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Succession and population dynamics of major insect pest of tomato in relation to weather parameters in Jabalpur region

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Abstract
The study was carried out at Vegetable Research Farm, Maharajpur, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during *Rabi* season 2020-21. The tomato crop in Jabalpur has been found to be affected by whitefly (*Bemisia tabaci),* fruit borer (*Helicoverpa armigera)* and leaf miner *(Liriomyza trifolii*). The whitefly infestation began in the first SMW (vegetative stage) until the crop was harvested. While percent leaf infection of the leaf miner was documented in the 3rd SMW (vegetative stage). The per cent fruit damage of the fruit borer was reported in the 6th SMW (Fruiting stage) and persisted till the harvest of the crop.
Relationship between the population of whiteflies and the weather factors showed that the number of white flies and the maximum temperature had a significant positive connection (r=0.560). The percent leaf infested by the leaf miner and maximum temperature had a substantial positive connection (r= 0.571). Percent leaf infestation was shown to have a substantial negative connection with morning relative humidity (r=-0.520) and evening relative humidity (r= -0.693). A significant positive correlation was observed between per cent fruit damage and temperature (maximum temperature (r=0.797) and minimum temperature (r=0.699)). A significant negative correlation was observed between per cent fruit damage of fruit borer with morning relative humidity (r= -0.560) and evening relative humidity (r= -0.697).

Keywords: Tomato pest, population dynamics, succession

Introduction
India is second in the world in vegetable production and it is vital for the agriculture sector as well, as India exported vegetables worth Rs. 4,350.13 crore or $608.48 million (Anonymous, 2020a) [1]. Vegetable production of India is estimated to be 189464 in thousands million tones. Whereas, West Bengal ranks first in the country with 1501.07 thousand hectare area and 28113.03 thousand million ton production. While Madhya Pradesh ranks third after Uttar Pradesh with 1007.86 thousand hectare area and 19832.27 thousand million ton production (Anonymous, 2020a) [1]. Tomato ranks third in India after potato and onion occupying 813 thousand hectares of area. It is estimated the total production of tomato will be 21195 thousands of million tons (Anonymous, 2020b) [2]. Nearly 90% of this production comes from states like Madhya Pradesh, Andhra Pradesh, Karnataka, Gujarat, Odisha, Chhattisgarh, West Bengal, Tamil Nadu, Bihar, Maharashtra, Uttar Pradesh, Haryana and Telangana. Madhya Pradesh contributes 13.79% to this production by 2520 ('000 MT) securing first rank. (Anonymous, 2020b) [2].
Tomato (*Lycopersicon esculentum* Miller) is a native of Tropical America and belongs to the genus *Lycopersicon* and family Solanaceae. In a country like India where major portion of population is vegetarian and having favorable climatic conditions, tomato becomes very popular in vegetable crops. Because of its softness and fragility, insects choose tomato crops as hosts over other crops (Sajjad *et al*., 2011) [25]. Tomato fruit borer *Helicoverpa armigera* (Hubner) (Lepidoptera Noctuidae) Aphids, *Aphis gossypii* (Glover) (Hemiptera: Aphididae), Serpentine leaf miners, *Liriomyza trifoli* (Burgess) (Diptera: Agromyzidae), Leafhopper, *Amrasca devastans* (Ishida) (Hemiptera Cicadellidae), Whitefly, *Bemisia tabaci* (Gena) are the important insect pest of tomato (Lal *et al*., 2008) [18].

These insects have a direct impact on the plant by eating on the leaves, stems, and fruits, as well as causing illnesses such as leaf curl virus. Insect assault occurs at every stage of the crop cycle, from planting through harvesting. Under current production standards, losses owing to these pests are expected to reach around 34.4 percent of possible tomato yield worldwide. Without crop protection, losses would rise to 77.7% of the maximum yield (Zalom, 2003) [32].

Review of Literature

To study the succession of insect pests of tomato

Gravena (1999) [13] reported that whitefly (*Bemisia tabaci),* fruit borer (*Helicoverpa armigera)* and leaf miner (*Liriomyza trifolii)* as major pests of tomato crop. Marcona and Issa (2000) [21] reported the presence of a considerable number of *Liriomyza trifolii* larval populations on tomato crops was detected throughout the crop period. Bagmare *et al.* (1995) [4] reported that the maximum temperature and sunshine hours had a positive correlation with the population of *Liriomyza trifolii* on tomato, whereas rainfall and relative humidity had negative association with the population of leaf miners.

