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Seasonal Incidence of *Scirtothrips dorsalis* and *Bemisia tabaci* on Chilli with Studies on Comparative Efficacy of Insecticides and Botanical Oils

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Authors' contributions

This work was carried out in collaboration among all authors. Author KSIL did the conceptualization, methodology, data curation and original draft. Author CNR did the writing, reviewing and statistical analysis. Authors BVJ and KRM did the methodology, reviewing and editing. Authors MS, JSP and VSA did the editing and review. All authors read and approved the final manuscript.

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ABSTRACT

The study conducted at Sam Higginbottom University of Technology and Sciences in Prayagraj during the 2019 and 2020 kharif seasons provided comprehensive insights into insect population dynamics and insecticide efficacy against thrips and whiteflies in chilli cultivation. Key findings

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revealed significant pest population fluctuations, with thrips peaking at 16 per plant during the 43rd Standard Meteorological Week (SMW) in late October for both years. Whitefly populations reached up to 17.6 per plant, peaking during the 44th week in 2019 and the 43rd week in 2020, both in late October. Correlation analyses showed significant negative relationships between insect populations and temperature, wind velocity, and rainfall, while a positive correlation was observed with sunshine duration. Multiple linear regression models demonstrated that weather parameters collectively explained 69.8% and 70.4% of thrips population variability in 2019 and 2020, respectively, and 87.7% and 17.2% of whitefly population variability. Stepwise regression models revealed that in 2019, maximum temperature and rainfall jointly accounted for 46% of pest population variability. In 2020, the addition of wind velocity to these factors explained 83% and 56% of variability in thrips and whitefly populations, respectively. Insecticide efficacy evaluation showed acetamiprid as most effective against thrips (92.14% reduction) and imidacloprid against whiteflies (88.89% reduction). Thiamethoxam and imidacloprid demonstrated comparable effectiveness. Economic analysis highlighted imidacloprid's superiority, providing effective pest control, the highest chili yield, and the best cost-benefit ratios (1:8.30 in 2019 and 1:5.38 in 2020).

Keywords: Chilli; weather factors; correlation; regression.

1. INTRODUCTION

Chilli (*Capsicum annuum* L.), a crucial Solanaceous crop, is integral to Indian cuisine as both spice and vegetable [1]. This year-round cash crop thrives across India's diverse climates, including greenhouse cultivation in cooler regions. India leads globally in chilli production, consumption, and export, renowned for high-quality produce with superior color and pungency. Key producing states include Andhra Pradesh, Telangana, Madhya Pradesh, Karnataka, West Bengal and Utter Pradesh. As per [2], India produced 5.74 million tons of chilli across 10.6 lakh hectares, solidifying its position as the world's top producer. However, chilli cultivation faces mounting challenges from pests and diseases, which are expected to intensify due to climate change, posing a threat to global food security.

Chilli crop is vulnerable to attack by diverse array of pests, which include 52 insect and 2 mite species across 26 families and 9 orders [3]. These pests can inflict substantial economic damage, with yield losses ranging from 50% to 90% [4]. Among the insect pests, aphids, thrips, and whiteflies are particularly detrimental, capable of reducing yields by up to 50% [5]. The chili thrips, *Scirtothrips dorsalis*, is a critical pest affecting chili plants throughout their lifecycle. Both nymphs and adults cause direct feeding damage, while also serving as vectors for Tospo viruses, resulting in indirect damage. Another major threat is the whitefly, *Bemisia tabaci*, which impacts chili production through direct feeding and virus transmission. *B. tabaci* is a vector for begomoviruses and criniviruses, with the chilli leaf curl disease being a particularly severe challenge to crop yields (Morales, 2007); [6]. The combined impact of these pests underscores the critical need for effective pest management strategies in chili cultivation to ensure sustainable production and food security.

Insects exhibit high sensitivity to climatic variations, significantly impacting plant population dynamics [7]. Understanding the intricate relationships between insect behaviour, weather patterns and chilli crop ecosystems is crucial for developing effective pest management strategies (Das et al. 2008). By monitoring the emergence and peak infestation periods of key pests like thrips and whiteflies, farmers can anticipate and prepare for potential outbreaks. Environmental factors such as temperature, humidity and rainfall significantly influence pest populations. Comprehending these pest-weather interactions enables farmers to forecast population increases and implement timely control measures (Prasannakumar & Chander 2014). This research aims to provide essential information on the succession of major sucking pests, specifically *Scirtothrips dorsalis* and *Bemisia tabaci*, in relation to weather parameters. Additionally, it seeks to assess the effectiveness of selected insecticides and botanical oils, contributing to the development of sustainable and cost-effective pest management strategies. Ultimately, this study supports stable chilli production and enhances food security by empowering farmers to optimize their pest control methods and minimize economic losses.

