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Survey of Major Insect Pests, Natural Enemies and Diseases of Brinjal in Tribal Belt of Surat District in Gujarat, India

R. K. Patel [a++*], S. K. Chawda [b#], H. V. Patel [c†], A. T. Patel [a‡], J. H. Rathod [a^] and J. J. Pastagia [d##]

[a] Krishi Vigyan Kendra, Navsari Agricultural University, Surat, Gujarat, India.
[b] Directorate of Extension Education, NAU, Navsari, Gujarat, India.
[c] ASPEE Shakilam Biotechnology Institute, NAU, Surat, Gujarat, India.
[d] Department of Entomology, N. M. College of Agriculture, NAU, Navsari, Gujarat, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] Scientist (Plant Protection);
[#] Assistant Extension Educationist;
[†] Assistant Professor;
[‡] Farm Manager;
[^] Senior Scientist and Head;
[##] Professor and Head;
**Corresponding author: E-mail: rkpatel@nau.in;*

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ABSTRACT

The survey was carried out to find seasonal abundance and impact of abiotic factors on major insect pests, their natural enemies and diseases in brinjal. The survey of brinjal fields were carried out at fortnight interval for the period of June to December during 2016 to 2022 in different villages of tribal belt of Surat district, Gujarat. The highest population of sucking pests *viz.*, whitefly, aphid and leafhopper in brinjal was found during first fortnight of October, first fortnight of December and second fortnight of September, respectively. The highest fruit damage in brinjal by shoot and fruit borer was found during second fortnight of December. The highest population of natural enemies *viz.*, lady bird beetle and *Chrysoperla* spp. in brinjal was found during second fortnight of September and November, respectively. Maximum incidence *Fusarium* wilt and little leaf diseases of brinjal were observed during mid-October to mid-December and December, respectively. The correlation of weather parameters with sucking pests *viz.*, whitefly and aphid; *Fusarium* wilt and little leaf diseases of brinjal showed significant negative correlation with minimum temperature, morning and evening relative humidity and wind speed while significant positive correlation with sunshine hours. The population of whitefly and aphid; little leaf disease showed significant negative correlation with maximum temperature. The population of aphid; *Fusarium* wilt and little leaf diseases showed significant negative correlation with rainfall and rainy days. The little leaf disease of brinjal showed highly significant positive correlation with its vector *i.e.* leafhopper population. The population of lady bird beetle showed significant negative correlation with maximum temperature and wind speed.

Keywords: Brinjal; whitefly; aphid; leafhopper; shoot and fruit borer; Fusarium wilt; little leaf disease; correlation.

1. INTRODUCTION

Brinjal (*Solanum melongena* L.) is one of the most important extensively grown vegetable crop. It is also known as eggplant which occupy an important place in the food basket of Indian consumers hence regarded as “king of vegetable”. Brinjal is rich in vitamins, protein, free reducing sugar, minerals like phosphorus, sulphur and calcium. It’s fruits mostly use as vegetables in the country due to its nutritional content, which consists of minerals such as iron, phosphorus, calcium and vitamins such as A, B and C (Kapil et al., 2022). India ranks second in brinjal production after China in the world. In India, brinjal is being cultivated in an area of 678 thousand hectares with a production of 12879 thousand metric tonne as per third advance estimates during 2023-24 (Anonymous, 2024). The major brinjal producing states of India are West Bengal, Odisha, Gujarat, Madhya Pradesh, Bihar *etc*. during 2020-21. In Gujarat, brinjal is cultivated in an area of 77.55 thousand hectares with a production of 1533.67 thousand metric tonne and productivity of 19.78 MT per hectare during 2020-21 (Anonymous, 2023).

Several biotic and abiotic factors are responsible for low productivity of brinjal. Among them, insect pests and diseases are important constraints that affect the quality and productivity of brinjal crop. More than 70 insect pests attacked the brinjal crop; among these, shoot and fruit borer (*Leucinodes orbonalis* Guenee) (Lepidoptera: Pyralidae) are the most destructive pest and damages the crop throughout the year. Sucking pests *viz.,* aphid, leafhopper and whitefly are also the main causes of infestation (Tupe et al., 2022). Soren et al*.* (2020) found total of eight insect species *viz.*, jassids (*Amrasca biguttula biguttula* Ishida) (Hemiptera: Cicadellidae)*,* aphids (*Aphis gossypii* Glover) (Hemiptera: Aphididae)*,* whitefly (*Bemisia tabaci* Gennadius) (Hemiptera: Aleyrodidae)*,* leaf roller (*Eublemma olivacae*) (Lepidoptera: Noctuidae), shoot and fruit borer (*L. orbonalis*), epilachna beetle (*Epilachna vigintioctopunctata*) (Coleoptera: Coccinellidae), leaf webber (*Psara bipunctalis*) (Lepidoptera: Pyralidae) and grass hopper (*Chrotogonus spp.*) (Orthoptera: Acrididae) were associated with brinjal crop at different crop growth stages. Among them, brinjal shoot and fruit borer (*L. orbonalis*) was recorded as major pest. The average losses due to shoot and fruit borer on brinjal fruits were 13.30 per cent, out of which 4.83 per cent were found to be totally unconsumable losses during *kharif* season (Singh et al., 2006). Avoidable losses due to *L. orbonalis* in brinjal were 48.47 per cent and increase in yield of brinjal over untreated control was 94.07 per cent during *kharif* season (Prasad et al., 2017). Kumar et al*.* (2019) found 10 insect species belonging to four orders and nine families attacking the brinjal crop from vegetative

to reproductive stage during *kharif* season. Among them jassid (*A. biguttula biguttula*), whitefly (*B. tabaci*) and fruit borer (*L. orbonalis*) were recorded as major pests. Singh et al. (2022) assessed an avoidable loss due to insect pests of brinjal were 48.87 and 47.63 per cent; increase yield of 95.60 and 90.93 per cent during *kharif* season of 2013 and 2014, respectively. Saini et al. (2024) estimated an avoidable loss due to insect pests of brinjal were 37.38 and 38.59 per cent; increase yield of 59.70 and 62.84 per cent during *kharif* season of 2022 and 2023, respectively.