Senguttuvan (1999) [27] has reported a non-significant positive association of damage and leaf miner population with maximum and minimum temperature. Choudhary and Rosaiah (2000) [10] observed that the incidence of the leaf miner (*L. trifolii*) began in the third week of November and peaked in the fourth week of January. The effect of climatic conditions on the incidence of leaf miners demonstrated a negative association between minimum temperature and night time relative humidity, while there was a favorable association between wind speed and sunshine hours. Asalatha (2002) [3] studied that the percentage of leaf miners infested and the pest population on leaf miners were linked to climatic variables. She discovered that maximum temperature and daylight hours were positively connected, while relative humidity and minimum temperature were inversely correlated.

Chaudhari and Senapati (2004) reported that the leaf miner population began around the 46th SMW, gradually increased to the 1st SMW, then steadily increased to the 6th SMW, peaking around the 8th SMW and remaining stable until the 13th SMW. Slowly, the populace was absorbed. Maximum temperature, minimum temperature, temperature gradient, average temperature, maximum relative humidity, minimum relative humidity, and sunshine hours all had a negative effect on the population of *L. trifolii*. A beneficial effect was reported in the case of relative humidity gradient. Hemalata and Maheshwari (2004) [14] studied the biology and seasonality of *L. trifolii* on tomatoes. Leaf miners infestation was started on tomatoes was in the first week of July (the 27th standard week) and the peak was in the first week of August.

Variya and Patel (2012) [30] concluded that The infection peaked in the third week of January, based on mines (10.26 mines/leaf) and larvae (2.24 larvae/leaf). The infestation reached its initial peak (16.41 percent) during the fourth week of November and its maximum peak (29.40 percent) during the first week of January. Overall, the activity was higher during December- January. Nitin *et al.* (2017) [22] investigated on the tomato crop, the number of trapped *Tuta absoluta* moths increased somewhat. The months of March and April were the busiest for moths. From January to May, the highest levels of tomato borer infestation were determined.

Kumar (2008) [16] reported that whitefly emerged in the second week of January, aphid in the first week of January and fruit borer in the last week of February. During the last week of February, there was a rapid increase in the population of whitefly and winged aphid. The highest leaf miner activity was observed in the last week of March, while the highest fruit borer larval population was observed in the first week of April in Jabalpur. Galande and Ghorpade (2010) [11] reported leaf miners can be found at any time of year. The highest temperature had a substantial and positive association (r=0.872) with *L. trifolii* occurrence, but morning relative humidity had a significant but negative correlation (r=-0.578).

Sarangdevot *et al.* (2010) [26] first noticed that the population of whiteflies was inversely proportional to mean temperature and positively proportional to mean relative humidity. The increased rate of development and reproduction of whitefly can be linked to the positive correlation between temperature and whitefly population and it was discovered that whitefly ovipositional activity was highest between 33^{0}C and 37^{0}C.

Chakraborty *et al.* (2012) [5] observed that the population of *H. armigera* initiated at about 48 SMW, improved slowly up to 1st SMW then steadily up to 5th SMW attaining the maximum at about 6th SMW. Chavan *et al.* (2013) [9] revealed that at 11 DAT, the aphid and whitefly population peaked at 7.31 aphids/leaf and 6.01 whiteflies/leaf, up from 1.35 aphids/leaf and 0.37 whitefly/leaf when the plants were transplanted. Aphid (r= -0.491) and whitefly (r= -0.449) had a substantial negative connection with maximum temperature and a significant negative association with minimum temperature (r= -0.645, r= -0.599), respectively.

Sharma *et al.* (2013) [28] noticed that the first sighting of whitefly on tomato occurred during the 14th standard meteorological week, and the population peaked during the 22nd standard meteorological week. Whitefly had a positive association with temperature (maximum and minimum), sunshine, and relative humidity (maximum and minimum), but a negative correlation with relative humidity (maximum and minimum) and rainfall. Kharpuse and Bajpai (2006) [15] studied the seasonal occurrence of significant tomato bug infestations Fruit borer *(H. armigera* Hub.) and white fly (*B. tabaci* Genn). They noticed whitefly and fruit borer in the second and third weeks of January and February, respectively. White fly and fruit borer activity peaked in the second and third weeks of March, respectively.