2. MATERIALS AND METHODS

2.1 Experimental Setup

Two field experiments were conducted during the *kharif* seasons of 2019 and 2020 at the central field, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (25.270° N, 80.500° E) to investigate the population dynamics of sucking pests in chilli in relation to climatic factors and assess the effectiveness of selected insecticides versus botanical oils. Each year, separate plots were allocated for the experiments, employing a randomized complete block design with three replications. The Suryamukhi variety of chilli was utilized in both experiments to ensure consistency in the study.

2.2 Population Dynamic Study

To investigate the seasonal occurrence of thrips (*Scirtothrips dorsalis*) and Whitefly (*Bemisia tabaci*) thrips and whiteflies in chilli crop, plots measuring 3 m × 2 m were established from nursery to harvest, following standard agronomic practices without insecticide application. Data was collected at weekly intervals during morning hours (7.00 am to 10.00 am). Five plants per plot were randomly selected and tagged to assess the population. Insects were counted from five leaves: two from the upper, two from middle and one from the lower part of each plant (Bhatt & Karnatak, 2018). Weekly meteorological data from the university meteorological observatory at the Department of Agrometeorology, SHUATS, Prayagraj, were used to correlate with insect population dynamics.

To observe effect of insecticides & botanical oils on the percent damage caused by chilli thrips and whitefly: A field trial was conducted to evaluate the efficacy of selected insecticides and botanical oils against the whitefly and the thrips on a chilli crop. The experimental unit plot size was 3 m × 2 m, with a spacing of 45 cm between rows and 30 cm between plants. The following treatments were included: (T_1) Acetamiprid 20 SP @ 0.6 ml/L; (T_2) Triazophos 40 EC @ 0.3 ml/L; (T_3) Imidacloprid 350 SC @ 0.3 ml/L; (T_4) Fipronil 5%SC @ 1 ml/L; (T_5) Pongamia oil (4%) @ 2 ml/L; (T_6) Neem oil 5%SC @ 0.5 ml/L; (T_7) Castor oil @ 0.4 ml/L; (T_8) Untreated control. The insecticide treatments (T_1 to T_7) were sprayed using a knapsack sprayer fitted with a hollow-cone nozzle. Observations were made before the treatment of insecticide and after 3, 7 and 10 days of spraying. Five plants were randomly selected and tagged in each plot, and three leaves per plant, one each from top, middle and bottom region from five plants per plot leaving border rows at weekly intervals. The reduction in the populations of the whitefly and the thrips compared to the untreated control (T_8) was calculated using the following formula:

Percent reduction over control = Number of insects in control - Number of insects in treatment / Number of insects in control x 100

Further, mature and tender fruits were harvested, weighed and mean yields were calculated for each treatment and cost benefit ratio of each treatment was calculated. Statistical analysis was performed using R (version 4.1.3). A multivariate regression and Pearson correlation were conducted to investigate the relationship between insect population dynamics and climate factors.

3. RESULTS AND DISCUSSION

3.1 Population Fluctuation and Association with Weather Factors

Thrips populations exhibited significant fluctuations, ranging from 2 to 16 per plant, with peak numbers consistently observed during the 43rd Standard Meteorological Week (SMW), corresponding to late October in both years (Table 1). These peak periods coincided with specific weather conditions *viz.,* maximum temperatures of 32.31°C, minimum temperatures of 22.51°C, relative humidity ranging from 62.85% to 90.57%, 0.65 hours of sunshine and wind velocities of 1.32 km/h. Correlation analyses for thrips revealed year-specific patterns. In 2019, thrips abundance negatively correlated with minimum temperature, rainfall, and wind velocity in the current week, while showing positive correlations with these factors in lag weeks (Table 2). The 2020 data presented a different picture, with negative correlations observed for maximum and minimum temperatures, wind velocity, and rainfall alongside a positive correlation with sunshine in the 1-week lag period. Whitefly populations demonstrated even more pronounced fluctuations, ranging from 1.60 to 17.6 per plant. Peak infestations were recorded during the 44th week in 2019 and the 43rd week in 2020, both falling in late October. These peak periods were characterized by maximum temperatures of

Table 1. Population dynamics of *Scirtothrips dorsalis* and *Bemisia tabaci* in chilli along with meteorological parameters during *Kharif* 2019 and 2020

