrysopa* and predatory spiders per plant were recorded on the randomly selected five plants. Meteorological data on weekly basis for *Kharif* seasons during the year 2020 and 2021 were obtained from meteorological observatory, MPKV, Rahuri. The data pertaining to population dynamics of major sucking pests was compared with various environmental factors.

Results and Discussion

Population dynamics of sucking insect pests in *Bt* Cotton

The data pertaining to population dynamics of sucking pests during *Kharif* -2020 and 2021 are presented in Table 1.

Aphids, *Aphis gossypii* (Glover)

The data revealed that during *Kharif*-2020, the aphid population in *Bt* cotton was ranged from 4.60 to 120.86 aphids/3 leaves. The infestation began at 28th MW (4.60 aphids/3 leaves) and reached its peak during 36th MW (22.32 aphids/3 leaves), followed by peaks at 43rd MW (61.42 aphids/3 leaves) and 48th MW (120.86 aphids/3 leaves). Whereas, during *Kharif* 2021, it was ranged from 0.64 to 63.60 aphids/3 leaves. The infestation began at the 28th MW (0.64 aphids/3 leaves), with the first peak observed during the 33rd MW (31.56 aphids/3 leaves). The results of present investigation are in conformity with the finding of Chakraborty *et al*. (2020) [5] who reported that aphid population were active during October to November with highest activity during the last week of November. Likewise, Meghana *et al*. (2019) [13] recorded the maximum population of aphid during 44th MW (94.20 and 102.17 aphids/3 leaves).

Jassids, *Amrasca bigutulla bigutulla* (Ishida)

The data during *Kharif* 2020 revealed that the jassid population was ranged between (2.04 to 11.46 jassids/3 leaves). The incidence was started from 28th MW. The peak incidence was recorded in 31st MW (11.46 jassids/3 leaves). After 31st MW the population of jassid decreased and reached to 2.10 jassids/3 leaves during 52nd MW. During *Kharif* 2021, it was ranged between 0.52 to 5.76 jassids/3 leaves. The incidence was first noticed in 30th MW with its peak during 37th MW (5.00 jassids/3 leaves). The highest population of jassid was observed during 46th MW (5.76 jassids/3 leaves). The trends of jassid infestation were more or less similar to those reported by earlier researchers like Patel and Radalia (2018) [17] who reported that the cotton jassid was observed throughout the cropping period during both seasons. The peak population of jassid was recorded in 43rd MW (37.22 jassids/3 leaves) and 46th MW (38.48 jassids/3 leaves) during 2015-16 and 2016-17, respectively.

Thrips, *Thrips tabaci* (Lindman)

During *Kharif* 2020, thrips population was ranged between 0.26 to 13.78 thrips/3 leaves. The incidence was first observed during the 29th MW (4.12 thrips/3 leaves) and reached its peak during 30th MW (13.78 thrips/3 leaves). Subsequently, the population showed a decreasing trend with lowest count of 0.26 thrips/3 leaves during the 42nd MW**.** The population of thrips during *Kharif*-2021 was ranged from 0.18 to 57.46 thrips/3 leaves.