Eggplant is susceptible to several fungal, bacterial and viral diseases, negatively affecting production and profitability. These diseases are *Cercospora* leaf spot, early blight, powdery mildew, target spot, little leaf disease, *Phomopsis* blight, fruit rot, *Choanephora* wet rot, anthracnose, bacterial wilt, *Verticillium* wilt, *Fusarium* wilt, *Phytophthora* blight, fruit rot, and southern blight (Aumentado and Balendres, 2024). *Fusarium* wilt of eggplant is a major cause of losses to eggplant production globally. The disease is caused by many *Fusarium* species (Owusu et al., 2023). Phytoplasma is one of the devastating pathogens responsible for significant crop losses in eggplant globally that causes little leaf of brinjal. In the field survey of Tamil Nadu, Coimbatore region showed highest disease incidence (*Kharif*- 32.40%, *Rabi*- 27.56%, Summer- 35.16%) and Tenkasi region showed lowest (*Kharif*- 17.42%, *Rabi*- 17.02%, Summer- 19.33%) (Gawande et al., 2023). Phytoplasmal little leaf disease is commonly encountered disease symptoms were leaf curling or cupping, reduced leaf size, reduced the petiole length, proliferation of auxiliary shoots, flowers malformed into leaf like structures (phyllody), yellowing and stunted plants growth and death of little leaf infected brinjal plants. The economical important showed capable of causing yield losses up to 40 percent (Shinde et al., 2023). A periodical survey reports are essential to know pest and disease status in brinjal. The present study is of significant importance for the scientific community and integrated management of pests and diseases in brinjal crop. Therefore, an investigation was conducted by survey of major insect pests, their natural enemies and diseases in brinjal in tribal belt of Surat district in Gujarat, India.

2. MATERIALS AND METHODS

The survey of brinjal fields were carried out in different villages of tribal belt of Surat district. Different villages from Mandvi, Umarpada, Mahuva and Mangrol talukas of Surat district were covered in the study. The observation of major insect pests, natural enemies and diseases in brinjal were recorded at fortnight interval during June to December of year 2016 to 2022. An insect species and diseases of brinjal were identified in the laboratory of entomology and plant pathology at Navsari Agricultural University during initial years of study. The weather data were collected from meteorological observatory, Surat.

2.1 Sucking Pests and Natural Enemies

The population of sucking pests *viz.*, whitefly, aphid, leafhopper as well as natural enemies *viz.*, lady bird beetle, *Chrysoperla*, syrphid fly and spider were recorded in brinjal crop. From each field five spots were selected. From each spot, five plants were selected and from each plant, three leaves each from top, middle and bottom portion of the plant was observed for the intensity of insects. The observation was recorded as number of sucking pests/3 leaves and natural enemies (predators)/plant.

2.2 Shoot and Fruit Borer

Five spots from each field and five plants from each spot were selected for an observation of shoot and fruit borer in brinjal. The number of healthy and damage fruits of brinjal were record separately and converted to per cent fruit damage by shoot and fruit borer.

2.3 Diseases of Brinjal

Observations on *Fusarium* wilt and little leaf diseases were recorded from brinjal fields. Five spots of 10 meter row length were selected from each field. From each spot total plant and infected plants were calculated and per cent disease incidence of entire field was worked out.

2.4 Statistical Analysis

The data on number of sucking pests and natural enemies, per cent fruit damage by shoot and fruit borer, incidence of *Fusarium* wilt and little leaf diseases of brinjal were subjected to statistical analysis. The simple correlation was worked out between insect pests and abiotic factors *viz.*, maximum and minimum temperature, morning and evening relative humidity, wind speed, sunshine hours, rainfall and rainy days.

3. RESULTS AND DISCUSSION

The results obtain during present studies are presented in Tables 1 to 12 and illustrated in Figs. 1 and 2.

3.1 Insect Pests of Brinjal

3.1.1 Whitefly

The population of whitefly in brinjal recorded for seven years from 2016 to 2022 in tribal belt *i.e.* Mandvi, Umarpada, Mahuva and Mangrol taluka of Surat district are presented in Table 1. Whitefly in brinjal was observed throughout the crop season *i.e.* June to December during 2016, 2017 and 2018 with its peak during second fortnight of September (3.56 whiteflies/3 leaves), second fortnight of October (3.25 whiteflies/3 leaves) and first fortnight of October (3.45 whiteflies/3 leaves), respectively. Whitefly was observed during August to December during 2019 and 2021 with its peak during first fortnight November (3.50 whiteflies/3 leaves) and first fortnight December (1.80 whiteflies/3 leaves), respectively. Whitefly was observed during July to December during 2020 and 2022 with its peak during first fortnight September (4.10 whiteflies/3 leaves) and second fortnight December (4.17 whiteflies/3 leaves), respectively. The highest mean whitefly population (2.86 whiteflies/3 leaves) was found during first fortnight of October.

3.1.2 Aphid

The higher population of aphids in brinjal was found during November in 2017 and December in 2016 as well as 2018 to 2022 (Table 2). The highest population of aphid in brinjal was observed during second fortnight December (3.74 aphids/3 leaves) and first fortnight of November (2.45 aphids/3 leaves) during 2016 and 2017, respectively. Aphid population in brinjal was the highest *i.e.* 5.80, 5.80, 5.60, 7.32 and 8.25 aphids/3 leaves during first fortnight of December for five years of 2018 to 2022. The highest mean aphid population (5.46 aphids/3 leaves) was found during first fortnight of December.

3.1.3 Leafhopper

Throughout seven years of studies during 2016 to 2022, the highest leafhopper population in brinjal was noticed during mid-September to end of November (Table 3). The highest leafhopper population *i.e.* 2.88, 4.10 and 3.55 leafhoppers/3 leaves were found during second fortnight of September in year 2016, 2018 and 2019, respectively. Leafhopper population was the highest *i.e.* 2.15, 3.70 and 4.12 leaf hoppers/3 leaves during first fortnight of October in year 2017, 2020 and 2022, respectively while it was the highest (1.76 leafhoppers/3 leaves) during second fortnight of November in 2021. The highest mean leafhopper population (2.83 leaf hoppers/3 leaves) was found during second fortnight of September.

3.1.4 Fruit damage by brinjal shoot and fruit borer

The higher damage in brinjal fruits by shoot and fruit borer was noticed during November and December (Table 4). Fruit damage in brinjal was the highest *i.e.* 3.32, 3.55, 4.80, 5.40 and 7.18 per cent during second fortnight of December in year 2016, 2018, 2019, 2020 and 2022, respectively. The highest fruit damage in brinjal was recorded during second fortnight of November (4.10%) and first fortnight of December (6.50%) in year 2017 and 2021, respectively. The highest mean fruit damage (4.82%) in brinjal was found during second fortnight of December.