Chatar *et al.* (2010) [6] revealed that *Helicoverpa armigera* began to appear in the second week of December and peaked in the second week of January (3.12 larvae per plant). From the last week of December to the third week of January, the pest was active. Later on, as the crop matured, the insect population gradually decreased. Mandloi *et al.* (2015) [20] investigated *Helicoverpa armigera* was discovered between November 2012 and March 2013, with two significant maxima during the 11th and 12th SW (6.02 and 6.11 larvae/plant, respectively). The population of borer had a substantial link with wet days (r=0.428) according to an analysis of correlation coefficients between abiotic conditions and main tomato insect pests. Chavan *et al.* (2013) [9] observed maximum population of *Helicoverpa armigera* on leaves (2.80-3.40/plant) from the third week of January to the end of February.

Ganai *et al.* (2017) [12] stated that *Helicoverpa armigera* appeared in the 7th standard week and continued until the 18th standard week, peaking in the 15th standard week. The correlation tests revealed a strong positive relationship between *H. armigera* larval population and mean maximum temperature (r=0.349) and a strong negative relationship between larval population and mean relative humidity (r=-0.284).

Kumar *et al*. (2017) [17] stated that during the 12th SMW, the pest reached its apex, with an average of 1.20 larvae/plant. Following that, the insect population rapidly increased, reaching a low of 0.80 larvae per plant in the 15th SMW. Fruit borer population and maximum, minimum and mean air temperature (r=0.628, 0.610, 0.633) had a positive and substantial connection (r=0.628, 0.610, 0.633). *Helicoverpa armigera* larvae and damaged tomatoes in tomato were found to have a favourable association.

The effect of weather parameters on *Helicoverpa armigera* (Hubner) incidence on tomato was studied by Vikram *et al*. (2018) [31] and was found that *H. armigera* incidence began in the 8th standard meteorological week (third week of February) with an average population of 2.0 larvae per plant, increased gradually and peaked at 6.0 larvae per plant in the 12th standard meteorological week (third week of March). Temperature [maximum (r=0.625) and minimum (r=0.668), wind velocity (r=0.527) and sunshine hours (r=0.722) were all found to have a significant positive link with larval population. Rainfall had a non-significant positive connection (r=0.091) with larval population, but relative humidity [morning (r=-0.160) and evening (r=-0.388)] had a non-significant negative correlation (r=-0.160).

Materials and Methods

The experiment was conducted during rabi season of 2020-21 at Vegetable Research Farm, Maharajpur, College of Agriculture, JNKVV, Jabalpur, Madhya Pradesh.

Climate and Weather Condition

Jabalpur is located in the "Kymore plateau and Satpura Hills" agro- climatic zone of Madhya Pradesh and has a sub-tropical, sub-humid climate. With an altitude of 411.78 meters above mean sea level, it is located at 23.10° North latitude and 79.58° East longitude. The cancer tropic runs through the district's heart. The summers are hot and dry, while the winters are cold and rainy. The typical annual rainfall is 900-1250 mm, with the majority of rain occurring between mid-June and the first week of October. The maximum temperature in April-May is above 46°C, while the minimum temperature in December-January is below 5°C, as is customary. (Ministry of Water, Central ground water board, North Central region Bhopal.) (www.cgwb.gov.in).

Weekly Meteorological data of weather factors were collected from Meteorological observatory at Krishi Nagar, JNKVV, Jabalpur (MP).

Details of Experiment layout

Tomato Genotype: 2019/TODHYB- 1
Plot size: 1.8 × 2.5 m x 04 plots
No. of rows: 3
Spacing (R×P): 60× 50 cm

Observations details

1. The observation on the population of major insect pests was taken at weekly interval on randomly selected 5 plants of each plot.
2. The population of whitefly (*Bemisia tabaci*) was recorded (adult) on 6 leaves each from (2 upper, 2 middle and 2 lower) plant canopy.
3. To record the leaf miner infestation, observation was taken on 5 randomly selected plants of each plot for healthy and damage leaves.
4. To record the fruit borer population on fruiting stage, observation was taken on 5 randomly selected plants of each plot for healthy and damage fruits after each picking at weekly interval.
5. The influence of different meteorological parameters *viz*., Temperature, Rainfall, relative humidity, on major insect pest population.