Table 1: Population dynamics of major sucking pest complex in *Bt* cotton

SMW	Duration	No. of sucking pests/ 3 leaves							
		Aphids		Jassids		Thrips		Whiteflies	
		2020	2021	2020	2021	2020	2021	2020	2021
28	09-15 July	4.60	0.64	2.04	0.00	0.00	0.00	1.41	0.04
29	16-22 July	10.50	3.08	2.84	0.02	4.12	0.00	2.60	0.28
30	23-29 July	8.04	7.70	8.44	0.52	13.78	0.18	1.79	0.18
31	30-05 Aug.	10.66	8.50	11.46	1.04	5.22	0.40	1.19	0.26
32	06-12 Aug.	15.34	9.54	4.44	0.30	2.81	0.20	1.96	0.56
33	13-19 Aug.	13.64	31.56	3.62	1.84	1.67	24.62	1.59	1.38
34	20-26 Aug.	15.86	15.82	5.88	1.42	3.37	11.92	2.70	2.22
35	27-02 Sept.	18.34	40.78	5.86	2.50	2.12	49.94	2.82	2.02
36	03-09 Sept.	22.32	16.98	3.80	2.68	2.86	57.46	3.28	2.24
37	10-16 Sept.	16.80	7.14	3.78	5.00	1.60	2.90	3.22	2.10
38	17-23 Sept.	12.56	12.06	3.46	4.16	1.40	0.22	2.06	1.60
39	24-30 Sept.	8.38	22.56	6.52	3.08	0.38	2.06	2.02	1.06
40	01-07 Oct.	24.22	16.14	7.04	3.26	1.90	0.38	2.52	0.94
41	08-14 Oct.	28.30	13.00	6.42	3.10	0.42	2.32	8.06	2.48
42	15-21 Oct.	22.76	14.74	6.32	2.48	0.26	1.68	8.32	1.52
43	22-28 Oct.	61.42	22.20	3.88	3.22	0.26	3.00	2.86	3.46
44	29-04 Nov.	70.92	27.80	3.74	3.84	0.62	3.98	3.20	3.40
45	05-11 Nov.	88.10	47.66	5.22	5.70	0.34	1.20	3.36	4.98
46	12-18 Nov.	86.14	54.22	3.74	5.76	2.04	1.24	3.18	5.82
47	19-25 Nov.	92.60	63.60	4.12	4.70	0.30	0.64	0.72	5.50
48	26-02 Dec.	120.86	30.08	6.10	4.22	0.52	0.42	1.46	2.98
49	03-09 Dec.	98.12	28.42	4.18	5.00	0.44	1.26	0.58	3.46
50	10-16 Dec.	84.72	15.58	2.54	3.68	0.36	0.72	0.44	2.76
51	17-23 Dec.	68.53	21.62	2.23	4.06	0.31	4.98	0.38	3.86
52	24-31 Dec.	78.28	19.90	2.10	5.38	0.28	4.52	0.24	5.14

The incidence was started from 30th MW and reached at its first peak (24.62 thrips/3 leaves) during 33rd MW. The results of present investigation are in accordance with the findings of Chauhan *et al*. (2017) [6] who reported that thrips population started building up from the last week of July (0.15 thrips/ leaf) and remained active throughout crop season. While, Divya *et al*. (2020) [8] reported the peak incidence of thrips (5.51 thrips/3 leaves) during 40th MW.

Whitefly (*Bemisia tabaci*)

During *Kharif*-2020, the whitefly population was ranged from 0.24 to 8.32 whiteflies/3 leaves, whereas in 2021, it was varied from 0.04 to 5.82 whiteflies/3 leaves. During both the years of investigations, whitefly infestation began in the 28th MW. Notably, peak whitefly activity was observed in the 42nd MW of 2020 (8.32 whiteflies/3 leaves) and the 46th MW of 2021 (5.82 whiteflies/3 leaves). Subsequently, the whitefly population gradually decreased until the 52nd MW. The results of the present investigation are comparable with the findings of Bhattacharyya *et al*. (2019) [3] who reported that maximum activity of whiteflies (4.50 whiteflies/leaf) was observed during the 39th MW. Similarly, Pal *et al*. (2020) [15] revealed that the occurrence of whitefly was noticed during the fourth week of July (0.20 whitefly/plant) which continued till late December.

Population dynamics of natural enemies in *Bt* cotton

The data on population fluctuations of natural enemies (Lady bird beetle, *Chrysopa* and predatory spiders) of sucking pests during *Kharif*-2020 and 2021 in *Bt* cotton are presented in Table 2. and Fig 1-4.