3.2 Correlation of Insect Pests in Brinjal with Weather Parameters

The correlation of insect pests in brinjal with weather parameters are presented in Table 5. The population of whitefly and aphid showed significant negative correlation with maximum and minimum temperature, morning and evening relative humidity and wind speed while significant positive correlation with sunshine hours. The population of aphid also showed significant negative correlation with rainfall and rainy days. The population of leafhopper showed significant negative correlation with maximum temperature and wind speed. The fruit damage in brinjal showed significant negative correlation with maximum and minimum temperature, morning and evening relative humidity, wind speed, rainfall and rainy days while significant positive correlation with sunshine hours.

The present findings are close in conformity with the findings of Soren et al. (2020) who observed that leafhoppers in brinjal showed negative and highly significant correlation with maximum, minimum temperature and sunshine hrs while negative correlation with RH (min) and wind

speed during both years of 2016-17 and 2017-18. The close observation with present findings is also obtained by Gupta et al. (2021) who revealed that brinjal fruit borer showed negatively significant correlation with minimum temperature, rainfall, morning and evening relative humidity and wind velocity while, showed positively significant correlation with sunshine hours. Brinjal fruit borer also showed non-significant negative correlation with maximum temperature. Berani and Patel (2020) reported that maximum temperature, bright sunshine hours and evaporation were significantly positively correlated with all the sucking pests (aphid, jassid, whitefly and mite) population while minimum temperature, relative humidity (morning, evening and mean), wind speed and rainfall were negatively correlated with all the sucking pests population in brinjal. Humane et al. (2021) investigated that population of aphids, jassids, whiteflies, mites and per cent fruit damage by *L. orbonalis* indicated negative significant correlation with minimum temperature and evening relative humidity whereas negative correlation with rainfall, morning relative humidity and wind speed. All pests showed positive significant correlation with bright sunshine hour, evapotranspiration and maximum temperature while positive correlation with maximum temperature.

The present studies are more or less in agreement with findings of many researchers. Rohokale et al. (2019) studied seasonal incidence of major insect pests of brinjal and noticed the highest incidence of whitefly (9.1 whiteflies/3 leaves), aphids (8.5 aphids/3 leaves) and jassids (12.0 jassids/3 leaves) during 38th MW (3rd week of September), 46th MW (mid-November) and 44th MW (end of October to 1st week of November), respectively. Highest fruit infestation was found 43.3 per cent at 46th MW. Simple correlation studies revealed that aphids was positively significant correlated with bright sunshine hours (r= 0.657*), jassids was negatively significant correlated with maximum temperature (r= -0.494*), whitefly was negatively significant correlated with wind velocity (r= -0.457*), minimum temperature (r= -0.791*), per cent shoot and fruit damage by *L. orbonalis* was positively significant with rainfall (r= 0.454*) and bright sunshine hours (r= 0.696*) respectively. Abirami et al. (2021) revealed that the incidence of whitefly (8.96 whiteflies/3 leaves) and jassid (1.29 jassids/3 leaves) reached to a peak level during second week of October, highest fruit infestation (50%) due to shoot and fruit borer during the first week of December. The maximum and minimum temperature exhibited significant positive correlation with whitefly (r= 0.73, r= 0.79) and jassid (r= 0.59, r= 0.79) population, morning relative humidity exhibited significant negative correlation (r= -0.56) with whitefly population, shoot and fruit borer showed significant negative correlation with minimum temperature and rainfall (r = -0.77, -0.56, respectively).

Table 1. Population of whitefly in brinjal in tribal belt of Surat district (2016 to 2022)

Month	Fort-night	No. of whitefly/3 leaves								
		Period								
		2016	2017	2018	2019	2020	2021	2022	Max.	Mean
June	I	0.675	0.55	0.20	0	0	0	0	0.68	0.20
	II	0.735	0.67	0.45	0	0	0	0	0.74	0.27
July	I	0.89	0.90	0.60	0	0.10	0	0	0.90	0.36
	II	1.57	0.85	0.85	0	0.30	0	0.46	1.57	0.58
August	I	2.055	1.10	1.15	0.50	0.50	0.24	0.77	2.06	0.90
	II	2.165	1.95	2.25	1.10	1.25	0.44	1.64	2.25	1.54
September	I	3.55	2.75	3.10	2.15	4.10	0.36	2.60	4.10	2.66
	II	3.56	2.90	3.15	2.30	3.20	0.52	2.24	3.56	2.55
October	I	3.36	3.15	3.45	3.25	3.15	0.76	2.90	3.45	2.86
	II	2.10	3.25	2.10	3.30	3.30	0.64	3.11	3.30	2.54
November	I	2.53	1.75	2.50	3.50	2.60	1.08	3.52	3.52	2.50
	II	2.77	2.25	2.75	2.50	2.50	1.32	2.70	2.77	2.40
December	I	2.295	2.10	2.10	2.20	2.10	1.80	3.36	3.36	2.28
	II	2.58	2.45	2.65	2.40	2.70	1.56	4.17	4.17	2.64
Min.		0.68	0.55	0.20	0	0	0	0		
Max.		3.56	3.25	3.45	3.50	4.10	1.80	4.17		
Mean ± SD		2.20 ±0.97	1.90 ±0.95	1.95 ±1.09	1.66 ±1.34	1.84 ±1.44	0.62 ±0.61	1.96 ±1.46		

Table 2. Population of aphid in brinjal in tribal belt of Surat district (2016 to 2022)

Month	Fort-night	No. of aphid/3 leaves								
		Period								
		2016	2017	2018	2019	2020	2021	2022	Max.	Mean
June	I	0.93	0.25	0.25	0	0	0	0	0.93	0.20
	II	1.425	0.65	0.55	0	0	0	0	1.43	0.38
July	I	1.845	0.90	1.10	0.50	0	0	0	1.85	0.62
	II	2.14	1.12	2.35	1.10	0	0	0	2.35	0.96
August	I	2.49	0.75	2.40	1.80	1.50	0.16	0	2.49	1.30
	II	2.10	0.65	3.10	2.00	2.70	0.60	1.10	3.10	1.75
September	I	1.51	1.10	2.15	2.10	3.70	0.48	2.28	3.70	1.90
	II	1.67	1.25	1.55	2.55	2.40	1.08	1.40	2.55	1.70
October	I	1.77	1.85	1.20	2.20	2.40	3.12	5.18	5.18	2.53
	II	2.02	2.10	3.15	1.70	3.20	1.68	3.45	3.45	2.47
November	I	2.26	2.45	3.75	1.30	3.70	2.88	6.20	6.20	3.22
	II	2.275	1.10	4.75	3.55	4.80	5.20	5.12	5.20	3.83
December	I	3.315	2.15	5.80	5.80	5.60	7.32	8.25	8.25	5.46
	II	3.74	1.65	4.65	5.55	4.90	5.04	4.96	5.55	4.36
Min.		0.93	0.25	0.25	0	0	0	0		
Max.		3.74	2.45	5.80	5.80	5.60	7.32	8.25		
Mean ± SD		2.11 ±0.73	1.28 ±0.66	2.62 ±1.67	2.15 ±1.78	2.49 ±1.96	1.97 ±2.39	2.71 ±2.80		