Result and Discussion

Study the succession of insect pests of tomato

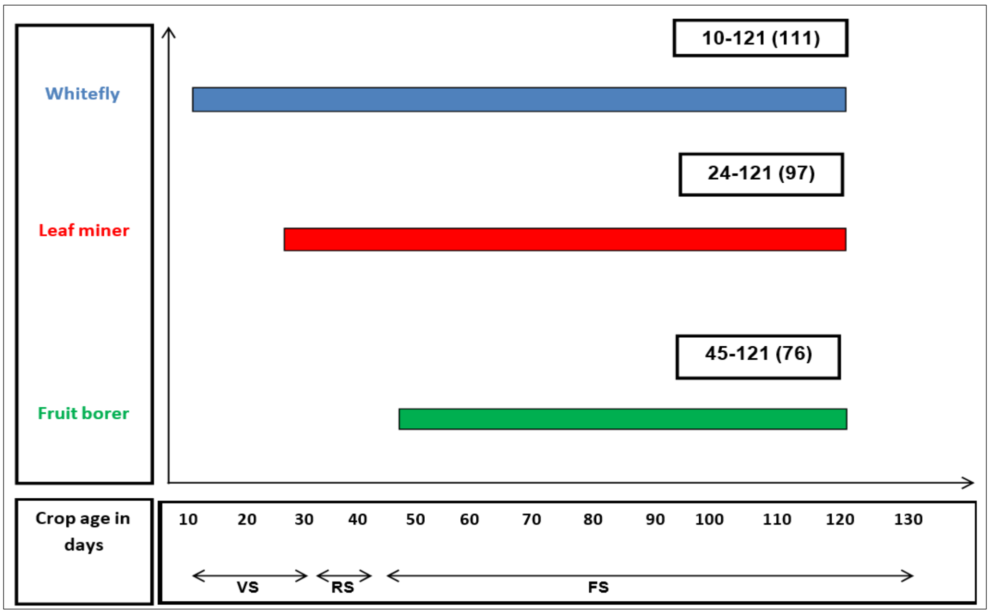
Studies on insect pests' succession revealed the presence of major three insect species associated with various stages of tomato crop (after transplanting) at Jabalpur, Madhya Pradesh during *Rabi* 2020-21(Table 1).

Table 1: Major insect pests of tomato found during *Rabi* season 2020-21 at Jabalpur

Common name	Scientific name	Order	Family
Whitefly	Bemisia tabaci (Genn.)	Hemiptera	Aleyrodidae
Leaf miner	Liriomyza trifolii (Burgess.)	Diptera	Agromyzidae
Fruit borer	Helicoverpa. armigera (Hub.)	Lepidoptera	Noctuidae

Whiteflies were the first significant insect group to assault the crop during the vegetative stage and remained active until the crop matured. Whitefly was initially noticed in the current study when the crop was around 10 days old (after transplanting). It is clear from the Table 2 and Figure 1 that the pest was present on the crop until it was harvested. The second group of insect was the leaf miner which was likewise found in the reproductive stage and remains until the crop was harvested. The pest was initially noticed when the crop was around 24 days old (after transplanting) (Table 4.2 and Figure 4.1) and active for the entire cropping season.

The tomato fruit borer was first observed when the crop was about 45 days old (after transplanting) (Table 2 and Figure 1). The pest was present on the crop during the fruiting stage and remained available until the crop was harvested, as shown in the diagram.



VS: Vegetative stage, RS: Reproductive stage, FS: Fruiting stage, (): Duration of pest activity on crop in days

Fig 1: Succession of insect pests of tomato in Rabi 2020-21

Table 2: Succession of insect pests of tomato at Jabalpur during *Rabi* season 2020-21