SMW	Insect pests		Meteorological parameters						
	S. dorsalis	*B. tabaci*	Temperature (ºC)		Relative humidity (%)		RF (mm)	SSH (hr/day)	WV (Km/hr)
			Max	Min	Morning	Evening			
***Kharif* 2019 cropping season**									
32	0.00	0.00	34.82	27.54	92.42	56.28	6.60	3.80	1.35
33	0.00	0.00	35.08	28.05	94.71	56.42	6.85	6.05	1.81
34	0.00	0.00	33.15	27.08	94.28	62.28	23.97	2.31	1.42
35	2.00	1.60	34.65	27.88	91.14	58.85	8.74	5.60	1.47
36	5.40	4.80	35.14	28.20	68.57	58.14	3.54	5.97	1.54
37	5.40	5.00	33.60	28.54	92.42	66.28	19.80	5.85	1.26
38	5.60	5.20	33.54	27.34	92.14	65.28	5.05	3.51	1.37
39	6.20	6.20	30.25	26.25	94.57	77.42	31.74	2.20	1.36
40	9.80	9.60	30.74	22.82	93.28	67.71	17.51	1.91	1.26
41	12.80	12.40	34.44	25.08	90.57	49.14	0.91	7.74	1.25
42	15.00	14.00	33.17	24.71	90.71	60.14	0.00	5.34	1.38
43	16.00	15.60	32.31	22.51	90.57	62.85	0.00	0.65	1.32
44	15.40	15.80	33.34	21.60	90.42	57.01	0.00	0.00	1.02
45	14.20	14.00	31.42	19.88	90.42	58.57	0.00	0.00	1.06
46	13.80	12.60	30.51	16.02	90.57	59.28	0.00	0.00	1.09
47	9.00	8.00	29.58	15.40	91.71	61.00	0.00	0.00	0.96
48	6.00	6.80	30.60	14.87	92.00	63.57	0.00	0.00	1.02
***Kharif* 2020 cropping season**									
32	0.00	0.00	35.65	28.14	94.42	56.85	6.68	5.45	1.31
33	0.00	1.20	33.32	27.11	94.28	62.14	19.82	2.45	1.32
34	0.00	0.50	34.57	27.57	91.57	66.85	13.85	5.57	1.44
35	2.00	1.80	35.08	28.08	68.14	58.71	1.74	5.82	1.58
36	5.80	3.20	33.74	28.48	68.14	58.71	1.74	5.62	1.58
37	5.00	5.90	33.62	27.57	68.14	58.71	1.74	3.91	1.58
38	5.60	7.10	30.91	26.42	94.14	75.42	31.31	2.85	1.37
39	6.40	7.40	34.04	24.71	91.00	49.28	0.91	6.88	1.27
40	9.66	11.80	33.62	24.85	90.57	57.71	0.00	6.51	1.41
41	12.73	14.30	31.91	23.00	90.71	62.14	0.00	6.28	1.26

SMW	Insect pests		Meteorological parameters						
	S. dorsalis	***B. tabaci***	**Temperature (ºC)**		**Relative humidity (%)**		**RF (mm)**	**SSH (hr/day)**	**WV (Km/hr)**
			Max	**Min**	**Morning**	**Evening**			
42	14.93	14.80	33.11	21.51	90.28	58.85	0.00	6.58	1.10
43	15.66	17.20	30.34	22.10	90.02	57.71	0.00	6.58	1.12
44	15.00	9.03	32.42	18.04	90.32	58.27	0.00	7.34	1.04
45	14.00	5.60	31.51	15.01	90.17	59.10	0.00	7.65	1.06
46	12.00	2.30	30.88	14.10	91.3	61.05	0.00	6.17	0.92
47	8.00	2.10	33.60	14.00	92.0	60.57	6.60	1.02	8.45
48	5.80	1.90	32.49	13.2	91.00	61.0	0.0	1.02	8.25

SMW = Standard metrological week, Relative Humidity, RF=Rainfall, SSH =Sunshine, WV =Wind velocity

Table 2. Correlation between insect pests and different weather parameters during 2019 and 2020