Table 3. Population of leafhopper in brinjal in tribal belt of Surat district (2016 to 2022)

Month	Fort-night	No. of leafhoppers/3 leaves								
		Period								
		2016	2017	2018	2019	2020	2021	2022	Max.	Mean
June	I	0.70	0.15	0.30	0	0	0	0	0.70	0.16
	II	0.45	0.30	0.65	0	0	0	0.24	0.65	0.23
July	I	0.825	0.62	0.95	0.50	1.10	0.12	0.40	1.10	0.65
	II	1.54	0.78	1.25	0.70	1.60	0.08	1.34	1.60	1.04
August	I	2.44	1.20	2.55	1.10	1.80	0.32	3.15	3.15	1.79
	II	2.56	1.65	2.85	2.10	2.10	0.20	3.08	3.08	2.08
September	I	2.74	1.90	3.70	2.70	2.30	0.28	2.40	3.70	2.29
	II	2.88	2.10	4.10	3.55	3.50	0.76	2.92	4.10	2.83
October	I	2.24	2.15	2.15	3.20	3.70	1.36	4.12	4.12	2.70
	II	1.43	1.20	1.25	3.25	3.20	1.24	2.57	3.25	2.02
November	I	1.74	1.50	2.19	2.20	2.60	0.96	1.84	2.60	1.86
	II	1.00	0.65	3.15	2.80	2.80	1.76	3.32	3.32	2.21
December	I	1.825	1.15	1.90	3.10	3.70	1.28	1.93	3.70	2.13
	II	1.565	1.35	1.65	3.25	2.40	0.72	2.77	3.25	1.96
Min.		0.45	0.15	0.30	0	0	0	0		
Max.		2.88	2.15	4.10	3.55	3.70	1.76	4.12		
Mean ± SD		1.71 ±0.78	1.19 ±0.64	2.05 ±1.14	2.03 ±1.30	2.20 ±1.21	0.65 ±0.59	2.15 ±1.25		

In past, Kapil et al. (2022) observed the peak activity of whitefly, jassids and red spider mite during October-November. The adults of whitefly showed significant positive correlation with maximum temperature and sunshine hours while significant negative correlation with morning and evening relative humidity. Jassid population showed significant negative correlation with minimum temperature, morning and evening relative humidity. Aphid population showed significant negative correlation with maximum and minimum temperature while significant positive correlation with morning relative humidity. Adhikari and Srivastava (2023) recorded the highest population of leafhoppers (3.88/3 leaves) during 40th SMW (1st week of October). The highest population of whiteflies (5.23/3 leaves) were recorded during 43rd SMW (end of October) and it showed significant negative correlation with rainfall. The peak population of brinjal fruit and shoot borer (5.42 larvae/plant on fruit) occurred during the 46th

Table 4. Fruit damage in brinjal by shoot and fruit borer (2016 to 2022)

Month	Fort-night	Fruit damage (%)								
		Period								
		2016	2017	2018	2019	2020	2021	2022	Max.	Mean
June	I	0	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0	0
July	I	0	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0	0
August	I	0.20	0.10	0.25	0	0	0	0	0.25	0.08
	II	0.55	0.15	0.40	0	0	0	0.80	0.80	0.27
September	I	0.78	0.25	0.55	0.50	0	0	1.29	1.29	0.48
	II	0.98	1.10	0.80	1.75	1.20	1.67	2.35	2.35	1.41
October	I	0.75	2.15	1.10	1.20	2.30	2.35	1.78	2.35	1.66
	II	1.64	1.75	1.75	1.70	3.40	1.87	2.73	3.40	2.12
November	I	1.94	2.15	2.10	2.00	3.10	4.44	3.40	4.44	2.73
	II	2.55	4.10	2.75	2.30	3.10	2.78	2.80	4.10	2.91
December	I	2.75	3.18	3.10	3.00	5.20	6.50	5.82	6.50	4.22
	II	3.32	3.45	3.55	4.80	5.40	6.03	7.18	7.18	4.82
Min.		0	0	0	0	0	0	0		
Max.		3.32	4.10	3.55	4.80	5.40	6.50	7.18		
Mean ± SD		1.10 ±1.14	1.31 ±1.48	1.17 ±1.26	1.23 ±1.46	1.69 ±2.03	1.83 ±2.34	2.01 ±2.26		

Table 5. Correlation of insect pests in brinjal with weather parameters (2016 to 2022)

Sr. No.	Weather Parameters	Sucking pests/3 leaves			Fruit damage (%)
		Whitefly	Aphid	Leafhopper	
1	Maximum temperature (^{O}C)	-0.4128**	-0.2942**	-0.5242**	-0.2150*
2	Minimum temperature (^{O}C)	-0.3668**	-0.5881**	-0.1746	-0.7070**
3	Morning relative humidity (%)	-0.4300**	-0.4881**	-0.1785	-0.5418**
4	Evening relative humidity (%)	-0.2845**	-0.4717**	-0.0075	-0.6498**
5	Wind speed (km/hr)	-0.5775**	-0.5626**	-0.4580**	-0.6806**
6	Sunshine (hrs)	0.2793*	0.4070**	0.0198	0.4788**
7	Rainfall (mm)	-0.1652	-0.2096*	0.0360	-0.3944**
8	Rainy days	-0.1364	-0.3516**	0.1072	-0.5326**

** indicate significance at 5% and ** indicate significance at 1% level*

SMW (mid-November) and it showed significant negative correlation with evening relative humidity while significant positive correlation with wind velocity. Verma et al. (2023) observed that the *L. orbonalis* and *A. biguttula biguttula* population exhibits a positive correlation with maximum temperature and morning relative humidity while negative correlation with minimum temperature and rainfall. Gehlot et al. (2024) revealed that, Tmax 23.3-31.8 °C, Tmin 8.4-25.1 °C, rainfall of 0.5-10 mm during 31st to 45th SMW with RHm 90.9-95.6% and RHe 52.1-79.6% were found conducive conditions for the infestation of shoot/fruit borer in brinjal.