Date of observation	Insects				Crop Age (DAS)	Crop Stage
	Name		Order	Family		
	Common	Scientific				
07-01-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	10-16	VS
14-01-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	17-23	VS
21-01-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	24-30	VS/RS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
28-01-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	31-37	RS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
04-02-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	38-44	RS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
11-02-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	45-51	FS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
	Fruit borer	*Helicoverpa armigera* (Hub.)	Lepidoptera	Noctuidae		
18-02-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	52-58	FS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
	Fruit borer	*Helicoverpa armigera* (Hub.)	Lepidoptera	Noctuidae		
25-02-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	59-65	FS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
	Fruit borer	*Helicoverpa armigera* (Hub.)	Lepidoptera	Noctuidae		
04-03-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	66-72	FS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
	Tomato Fruit borer	*Helicoverpa armigera* (Hub.)	Lepidoptera	Noctuidae		
11-03-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	73-79	FS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
	Fruit borer	*Helicoverpa armigera* (Hub.)	Lepidoptera	Noctuidae		
18-03-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	80-86	FS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
	Fruit borer	*Helicoverpa armigera* (Hub.)	Lepidoptera	Noctuidae		
01-04-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	94-100	FS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
	Fruit borer	*Helicoverpa armigera* (Hub.)	Lepidoptera	Noctuidae		
08-04-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	101-107	FS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
	Tomato Fruit borer	*Helicoverpa armigera* (Hub.)	Lepidoptera	Noctuidae		
15-04-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	108-114	FS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
	Fruit borer	*Helicoverpa armigera* (Hub.)	Lepidoptera	Noctuidae		
23-04-2021	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	115-121	FS
	Leaf miner	*Liriomyza trifolii* (Burgess)	Diptera	Agromyzidae		
	Fruit borer	*Helicoverpa armigera* (Hub.)	Lepidoptera	Noctuidae		

VS: Vegetative stage, RS: Reproductive stage, FS: Fruiting stage.

Study the population dynamics of major insect pests of tomato in relation to weather parameters

Seasonal Incidence of leaf miner on tomato at Jabalpur during *Rabi* 2020-21

Leaf miner was seen from the 3rd to the 15th standard week, according to the data collected on the incidence of *Liriomyza trifolii* during the experiment. As shown in Table 3 and Fig. 2 the first appearance of leaf miner was documented at the 3rd week with a 15 percent leaf infestation and the infestation remained in the crop until harvest. During the initial infestation, the percent infestation maximum and minimum temperatures were 25.40C and 8.0 0C, respectively, while the percent infestation morning and evening relative humidity were 75% and 31%, respectively. Throughout the season, the leaf infestation peaked at one point. The maximum and minimum temperatures were 32.30 0C and 15.30 0C, respectively and the morning and evening relative humidity was 78% and 29%, respectively, the percent leaf infestation reached its highest in 11th standard week with a percent leaf infestation of 51.25 percent. After peaking in the 15th standard week, when maximum and minimum temperatures were 37.7°C and 18.60°C, respectively, and morning and night time relative humidity was 61% and 22%, respectively, the infestation reduced 28.20 percent.

Correlation studies

The relationship between per cent leaf infestation and weather parameters were worked out through simple correlation studies. The results indicated a non-significant positive correlation was observed between per cent leaf infestation with minimum temperature (r=0.358), sunshine (hr)(r=0.473), rainfall (mm)(r=0.184) and wind velocity (km/hr) (r=0.131).

Seasonal incidence of fruit borer on tomato at Jabalpur during *Rabi* 2020-21

Helicoverpa armigera was found from the 6th to the 15th standard week. The initial indication of a percent fruit infection was documented in the 6th standard week, with a 12.5 percent fruit damage that remained in the crop until harvest time (Table 3 and fig 2). During the infestation, the maximum and minimum temperatures that caused fruit destruction were 26.40 °C and 8.90 °C, respectively. When the per cent fruit damage maximum and minimum temperatures were 33.90 °C and 16.70 °C, respectively and morning and evening relative humidity were 67 percent and 27 percent, respectively, the per cent fruit damage reached its highest in 12th standard week with a per cent fruit damage of 27.27 percent.

Correlation studies

Simple correlation studies were used to determine the association between percent fruit damage and major meteorological factors. The findings revealed a non-significant positive correlation between percent fruit damage and sunshine (hr) (r=0.334), rainfall (mm) (r=0.168), and a non-significant negative correlation between percent fruit damage and wind velocity (km/hr) (r=-0.033).