More or less lady bird beetle population was observed throughout cropping period from 29th to 52nd MW. The population beetle was ranged between 0.30-3.74/ plant during 2020 and 0.16-3.82/ plant during 2021. The occurrence of lady bird beetle initiated from 29th MW (0.30 lady bird beetles/ plant) and during *Kharif* 2021 it was initiated from 30th MW (0.22 lady bird beetles/ plant). The highest population (3.74 beetles/ plant) was recorded in 48th MW during 2020 and in 46th MW (3.82 beetles/ plant) during 2021.

The population of *C. carnea* in *Bt* cotton was ranged between 0.12 to 0.76 grubs and adults/plant (2020) and 0.08-0.54 grubs and adults/plant (2021). First occurrence of *Chrysopa* during 2020 was observed during 29th MW (0.22 grubs and adults/plant) whereas, it was first noticed in 33rd MW (0.10 grubs and adults/plant) during 2021. During *Kharif* 2020, highest population of *chrysopa* was first noticed during 39th MW (0.76 grubs and adults/plant) while, it was highest in 37th MW (0.54 grubs and adults/plant) during 2021.

The data on population fluctuations of spiders during *Kharif*-2020 ranged between 0.38 to 2.10 spiders/plant. The occurrence of spider was started from 30th MW (0.72 spiders/plant) and increased gradually and the peak activity (1.54 spiders/plant) was noticed in 32nd MW. More or less similar population fluctuation trend was observed during *Kharif* 2021. The range of spider population was 0.12 to 3.44 spiders/plant during *Kharif* 2021. The first incidence of spider was noticed during 31st MW (0.08 spider/plant) and rose to its peak (3.44 spider/plant) in 46th MW. The present findings are in accordance with earlier researchers like Liu *et al*. (2003) [11] who reported that spider population was low in early stage of the *Bt* cotton but built up quickly in middle and late stages. Purohit *et al*. (2006) [19] recorded the maximum population of lady bird beetle during 3rd week of August and in the 2nd week of December during 2003 while Parsai and Shashtry (2009) [16] observed that the population of predators (Coccinellids and *Chrysopa*) from 30th to 50th MW. Agarwal *et al*. (2007) [1] documented that spiders, coccinellids, green lace wings were the main natural enemies observed on cotton hybrids.

Table 2: Population dynamics of natural enemies of major pests in *Bt* cotton

SMW	Duration	Natural enemies/ plant					
		LBB		*Chrysopa*		Spiders	
		2020	2021	2020	2021	2020	2021
28	09-15 July	0.00	0.00	0.00	0.00	0.00	0.00
29	16-22 July	0.30	0.00	0.22	0.00	0.00	0.00
30	23-29 July	1.74	0.22	1.38	0.00	0.72	0.00
31	30-05 Aug.	0.76	0.28	0.44	0.04	0.76	0.08
32	06-12 Aug.	1.17	0.16	0.38	0.00	1.54	0.00
33	13-19 Aug.	1.18	1.02	0.48	0.10	1.24	0.28
34	20-26 Aug.	0.58	1.58	0.48	0.00	0.62	0.12
35	27-02 Sept.	0.74	1.54	0.38	0.08	0.74	0.42
36	03-09 Sept.	1.10	1.84	0.48	0.10	0.92	0.28
37	10-16 Sept.	1.26	1.10	0.52	0.54	1.30	1.28
38	17-23 Sept.	0.64	0.46	0.24	0.22	0.44	0.30
39	24-30 Sept.	1.46	1.12	0.76	0.18	1.02	0.68
40	01-07 Oct.	1.18	0.40	0.40	0.20	0.46	0.42
41	08-14 Oct.	0.68	0.36	0.32	0.08	0.66	0.18
42	15-21 Oct.	0.66	0.50	0.24	0.10	0.44	0.50
43	22-28 Oct.	1.88	0.70	0.44	0.08	1.88	0.40
44	29-04 Nov.	0.96	0.64	0.26	0.16	0.52	0.50
45	05-11 Nov.	1.48	1.66	0.26	0.14	0.90	0.50
46	12-18 Nov.	1.44	3.82	0.14	0.24	0.82	3.44
47	19-25 Nov.	1.88	0.56	0.20	0.16	1.10	1.90
48	26-02 Dec.	3.74	1.86	0.24	0.08	2.10	0.70
49	03-09 Dec.	2.46	2.00	0.38	0.14	0.78	1.64
50	10-16 Dec.	1.94	1.40	0.26	0.08	0.72	1.06
51	17-23 Dec.	1.88	1.48	0.18	0.10	0.68	1.74
52	24-31 Dec.	0.64	1.36	0.12	0.02	0.38	1.36