3.3 Natural Enemies

The population of natural enemies in brinjal was found low during entire season. The highest population of lady bird beetle in brinjal was recorded during second fortnight of September in year 2016 (2.78 LBB/plant), 2017 (3.25 LBB/plant) and 2020 (3.10 LBB/plant) whereas it was the highest during first fortnight of October in year 2018 (2.80 LBB/plant) and 2019 (3.10 LBB/plant) (Table 6). The highest population of lady bird beetle in year 2021 (1.44 LBB/plant) and 2022 (2.03 LBB/plant) were noticed during second fortnight of November and second fortnight of October, respectively. The highest mean lady bird beetle population (2.30 LBB/plant) was found during second fortnight of September.

Maximum population of *Chrysoperla* spp. was noticed during mid-July to mid-November (Table 7). The highest population of *Chrysoperla* in brinjal was found during second fortnight of October in year 2016 (1.78 *Chrysoperla*/plant) and 2022 (0.30 *Chrysoperla*/plant) whereas it was the highest during second fortnight of August in year 2019 (1.50 *Chrysoperla*/plant) and 2020 (0.80 *Chrysoperla* /plant). The highest

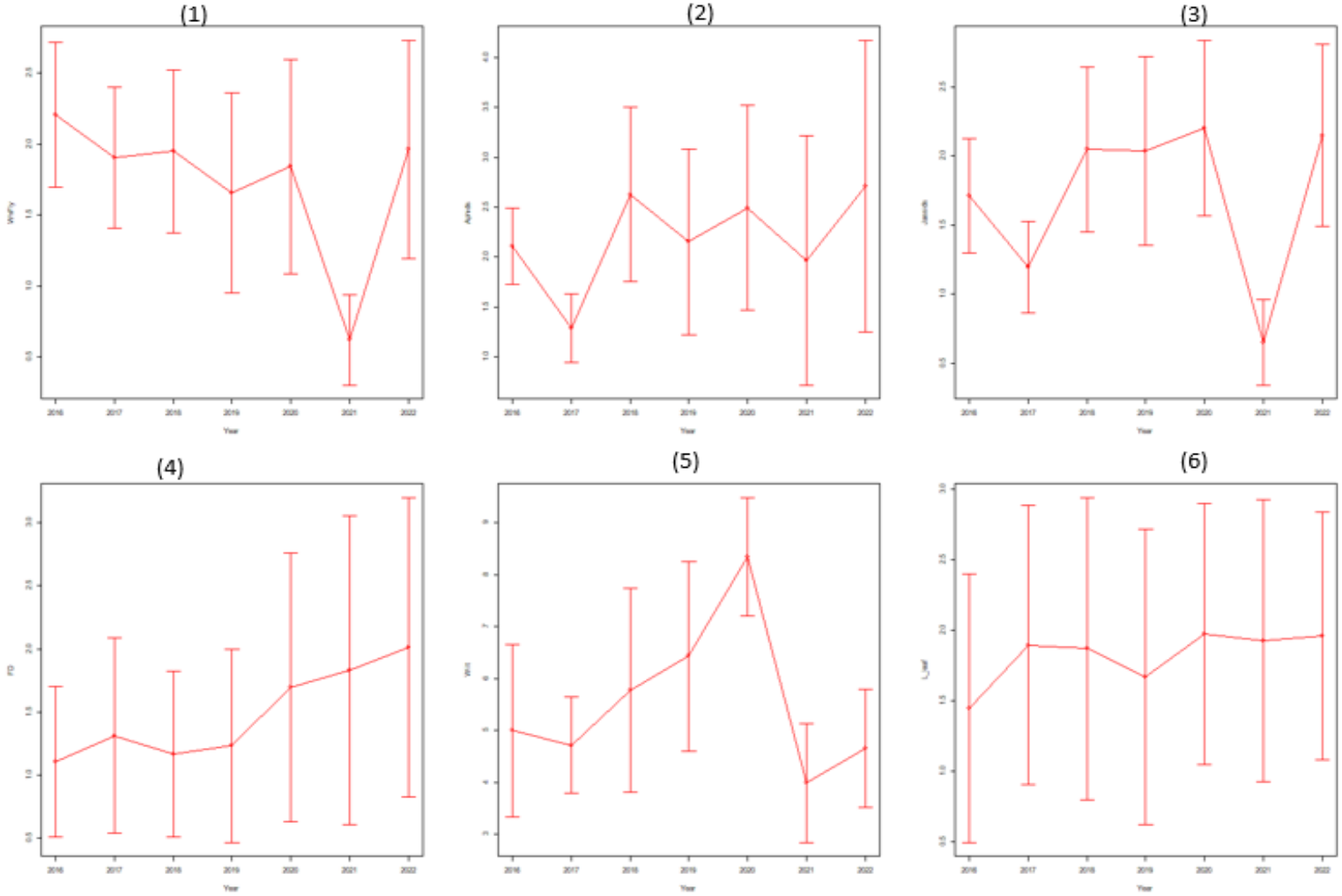

Fig. 1. Status of insect pests and diseases in brinjal (2016 to 2022)
(1. Whitefly, 2. Aphid, 3. Leafhopper, 4. Fruit damage, 5. Wilt, 6. Little leaf)