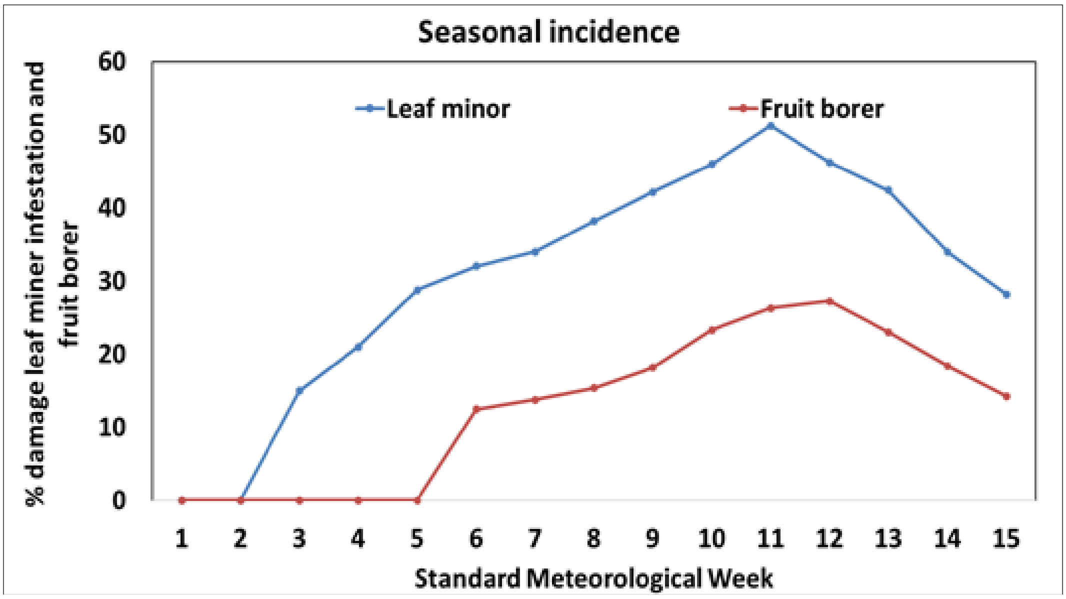


Fig 2: Per cent damage of leaf miner and fruit borer of tomato

Present findings are in accordance with those of Marcona and Issa (2000) [21] and Chaudhuri *et al.* (2001) [7-8]. They recorded *Liriomyza trifolii as* the major pest in tomato.

Seasonal incidence of white fly on tomato at Jabalpur during *rabi* season 2020-21

Whitefly was observed from the 1st SMV until the 15th SMV. Whitefly first appeared in the crop with a mean population of 0.74 per 6 leaves and remained in the crop until harvest (Table 3 and fig 3). During the initial infestation, the mean population maximum and lowest temperatures were 26.50 0C and 12.400C, respectively, with morning and evening humidity of 87 percent and 50 percent, respectively. With a mean population of 7.20 per 6 leaves, the pest population peaked in the 11th standard meteorological week. The mean population maximum and lowest temperatures were 32.300C and 15.300C, respectively, with 78 percent and 29 percent RH in the morning and evening. The pest population gradually decreased after that and the least infestation was observed during the 15 th Standard week, with a mean population of 0.60 per 6 leaves, when mean population maximum and minimum temperature were 37.700C and 18.600C, respectively and morning and evening relative humidity was 61 percent and 22 percent.

Correlation studies

The relationship between whitefly population and major weather parameters were worked out through simple correlation studies. The results indicated that a positive non-significant association between the whitefly population and minimum temperature (°C) (r=0.472), sunshine (hrs) (0.179), rainfall (mm)(r=0.240), wind velocity (km/hr) (r=0.103) and a negative non-significant morning relative humidity (r=-0.228) and evening relative humidity (r=-0.498).