Relationship between weather parameters and major sucking pests of *Bt* cotton

The study examined sucking pest population in *Bt* cotton and their relationship with weather variables like rainfall, temperature, humidity, evaporation, sunshine and wind speed. Simple correlation, regression coefficients and multiple regression were calculated for *Kharif* 2020 and 2021.

Aphids

The data on simple correlation and regression coefficient for aphids during *Kharif* 2020 showed positive, highly significant correlation with wind speed (r = 0.702**). While negative, highly significant with rainfall (r =-0.533**), minimum temperature (r =-0821**) and evening RH (r= -0.819**). While it was negatively non-significant with maximum temperature (r= -209) and morning RH (r= -0.385). During 2021, maximum temperature (r= -0.042), minimum temperature (r= -0.208), evening RH (r= -0.344), rainfall (r= -0.084) and bright sunshine showed negatively non-significant correlation with aphid population.

Jassids

During the *Kharif* seasons of both 2020 and 2021, similar trends were observed in the correlation analysis of jassid population with meteorological factors. Positive significant

correlations were found with morning RH (2020: r = 0.354*) and evening relative humidity (2020: r = 0.348*, 2021: r = -0.485). Conversely, negative significant correlations were observed with rainfall (2020: r = -0.273, 2021: r = -0.292) and minimum temperature (2020: r = -0.267, 2021: r = -0.525) in both years.

Thrips

The population of thrips in relation to minimum temperature (r = -0.374*) was negatively significant during *Kharif* 2020. While, it was positively non-significant with maximum temperature (r = 0.338), evening RH (r = 0.225) and rainfall (r = 0.206). Thrips population showed negatively non-significant effect with morning RH (r = -0.205). While during *Kharif* 2021, it was negatively non-significant with maximum temperature (r = -0.157) whereas, it showed positively non-significant effect with minimum temperature (r = 0.183), morning RH (r = 0.240), evening RH (r = 0.294) and rainfall (r = 0.290).

Whitefly

The data regarding the correlation between whitefly population with weather parameters in *Bt* cotton showed that minimum temperature (r = -0.401*) showed negative significant correlation whereas, other parameters like maximum temperature (r = 0.389), morning RH (r = 0.201), evening RH (r = 0.152) and rainfall (r = 0.006) were exhibited positively non-significant effect with whitefly population. While during *Kharif* -2021, minimum temperature (r = -0.555*) showed negatively significant effect and evening RH (r = 0.421*) showed positive significant relationship.

The present investigation aligns with previous studies regarding aphids, where Bhattacharyya *et al*. (2019) [3] and Divya *et al*. (2020) [8] reported positive correlations with maximum temperature and negative correlations with rainfall. Similarly, for jassids, the

Table 3: Correlation between weather parameters and sucking pests in *Bt* cotton

Pests	Year	Correlation coefficient (r)							
		Max. Temp.	Min. Temp.	RH-I	RH-II	Rainfall	BSS	WS	EVP
Aphids	2020	-0.209	-0.821**	-0.385	-0.819**	-0.533**	-0.473*	0.702**	-0.002
	2021	- 0.042	-0.208	0.029	-0.344	-0.084	-0.343	0.280	0.023
Jassids	2020	0.112	-0.267	0.354	0.258	-0.273	0.003	-0.073	-0.048
	2021	0.131	-0.525**	0.113	-0.485*	- 0.292	-0.409*	0.449*	-0.205
Thrips	2020	0.338	-0.374	-0.205	0.225	0.206	0.442*	-0.213	-0.057
	2021	-0.157	0.183	0.240	0.294	0.541**	-0.043	-0.141	-0.163
Whiteflies	2020	0.389	-0.401*	0.201	0.152	0.006	0.024	0.333	0.083
	2021	-0.049	-0.555**	0.077	0.421*	-0.323	-0.482*	0.529**	-0.073