Year	Pest	Time period	Weather parameters						
			T max	**T min**	**RH_1**	**RH_2**	**RF**	**SSH**	**WV**
2019	*S. dorsalis*	Current week	-0.36	-0.53*	-0.07	-0.11	-0.49*	-0.38	-0.57*
		1-Lag week	-0.42	-0.66**	-0.07	-0.10	-0.53*	-0.42	0.64**
		2-Lag week	-0.44	0.76***	-0.07	-0.10	-0.53*	-0.44	0.69**
	B. tabaci	Current week	0.37	-0.53*	-0.05	-0.10	-0.49*	-0.40	-0.59*
		1-Lag week	-0.42	-0.64**	-0.05	-0.09	-0.51	-0.43	0.64**
		2-Lag week	-0.44	-0.76	-0.05	-0.09	-0.52	-0.45	-0.71
2020	*S. dorsalis*	Current week	-0.55*	-0.61**	0.29	-0.17	-0.49*	0.50	-0.69**
		1-Lag week	-0.56*	-0.73**	0.31	-0.17	-0.51*	0.56*	-0.74**
		2-Lag week	-0.61*	-0.83***	0.31	-0.17	-0.51	0.61	0.77***
	B. tabaci	Current week	-0.07	0.08	0.10	-0.23	-0.26	0.08	-0.04
		1-Lag week	-0.09	-0.04	0.14	-0.22	-0.29	0.18	-0.12
		2-Lag week	-0.20	-0.16	0.17	-0.19	-0.29	0.29	-0.19

* p <0.05; ** p <0.01; and *** p < 0.001

Table 2. Cont.

Multiple regression	2019	Thrips = 290.748 -7.865 X_1 + 2.567 X_2 -0.146 X_3 -0.815 X_4 -0.658 X_5 -0.326 X_6 -12.241 X_7 (R^2 =69.8%)
		Whitefly = 282.165 -7.655 X_1 + 2.545 X_2 -0.130 X_3 -0.805 X_4 -0.638 X_5 -0.415 X_6 -12.326 X_7 (R^2 =70.4%)
	2020	Thrips = 100.449 -3.182 X_1 + 1.078 X_2 + 0.013 X_3 + 0.204 X_4 -0.472 X_5 + 0.891 X_6 -22.672 X_7 (R^2 =87.7%)
		Whitefly =115.036 -5.772 X_1 + 2.814 X_2+ 0.356 X_3 -0.055 X_4 -0.720 X_5 + 1.161 X_6 -11.767 X_7 (R^2 =17.2%)
Step wise regression	2019	Thrips = 63.87 - 1.62 X_1 - 0.34 X_5 (R^2 =46%)
		Whitefly = 63.53 - 1.62 X_1 - 0.33 X_5 (R^2 =46%)
	2020	Thrips = 90.36 - 1.97 X_1 - 0.31 X_5 - 12.19 X_7 (R^2 =83%)
		Whitefly = 84.95 - 5.1 X_1 + 2.18 X_2 + 0.49 X_3 - 0.87 X_5 (R^2 =56%)

Note: X_1 =Maximum temperature, X_2 = Minimum temperature, X_3 =Maximum Relative Humidity, X_4 = Minimum Relative Humidity, X_5 =Rainfall, X_6 =Sunshine, X_7 =Wind velocity

Table 3. Efficacy of selected insecticides and botanical oils on major sucking pests of chilli during 2019 and 2020

Treatments	**Concentration/ Dose(gm/ml)/lit**	**Pooled data of 2019 and 2020**			
		Mean no. of *S. dorsalis*	**% reduction over control**	**Mean no. of *B. tabaci***	**% reduction over control**
Acetamiprid 20 SP (T1)	0.6	0.86^{c}	92.14	3.27^{b}	72.09
Triazophos 40 EC (T2)	0.3	1.85^{bc}	83.08	3.16^{b}	72.99
Imidacloprid 350 SC (T3)	0.3	1.36^{c}	87.52	0.47^{c}	88.89
Fipronil 5%SC T4)	1	3.08^{b}	71.79	3.74^{b}	68.03
Pongamia oil (4%) (T5)	2	1.39^{c}	87.27	3.48^{b}	70.26
Neem oil (T6)	0.5	3.11^{b}	71.57	3.41^{b}	70.85
Castor oil (T7)	0.4	1.88^{bc}	82.76	3.64^{b}	68.88
Control (T_8)	-	10.85^{a}	-	11.70^{a}	-
Level of significance		**		**	
CV (%)		10.59		11.01	

*Means followed by the same letter(s) in the same column are not significantly different from one another according to Tukey's HSD. ** and * denote significance at 1% and 5% levels of significance, respectively*

Table 4. Effectiveness of various treatments on marketable yield and cost-benefit ratio in chilli production

Treatments	Yield (q/ha)		Cost: Benefit Ratio	
	2019	**2020**	**2019**	**2020**
Acetamiprid 20 SP (T1)	105	106.6	1:7.5	1:5.08
Triazophos 40 EC (T2)	100	103.3	1:6.3	1:4.90
Imidacloprid 350 SC (T3)	117.35	111.57	1:8.3	1:5.38
Fipronil 5%SC T4)	110	98.1	1:7.7	1:4.60
Pongamia oil (4%) (T5)	90	65.12	1:6.3	1:2.72
Neem oil (T6)	95	89.25	1:6.7	1:4.10
Castor oil (T7)	85	82.35	1:5.9	1:3.67
Control (T_8)	65	68.85	1:4.4	1:2.85