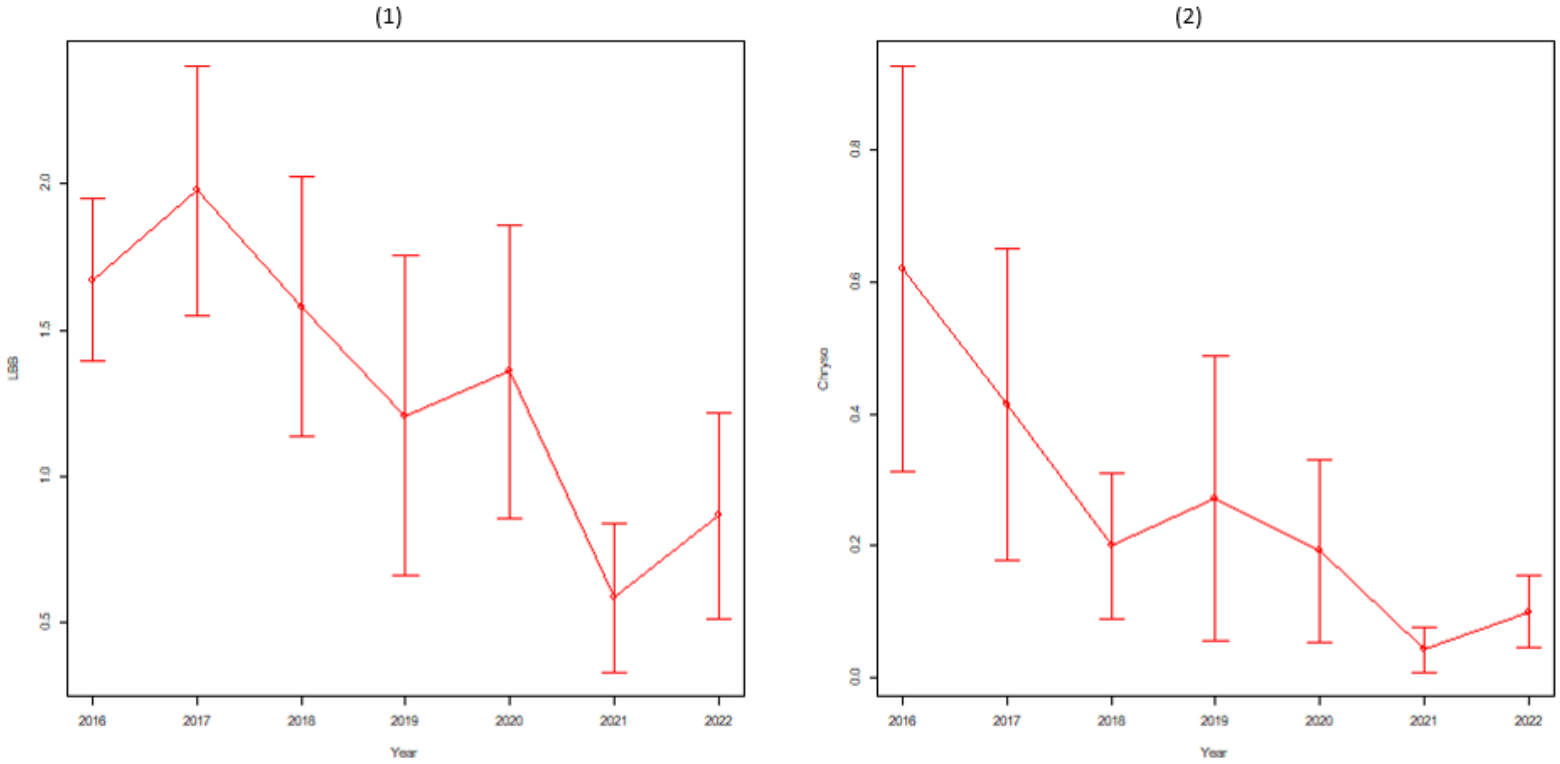

Fig. 2. Status of natural enemies in brinjal (2016 to 2022)
(1. Lady bird beetle, 2. Chrysoperla)

population of *Chrysoperla* was recorded during first fortnight of October, second fortnight of July and first fortnight of November in year 2017 (1.15 *Chrysoperla*/plant), 2018 (0.70 *Chrysoperla*/ plant) and 2021 (0.20 *Chrysoperla*/ plant), respectively. The highest mean *Chrysoperla* population (0.45 *Chrysoperla*/plant) was noticed during second fortnight of November.

The population of syrphid fly was only recorded during three years of 2016, 2018 and 2019 (Table 8). The highest population of syrphid fly in brinjal was found during second fortnight of December in year 2016 (0.57 syrphid fly/plant) and 2018 (0.60 syrphid fly/plant) whereas it was the highest during second fortnight of November in year 2019 (0.30 syrphid fly/plant). The population of spider was only observed during last two years with its peak during first fortnight of December (0.68 spider/plant) and second fortnight of November (0.56 spider/plant) in year 2021 and 2022, respectively (Table 8).

Table 6. Population of lady bird beetle in brinjal in tribal belt of Surat district (2016 to 2022)

Month	Fort-night	Lady bird beetle/plant								
		Period								
		2016	2017	2018	2019	2020	2021	2022	Max.	Mean
June	I	0.95	0.65	0.10	0	0	0	0	0.95	0.24
	II	1.12	1.10	0.10	0	0	0	0.04	1.12	0.34
July	I	1.68	1.65	0.75	0	0	0.08	0.16	1.68	0.62
	II	1.50	1.35	1.50	0.20	0.50	0.20	0.26	1.50	0.79
August	I	1.80	2.10	1.80	0.50	1.30	0.12	0.45	2.10	1.15
	II	2.05	2.25	2.10	0.80	2.00	0.36	0.40	2.25	1.42
September	I	2.18	3.10	2.20	2.30	2.00	0.52	0.64	3.10	1.85
	II	2.78	3.25	2.75	2.70	3.10	0.44	1.06	3.25	2.30
October	I	2.12	2.50	2.80	3.10	2.50	1.04	1.40	3.10	2.21
	II	1.98	1.90	1.75	1.00	1.50	0.80	2.03	2.03	1.57
November	I	1.68	2.10	1.45	1.10	1.30	1.16	1.08	2.10	1.41
	II	1.47	1.47	1.75	1.30	1.60	1.44	1.30	1.75	1.48
December	I	1.12	1.12	2.10	1.90	2.00	1.12	1.75	2.10	1.59
	II	0.98	3.15	0.98	2.00	1.20	0.88	1.53	3.15	1.53
Min.		0.95	0.65	0.10	0	0	0	0		
Max.		2.78	3.25	2.80	3.10	3.10	1.44	2.03		
Mean ± SD		1.67 ±0.53	1.98 ±0.82	1.58 ±0.85	1.21 ±1.05	1.36 ±0.96	0.58 ±0.49	0.86 ±0.67		

Table 7. Population of *Chrysoperla* spp. in brinjal (2016 to 2022)

Month	Fort-night	*Chrysoperla*/plant								
		Period								
		2016	2017	2018	2019	2020	2021	2022	Max.	Mean
June	I	0	0.10	0.10	0	0	0	0	0.10	0.03
	II	0	0	0.15	0	0	0	0	0.15	0.02
July	I	0.88	0.02	0.55	0.20	0	0	0	0.88	0.24
	II	0.92	0.025	0.70	0.50	0.20	0	0.08	0.92	0.35
August	I	0.22	0	0.10	0.70	0.50	0.04	0.05	0.70	0.23
	II	0.35	0	0.22	1.50	0.80	0	0	1.50	0.41
September	I	0	0	0	0.10	0	0.12	0	0.12	0.03
	II	1.10	0.75	0	0	0	0.04	0.20	1.10	0.30
October	I	1.52	1.15	0	0	0	0.08	0.14	1.52	0.41
	II	1.78	0.90	0	0	0	0	0.30	1.78	0.43
November	I	0.98	0.75	0.25	0.10	0.20	0.20	0.28	0.98	0.39
	II	0.55	1.10	0.30	0.30	0.60	0.12	0.18	1.10	0.45
December	I	0.28	0.65	0.28	0.30	0.10	0	0.11	0.65	0.25
	II	0.10	0.35	0.15	0.10	0.30	0	0.07	0.35	0.15
Min.		0	0	0	0	0	0	0		
Max.		1.78	1.15	0.70	1.50	0.80	0.20	0.30		
Mean ± SD		0.62 ±0.59	0.41 ±0.45	0.20 ±0.21	0.27 ±0.41	0.19 ±0.26	0.04 ±0.06	0.10 ±0.11		