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

Table 4: Multiple regression equation for PBW and meteorological conditions in Kharif 2020 and 2021

Sucking pests	Year	Regression equation	R^2
Aphids	2020	$Y = 315.6 - 4.305X_1 - 1.604X_2 - 0.480X_3 - 1.260X_4 - 0.100X_5 - 5.100X_6 + 1.746X_7 + 0.224X_8$	0.80
	2021	$Y = 165.5 - 3.054X_1 + 1.813X_2 - 0.227X_3 - 1.025X_4 + 0.051X_5 - 3.269X_6 - 0.797X_7 - 1.001X_8$	0.26
Jassids	2020	$Y = -21.96 - 0.064X_1 + 0.287X_2 + 0.289X_3 - 0.074X_4 + 0.006X_5 + 0.219X_6 + 0.159X_7 - 0.025X_8$	0.23
	2021	$Y = 7.39 - 0.019X_1 + 0.072X_2 + 0.020X_3 - 0.029X_4 - 0.011X_5 - 0.041X_6 + 0.548X_7 - 1.788X_8$	0.54
Thrips	2020	$Y = 3.19 + 2.640X_1 - 0.942X_2 - 1.060X_3 + 0.409X_4 + 0.074X_5 + 2.365X_6 + 0.904X_7 + 0.045X_8$	0.52
	2021	$Y = 163.5 - 4.694X_1 + 0.063X_2 - 0.955X_3 + 0.232X_4 + 0.398X_5 + 2.217X_6 + 5.514X_7 + 1.157X_8$	0.46
Whitefly	2020	$Y = -10.34 - 0.690X_1 + 0.948X_2 + 0.391X_3 - 0.311X_4 - 0.013X_5 - 0.268X_6 - 0.489X_7 - 0.019X_8$	0.58
	2021	$Y = 7.75 - 0.060X_1 + 0.110X_2 + 0.053X_3 - 0.105X_4 - 0.007X_5 - 0.172X_6 + 0.144X_7 - 1.085X_8$	0.60

Where, Y = Particulars, X_1 = max temperature, X_2 = min temperature, X_3 = morning RH, X_4 = eve. RH, X_5 = rainfall, X_6 = wind speed, X_7 = BSS, X_8 = evaporation and R^2 = Coefficient of determination.