33.34°C, minimum temperatures of 21.60°C, relative humidity between 57.01% and 90.42%, and wind velocities of 1.02 km/h. Correlation analyses for whiteflies in 2019 revealed negative associations between population abundance and minimum temperature (both in the current week and 1-week lag period), rainfall, and wind velocity in the current week. Conversely, a positive correlation was observed with sunshine in the 1-week lag period. These findings align with previous research by Bhede et al. (2008) who reported peak thrips incidence around the 40th SMW, while Saini et al. [8] observed high thrips numbers (10.40 thrips) after the 7th week of transplanting (49th SMW). Both studies noted negative correlations between thrips abundance and temperature extremes and rainfall. Aidoo et al. [9] reported a significant correlation between insect abundance and weather parameters. Similarly, Correlation between meteorological parameters and whitefly population was negatively correlated with rainfall as also reported Anzola and Lastra [10] in tomato.

Multiple linear regression analysis revealed varying effects of weather parameters on pest populations across seasons. In 2019, weather parameters showed a moderate, non-significant collective effect on both thrips and whitefly populations, accounting for 69.8% and 70.4% of the variability, respectively. The 2020 season displayed a strong, significant collective effect on thrips and a weak, significant effect on whitefly, explaining 87.7% and 17.2% of the variability, respectively. Stepwise regression models revealed varying impacts of weather factors on pest populations across years. In 2019, maximum temperature and rainfall jointly accounted for 46% of variability in both thrips and whitefly populations. During 2020, maximum temperature, rainfall and wind velocity together explained 83% of thrips variability of thrips population. Maximum and minimum temperatures, maximum relative humidity and rainfall collectively contributed to 56% of population variability of whiteflies (Table 2). Similar studies conducted by Sharma et al. [11] who reported the multiple linear regression analysis showed that all the weather parameters accounted 89 % variability of total change in whitefly population.

3.2 Comparative Efficacy of Chemical and Botanical Oils against Sucking Insect Pests of Chilli

The evaluation of insecticides and botanical oils against major sucking pests of chilli is detailed in Table 3. For thrips control, Acetamiprid (T1) emerged as the most effective treatment, reducing the thrips population to an average of 0.86 per plant, representing a 92.14% reduction compared to the untreated control (Table 3). This finding aligns with previous research by Ghosh et al. [12], Jayewar et al. [13], Agale et al. [14], and Varghese and Mathew [15], all of which reported high efficacy of acetamiprid in managing thrips populations. Rai et al. [16] further corroborated these results, noting a 90.31% reduction in thrips population and a 63.48% increase in yield with acetamiprid 20 SP treatment. In the case of whitefly control, Imidacloprid (T3) proved most effective, reducing the population to an average of 0.47 individuals per plant, corresponding to a 88.89% reduction compared to the control. This efficacy is supported by several previous studies. Singh (2004) reported up to 95.58% reduction in whitefly populations with imidacloprid application. Mhaske & Mote (2005) found higher doses of imidacloprid highly effective against whiteflies in brinjal crops. Similar results were observed by Thorat et al. [17] and Simkhada & Paneru [18] in tomato crops, and by Yadav et al. [19] in mesta. Aina et al. (2017) reported up to 90.03% whitefly reduction in brinjal with imidacloprid treatment, while Kumawat et al. [20] noted an 88.64% mean reduction in whitefly population. The study also examined the economic aspects of these treatments. Imidacloprid (T_3) not only provided effective pest control but also resulted in the highest chili yield and the best cost-benefit ratio, with 1:8.30 for 2019 and 1:5.38 for 2020 (Table 4) [21-25].

4. CONCLUSION

This study elucidates the seasonal patterns of thrips and whitefly infestations in chili crops, correlating peak periods with specific weather conditions. Imidacloprid demonstrated high efficacy against these pests, comparable to acetamiprid, while also proving economically advantageous. These findings offer a foundation for developing integrated pest management strategies that balance effectiveness with sustainability. The research emphasizes the importance of timing in pest control and the potential of chemical interventions when used judiciously. Future work should explore combining these treatments with ecological approaches to enhance long-term crop protection, minimize environmental impact, and ensure food security. This holistic approach aims to optimize chili production while promoting agricultural sustainability.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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