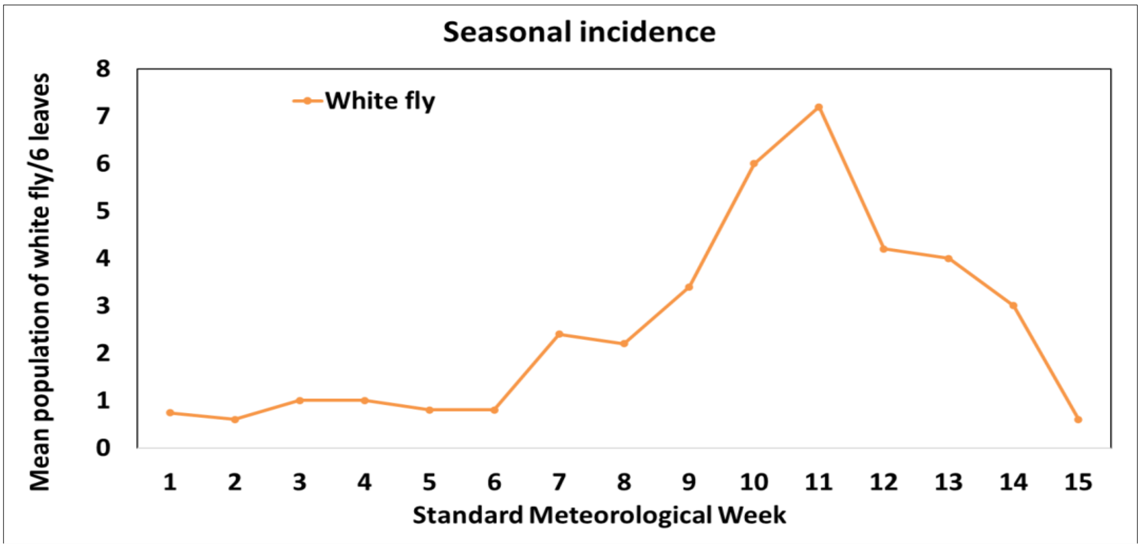


Fig 3: Seasonal incidence of white fly on tomato

Table 3: Seasonal incidence of insect pests on tomato during rabi season 2020-21

SMW	Crop stage	% Leaf infestation caused by leaf miner	Population of White fly per 6 leaves	%Fruit damage caused by fruit borer	Temp. max. (°C)	Temp. min. (°C)	Sunshine (hrs.)	Rainfall (mm)	RH Morn (%)	RH Eve (%)
1	VS	0.00	0.74	0.00	26.5	12.4	4.5	0.5	87	50
2	VS	0.00	0.60	0.00	25.0	11.8	5.7	0.4	86	49
3	VS	15.00	1.00	0.00	25.4	8.0	8.2	0.0	75	31
4	RS	21.00	1.00	0.00	24.6	8.6	7.4	0.0	86	49
5	RS	28.80	0.80	0.00	21.4	4.8	6.0	0.0	73	31
6	MS	32.00	0.80	12.50	26.4	8.9	9.1	0.0	72	34
7	MS	34.00	2.40	13.79	27.7	11.8	7.7	12.6	83	42
8	MS	38.20	2.20	15.38	28.6	10.6	9.3	0.0	79	28
9	MS	42.20	3.40	18.18	32.7	12.4	9.8	0.0	74	25
10	MS	46.00	6.00	23.30	34.8	13.0	8.9	0.0	74	20
11	MS	51.25	7.20	26.31	32.3	15.3	7.0	6.2	78	29
12	MS	46.20	4.20	27.27	33.9	16.7	5.0	0.0	67	27
13	MS	42.40	4.00	23.03	36.8	16.7	8.5	0.0	57	13
14	MS	34.00	3.00	18.40	38.3	14.8	8.6	0.0	64	11
15	MS	28.20	0.60	14.28	37.7	18.6	8.0	0.6	61	22

Similar findings have been reported by Chaudhari *et al.* (2001), Reddy and Kumar (2004) [23], Mandal (2012) [19]. They also stated that *B. tabaci* is a key tomato sucking pest that was present throughout the crop's growth season.

Correlation (r) and regression coefficient (byx)

Regression of maximum temperature on leaf miner infesting tomato

A significant positive correlation was observed between per cent leaf infestation and maximum temperature (r=0.571).

The regression equation being: $\hat{Y}$ =1.67X-19.718 (R2=0.32)

The above equation indicates that with every unit increase of maximum temperature there will be an increase of 1.67 per cent leaf infestation.

Regresion of morning relative humidity on leaf miner infestng tomato

A significant negative correlation was observed between percent leaf infestation and morning relative humidity (r= -0.520).

The regression equation being: $\hat{Y}$=96.805-0.889X (R2=0.27).

The above equation indicates that with every unit increase in the morning relative humidity there will be a decrease of 0.889% leaf infestation.

Regression of evening humidity on leaf miner infesting tomato

A significant negative correlation was observed between per cent leaf infestation evening relative humidity (r= -0.693).

The regression equation being: Ŷ = 57.867-0.886X (R^2=0.48)

The above equation indicates that with every unit increase in the evening relative humidity there will be a decrease of 0.886 per cent leaf infestation.

Regression of maximum temperature on white fly infesting tomato

A significant positive correlation was observed between number of white fly and maximum temperature (r=0.560).

The regression equation being: Ŷ = 0.2173X-4.0203 (R^2=0.31)

The above equation indicates that every unit increase of maximum temperature there will be an increase of 0.2173 white fly populations.

Regression of maximum temperature on fruit borer infesting tomato

A significant positive correlation was observed between per cent fruit damage and maximum temperature (r=0.797).