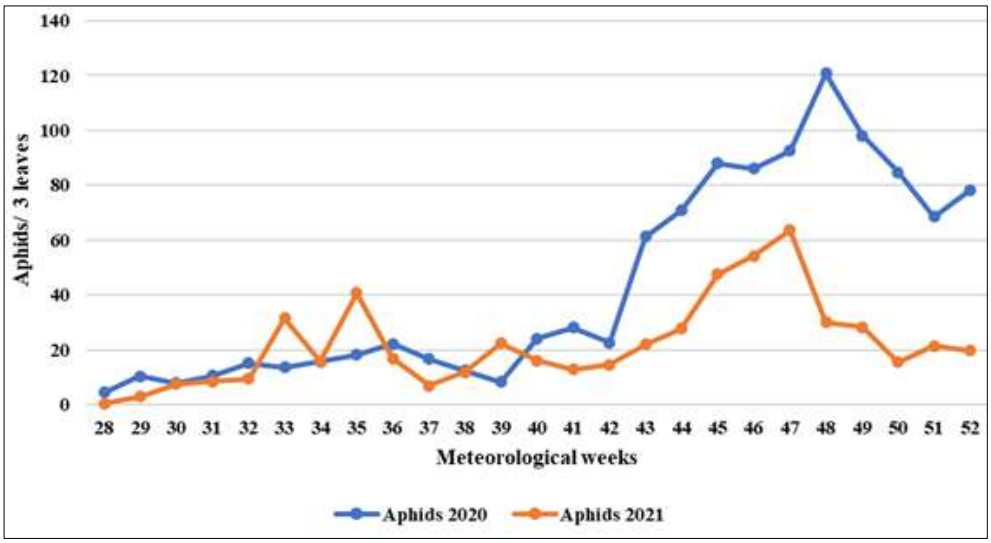

Fig 1: Population dynamics of aphids infesting *Bt* cotton in relation to meteorological weeks during *Kharif* 2020 and 2021

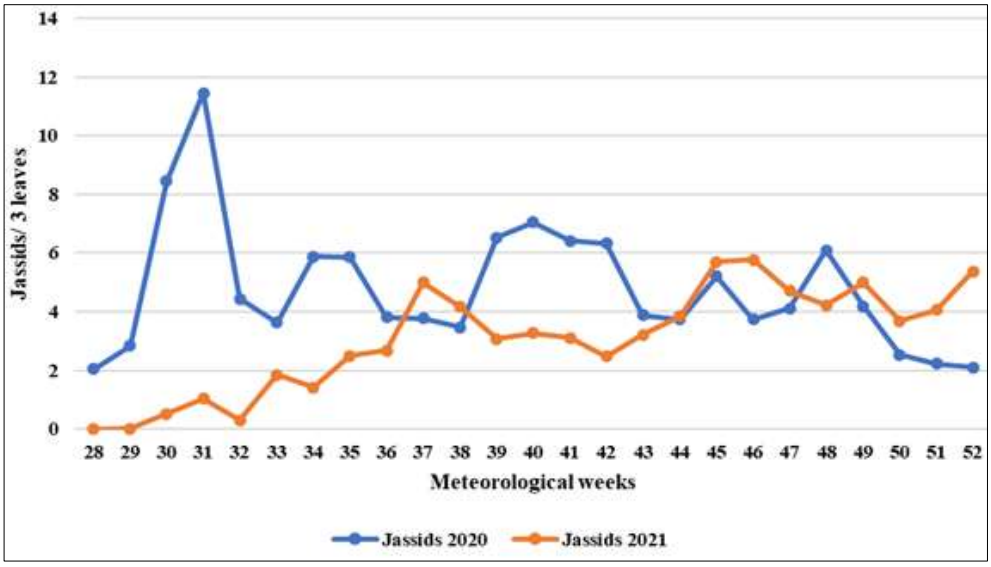

Fig 2: Population dynamics of jassids infesting *Bt* cotton in relation to meteorological weeks during *Kharif* 2020 and 2021