Table 8. Population of syrphid fly and spider in brinjal in tribal belt of Surat district

Month	Fortnight	Syrphid fly/plant			Spider/plant	
		Period			Period	
		2016	2018	2019	2021	2022
June	I	0	0	0	0	0
	II	0	0	0	0	0
July	I	0	0	0	0	0
	II	0	0	0	0.08	0
August	I	0	0	0	0.16	0.12
	II	0	0	0	0.08	0.18
September	I	0	0	0	0.24	0.16
	II	0	0	0	0.40	0.36
October	I	0	0	0	0.32	0.30
	II	0	0	0.20	0.20	0.25
November	I	0.12	0.10	0.10	0.52	0.40
	II	0.22	0.25	0.30	0.44	0.56
December	I	0.38	0.39	0.25	0.68	0.35
	II	0.57	0.60	0.10	0.36	0.44
Min.		0	0	0	0	0
Max.		0.57	0.60	0.30	0.68	0.56
Mean ± SD		0.09 ±0.18	0.10 ±0.19	0.07 ±0.11	0.25 ±0.21	0.22 ±0.19

Table 9. Correlation of natural enemies in brinjal with weather parameters (2016 to 2022)

Sr. No.	Weather Parameters	Predators/plant	
		Lady bird beetle	*Chrysoperla*
1	Maximum temperature (°C)	-0.4464**	-0.1232
2	Minimum temperature (°C)	-0.1927	-0.1146
3	Morning relative humidity (%)	-0.1538	-0.1197
4	Evening relative humidity (%)	-0.0436	-0.0662
5	Wind speed (km/hr)	-0.2869**	-0.1188
6	Sunshine (hrs)	0.1271	0.1274
7	Rainfall (mm)	-0.0175	0.1389
8	Rainy days	0.1093	0.0745

** indicate significance at 5% and ** indicate significance at 1 Little leaf % level*

3.4 Correlation of Natural Enemies in Brinjal with Weather Parameters

The correlation of natural enemies *viz.,* lady bird beetle and *Chrysoperla* in brinjal with weather parameters are presented in Table 9. The population of lady bird beetle showed significant negative correlation with maximum temperature and wind speed. The other weather parameters showed non-significant effects with lady bird beetle population in brinjal. The population of *Chrysoperla* showed non-significant negative correlation with maximum and minimum temperature, morning and evening relative humidity and wind speed while non-significant positive correlation with sunshine hours, rainfall and rainy days.

More or less similar activities of natural enemies in brinjal are reported by Adhikari and Srivastava (2023). They noted that the peak numbers of natural enemies *viz.,* coccinella (2.66/plant) and spider (1.36/plant) during 38th SMW (3rd week of September) and 37th SMW (2nd week of September), respectively. The coccinella population showed negative significant correlations with evaporation. The spider population showed a negative significant correlation with rainfall and evaporation, while positive significant correlation with sunshine hours. Other weather parameters exhibited non-significant correlation with population of natural enemies.

3.5 Diseases of Brinjal

3.5.1 *Fusarium* wilt

Fusarium wilt disease incidence in brinjal was noticed almost throughout the season with its peak during mid-October to mid-December (Table 10). The highest wilt incidence *i.e.* 10.30 and 12.75 per cent was found during second fortnight of November in year 2016 and 2019,

respectively. In four years of 2017, 2018, 2020 and 2021, the highest wilt incidence *i.e.* 7.15, 12.10, 12.30 and 7.50 per cent was recorded during first fortnight of December, respectively. The highest wilt incidence (8.24%) was noticed during second fortnight of October in 2022. Overall *Fusarium* wilt disease incidence was found maximum (12.75%) during second fortnight of November.

3.5.2 Little leaf

The little leaf disease of brinjal was observed during August to December (Table 11). The highest incidence of little leaf in brinjal *i.e.* 5.38, 7.50, 5.75, 6.10, 5.71 and 4.44 per cent was found during second fortnight of December in six years of 2016, 2018, 2019, 2020, 2021 and 2022, respectively whereas it was the highest (6.10%) during first fortnight of December in 2017. Overall little leaf disease incidence was found maximum (7.50%) during second fortnight of December.

3.6 Correlation of Brinjal Diseases with Weather Parameters

The correlation of brinjal diseases with weather parameters are presented in Table 12. An incidence of wilt and little leaf diseases in brinjal showed significant negative correlation with minimum temperature, morning and evening relative humidity, wind speed, rainfall and rainy days while significant positive correlation with sunshine hours. The little leaf of brinjal also showed significant negative correlation with maximum temperature. The little leaf disease of brinjal showed highly significant positive correlation with its vector *i.e.* leafhopper population.

Earlier, many researchers reported an incidence of *Fusarium* wilt and little leaf diseases in brinjal. Pandey (2010) reported that different atmospheric factors *viz*., T.max., T.min., relative humidity and rainfall play important role in development of fungal diseases on Brinjal. The growth of five fungi including *Fusasium solani* was found luxurious especially from October to November and February to April. Fruit spoilage was maximum from August to January; the reason may be high humidity, high temperature and less rainfall. Owusu et al*.* (2023) determined an incidence, diversity and distribution of *Fusarium* wilt pathogens of eggplants in five communities each from Ashanti, Eastern and Volta Regions of Ghana and revealed that *Fusarium* wilt incidence was below 10% in 57.3% of the sampled farms. Gehlot et al*.* (2024) observed that *Fusarium* wilt of brinjal was significant during October (41st week) to December (52nd week), when Tmax 23.5- 33.0 °C, Tmin 12.1-26.7 °C, RHm 83.9-87.8%, RHe 48.1-71.5% and rainfall of 0-0.75 mm. It has been found that the severity of *Fusarium* wilt increases with decrease in temperature and high relative humidity and very low rainfall.