The regression equation being: Ŷ = -33.258+1.529x (R^2=0.63)

The above equation indicates that with every unit increase of maximum temperature there will be an increase of 1.529 per cent fruit damage.

Regression of minimum temperature on fruit borer infesting tomato

A significant positive correlation was observed between per cent fruit damage and minimum temperature(r=0.699).

The regression equation being: Ŷ = 1.924X-10.823 (R^2=0.48)

The above equation indicates that with every unit decrease of minimum temperature there will be an increase of 1.924 per cent fruit damage.

Regression of morning RH on fruit borer infesting tomato

Percentage of fruit damage and morning relative humidity was found to have a substantial negative relationship. (r= -0.560).

The regression equation being: Ŷ = 59.596-0.6286X (R^2=0.31)

The above equation indicates that with every unit increase in the morning relative humidity there will be a decrease of 0.6286 per cent fruit damage.

Regression of evening RH on fruit borer infesting tomato

A significant negative correlation was observed between per cent fruit damage and evening relative humidity(r=-0.697).

The regression equation being: Ŷ = 30.784-0.5842X (R^2=0.48)

The above equation indicates that with every unit increase in the evening relative humidity there will be a decrease of 0.584 per cent fruit damage.

Rudendko *et al.* (2001) [24], Chaudhuri *et al.* (2001) [7-8] and Subba *et al.* (2017) [29] found similar results. *Helicoverpa armigera* was the most common insect pest of tomatoes, according to all of them.

Table 4: Correlation (r) and regression coefficient (byx) of abiotic factors on insect pests of tomato

Weather factors	Insect pests					
	Leaf miner		White fly		Fruit borer	
	r	byx	r	byx	r	byx
Maximum temperature (0c)	0.571*	1.670	0.560*	0.217	0.797**	1.529
Minimum temperature (0c)	0.358NS	-	0.472NS	-	0.699**	1.924
Sunshine (hrs)	0.473NS	-	0.179NS	-	0.334NS	-
Rainfall (mm)	0.184NS	-	0.240NS	-	0.168NS	-
Morning relative humidity (%)	-0.520*	-0.889	-0.228NS	-	-0.560*	-0.628
Evening relative humidity (%)	-0.693**	-0.886	-0.498NS	-	-0.697**	-0.584
Wind velocity (km/hr.)	0.131NS	-	0.103NS	-	-0.033NS	-

*Significant at 5% Level of significance, NS- Non significant,
** Significant at 1% Level of significance

Conclusion

Whitefly was first observed when the crop was around ten days old (after transplanting). Whitefly was first noticed in the first Standard week, with a mean population of 0.74 per 6 leaves and remained in the crop until harvest. At the 11th standard meteorological week, the pest population peaked. The number of white flies and the maximum temperature had a significant positive connection (r=0.560).

The percentage of leaves infested by leaf miners was observed in the third standard week and remained in the crop until harvest. In the entire season, the pest population has achieved a single high. The high was recorded at the eleventh standard week, respectively. A significant positive correlation was observed between per cent leaf infestation and maximum temperature (r=0.571). A significant negative correlation was observed between per cent leaf infestation and morning relative humidity (r= -0.520). A significant negative correlation was observed between per cent leaf infestation evening relative humidity(r=-0.693).

Fruit borer first appeared in the 6th standard week and a percentage of fruit damage continued in the crop until harvest. At the 12th standard week, the percent fruit damage reached its greatest point. The damage potentiality of the larval population began from 9^{th} SMW and continued to 17^{th} SMW. The population rapidly increased and gradually reached its weak level of infestation 48.14% at 13th SMW (March second week) there after declined trend was observed as temperature decreased. The temperature had a substantial positive link with fruit borer population, whereas the relative humidity had a significant negative correlation.

A significant positive correlation was observed between per cent fruit damage and maximum temperature (r=0.797). A significant positive correlation was observed between per cent fruit damage and minimum temperature (r=0.699). Kumar *et al*. (2017) reported that positive correlation was found between *H. armigera* larvae and damaged fruits in tomato. A significant negative correlation was observed between per cent fruit damage and morning relative humidity (r=-0.560). A significant negative correlation was observed between per cent fruit damage and evening relative humidity (r=-0.697). Ganai *et al.* (2017) [12] reported that highly significant negative association between larval population and mean relative humidity (r=-0.284).

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