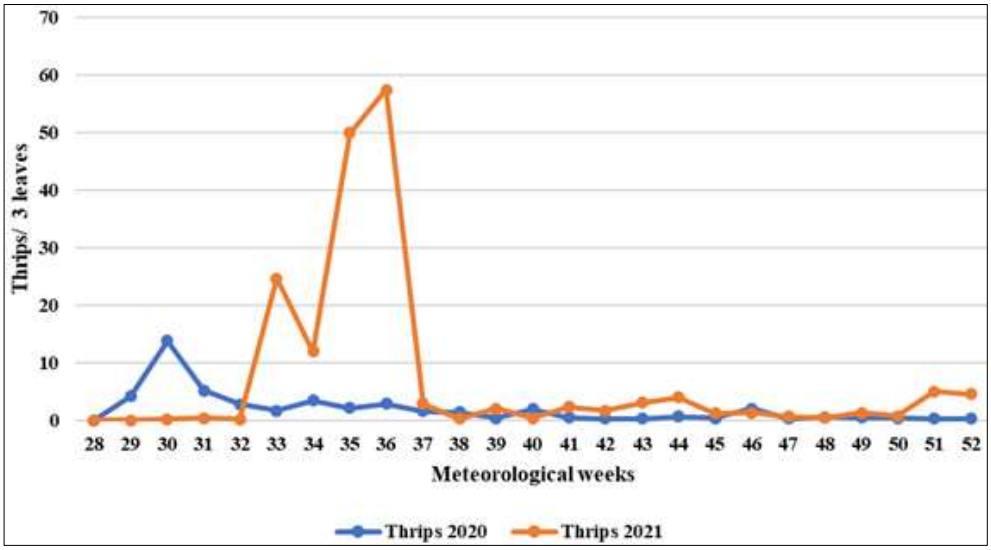

Fig 3: Population dynamics of thrips infesting *Bt* cotton in relation to meteorological weeks during *Kharif* 2020 and 2021

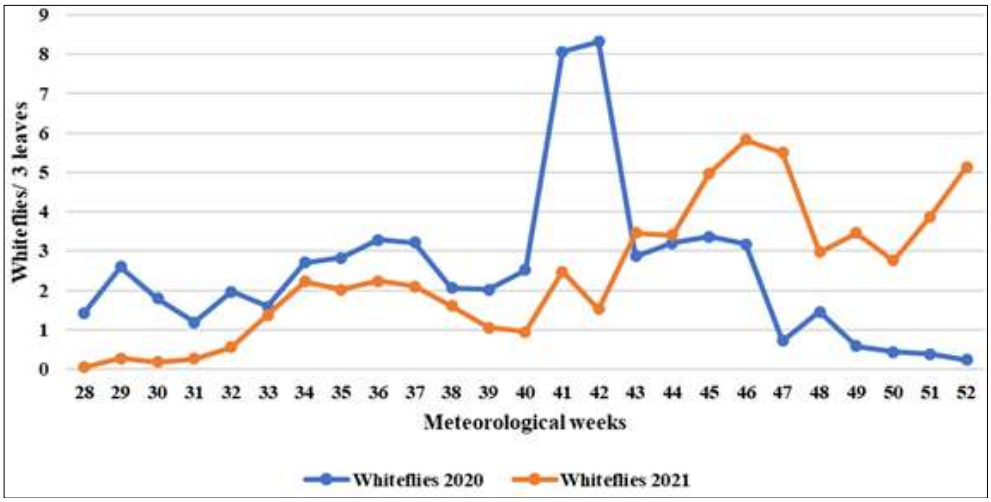

Fig 4: Population dynamics of whiteflies infesting *Bt* cotton in relation to meteorological weeks during *Kharif* 2020 and 2021

The (R^2) coefficient of determination reveals the shared variability between weather parameters and various aspects of *Bt* cotton cultivation. During *Kharif* 2020, weather factors influenced 80 percent of aphid population, 23 percent of jassids population, 52 percent of thrips population and 58 percent whitefly population. In contrast, during *Kharif* 2021, these figures were 26 percent, 54 percent, 46 percent and 60 percent, respectively. These findings underscore the enhanced reliability of using weather parameters for predictions in *Kharif* 2021 compared to the preceding year.

Conclusion

The investigation underscores the persistent presence of aphids, jassids, thrips and whiteflies on *Bt* cotton crops across consecutive years. Despite fluctuations in population dynamics, aphids consistently emerged as the dominant sucking pest. Timing of peak infestations varied, reflecting the nuanced responses of each pest to environmental conditions. Notably, weather factors exerted a substantial influence, with early and mid-season stages favouring thrips and jassids, while cooler temperatures later in the season were conducive to aphid proliferation. The research underscores the complex relationship between pest populations and their natural predators, showing that predator abundance corresponds with pest activity. These findings not only contribute to our understanding of pest ecology in *Bt* cotton cultivation but also underscore the necessity of holistic pest management approaches to mitigate crop damage effectively.

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