Table 10. *Fusarium* wilt incidence in brinjal in tribal belt of Surat district (2016 to 2022)

Month	Fort-night	*Fusarium* wilt (%)								
		Period								
		2016	2017	2018	2019	2020	2021	2022	Max.	Mean
June	I	2.12	3.10	2.10	3.25	10.20	0	0	10.20	2.97
	II	3.10	4.15	3.15	4.10	9.10	0	2.35	9.10	3.71
July	I	3.25	3.20	4.20	5.10	9.40	2.86	3.08	9.40	4.44
	II	2.19	1.35	3.15	4.75	9.50	4.21	3.33	9.50	4.07
August	I	3.27	6.25	1.25	2.30	8.70	2.35	6.25	8.70	4.34
	II	2.60	6.85	4.00	3.55	6.10	5.33	3.16	6.85	4.51
September	I	2.50	5.25	3.70	4.10	6.10	4.29	5.71	6.10	4.52
	II	4.55	3.75	3.20	4.75	5.30	3.75	4.44	5.30	4.25
October	I	2.10	3.15	4.25	5.30	5.00	5.88	4.00	5.88	4.24
	II	6.55	3.75	8.15	7.75	6.70	4.00	8.24	8.24	6.45
November	I	9.80	6.25	10.75	12.30	8.60	6.67	6.32	12.30	8.67
	II	10.30	5.20	11.45	12.75	10.50	4.71	7.06	12.75	8.85
December	I	9.35	7.15	12.10	10.25	12.30	7.50	5.71	12.30	9.19
	II	8.30	6.65	9.45	9.75	9.30	4.29	5.56	9.75	7.61
Min.		2.10	1.35	1.25	2.30	5.00	0	0		
Max.		10.30	7.15	12.10	12.75	12.30	7.50	8.24		
Mean ± SD		5.00 ±3.16	4.72 ±1.76	5.78 ±3.75	6.43 ±3.47	8.34 ±2.17	3.99 ±2.17	4.66 ±2.16		

Table 11. Little leaf incidence in brinjal in tribal belt of Surat district (2016 to 2022)

Month	Fort-night	Little leaf (%)								
		Period								
		2016	2017	2018	2019	2020	2021	2022	Max.	Mean
June	I	0	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0	0
July	I	0	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0	0
August	I	0	1.10	1.15	0	2.10	0	1.25	2.10	0.80
	II	0	1.20	1.20	0	2.30	1.33	2.11	2.30	1.16
September	I	0	1.65	1.35	0.50	3.10	2.86	1.43	3.10	1.56
	II	1.22	2.10	1.20	1.20	2.20	2.50	1.11	2.50	1.65
October	I	1.48	2.35	1.45	1.70	1.30	1.18	2.67	2.67	1.73
	II	2.18	2.05	2.55	2.50	1.10	2.67	2.35	2.67	2.20
November	I	2.60	1.80	2.75	3.20	2.20	3.33	4.21	4.21	2.87
	II	3.10	2.75	3.25	3.70	3.70	2.35	3.53	3.70	3.20
December	I	4.26	6.10	3.75	4.80	3.50	5.00	4.29	6.10	4.53
	II	5.38	5.38	7.50	5.75	6.10	5.71	4.44	7.50	5.75
Min.		0	0	0	0	0	0	0		
Max.		5.38	6.10	7.50	5.75	6.10	5.71	4.44		
Mean ± SD		1.44 ±1.81	1.89 ±1.89	1.87 ±2.04	1.67 ±2.00	1.97 ±1.77	1.92 ±1.90	1.96 ±1.68		

Table 12. Correlation of brinjal diseases with weather parameters (2016 to 2022)

Sr. No.	Weather Parameters	Diseases of Brinjal	
		***Fusarium* wilt (%)**	**Little leaf (%)**
1	Maximum temperature (^{O}C)	-0.1499	-0.3722**
2	Minimum temperature (^{O}C)	-0.5543**	-0.7812**
3	Morning relative humidity (%)	-0.5346**	-0.4870**
4	Evening relative humidity (%)	-0.5503**	-0.6033**
5	Wind speed (km/hr)	-0.4267**	-0.7041**
6	Sunshine (hrs)	0.5269**	0.4432**
7	Rainfall (mm)	-0.3149**	-0.3097**
8	Rainy days	-0.3475**	-0.4597**
	Leafhoppers/3 leaves		0.3486**

** indicate significance at 5% and ** indicate significance at 1% level*

Gawande et al. (2022) focused on survey, disease incidence and molecular characterization of BLL (Brinjal little leaf) phytoplasma, when surveys in nine districts of Tamil Nadu where brinjal is grown. During *Kharif* season, the highest (32.40%) and lowest (17.42%) disease incidence of brinjal little leaf in Coimbatore and Tenkasi region, respectively. They discovered that the *Candidatus* Phytoplasma trifolii was associated with BLL with 98.54 per cent and identity with other isolates. Aumentado and Balendres (2024) reviewed that the little leaf disease in eggplant is caused by phytoplasma/mycoplasma, which is transmitted by leafhoppers and planthoppers/jassids such as *Amrasca devastans* (syn. *Empoasca devastans*) and *Cestius phycitis* (formerly *Hishimonus phycitis*; *Eutettix phycitis*). It is one of the most important diseases in eggplant that can result in yield loss.

The present studies are close in conformity with findings of Shinde et al. (2023) reported that the insect vector leafhopper population was positively and significantly correlated with little leaf disease incidence in brinjal. Darabakula et al. (2024) found that the seed transmission of phytoplasmas in eggplants for two subsequent generations highlights the risk of additional sources of infection of the disease represented by asymptomatic and infected seedlings in the presence of insect vectors, it can cause an outbreak by insect vectors, which spreads the disease in the surrounding natural and agricultural environments, causing epidemics in agricultural and landscape environments.

4. CONCLUSION

The present study of survey provides information of insect pests, natural enemies and diseases in brinjal in tribal belt of Surat district, Gujarat. The maximum whitefly population in brinjal was found during September to December of 2016 to 2022 with the highest mean population during first fortnight of October. Aphid population was found maximum during November-December with its peak during first fortnight of December. Maximum leafhopper population was found during September to November with the highest mean population during second fortnight of September. The fruit damage in brinjal by shoot and fruit borer was found maximum during November-December with its peak during second fortnight of December. Among natural enemies in brinjal, maximum population of lady bird beetle was found during mid-September to November with its peak during second fortnight of September. Maximum population of *Chrysoperla* spp. was recorded during mid-July to mid-November with the highest mean population during second fortnight of November. The population of syrphid fly and spider were found higher during November-December. *Fusarium* wilt disease incidence in brinjal was found higher during mid-October to mid-December with maximum during second fortnight of November. Little leaf incidence was found maximum during second fortnight of December. The seasonal fluctuations of major insect pests, their natural enemies and diseases in brinjal crop are influenced by abiotic factors.

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 this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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