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Arthropod Richness and Abundance in Brinjal Crop Ecosystems

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Authors' contributions

This work was carried out in collaboration among all authors. Author MT helped in conceptualization, performed the methodology, investigated the study, searched for resources, did data curation, Software and formal analysis. Authors TKH and PM wrote original draft and did funding acquisition. Author SP Conceptualized the study, performed the methodology, searched for resources, did data validation, wrote, reviewed and edited the manuscript. Author IKK searched for resources, did data Validation, wrote, reviewed and edited the manuscript, proofread the drafted manuscript. All authors read and approved the final manuscript.

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ABSTRACT

In the study on arthropod biodiversity in brinjal with the variety Navakiran, 12 numbers of different insect pests under 6 orders and 12 families were recorded. These included *Phyllotreta sp*., epilachna beetle, *Henosepilachna vigintioctopunctata* Fab. cotton aphid, *Aphis gossypii* Glover, cotton whitefly, *Bemisia tabaci* (Genn.), cotton jassid, *Amrasca biguttula biguttula* Ishida, hooded

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hopper, *Oxyrachis terandus* Fab., thrips, *Thrips tabaci* (Linderman), brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen, short horned grasshopper, *Hieroglyphus banian* Fab., long horned grass hopper (unidentified), red pumpkin beetle, *Aulachophora foviecollis* (Lucas) and dipteran fruit fly (unidentified). Besides, six different natural enemies namely, one species of lynx spider (unidentified), one species of Syrphid fly (unidentified), one species of ant (*Solenopsis sp*.) and three species of ladybird beetles (*Cheilomenes sexmaculatus* Fab., *Coccinella transvarsalis* Fab. and *Brumoides sp*.) were recorded from the field. The cotton aphid showed its peak during 8th SW (Standard Week) while in case of jassid, whitefly and leaf hopper it was during 9th SW. Epilachna beetle had two peaks- during 8th and 18th SW. Brinjal shoot and fruit borer attained peak during 8th SW.

Keywords: Brinjal; henosepilachna vigintioctopunctata; bemisia tabaci; leucinodes orbonalis; (Solenopsis sp.); hieroglyphus banian.

1. INTRODUCTION

Brinjal (*Solanum melangena* L.) or egg plant is an important solanaceous vegetable among the listed popular vegetables grown in the tropics and sub tropics Vysali et al., (2021); Pandey et al., (2023). It is predominantly cultivated in the Asian countries viz. India, Pakistan, China, Philippines, Egypt; Europe viz; France, Italy; middle East, Far East and U.S.A. (Anon., 2010; Harish et al., 2011). As many as 53 species of insect pests have been recorded by Nayar et al. (1995) whereas a total of 28 numbers of insect pests were reported from Sudan (EL- Shafie, 2011).

In northern part of India 20 arthropods were recorded to damage the crop (Latif *et al.,* 2009) while in Himachal Pradesh, the number was 28 including the mite pest (Patil and Mehta, 2008; Kasi et al., 2021a; Kasi et al., 2021b; Waiba et al., 2021b) and in Kashmir 13 species of insect pests were reported to cause damage to brinjal (Dar et al., 2015; Kasi et al., 2020). Other insect pests and mites of major importance include jassid (*Amrasca biguttula biguttula* Ishida and Amrasca devastans Distant), hadda beetle (*Henosepilachna* (Epilacha) *vigintioctopunctata* Fab.), aphid (*Aphis gossypii* Glover), white fly (*Bemisia tabaci* Genn.; *Trialeurodes vaporariorum* Westwood), brinjal mealy bug (*Planococcus insolitus* Green), lace wing bug (*Urentius hystricellus* Richt.), stem borer (*Ezophera perticella* Ragonot), thrips (*Thrips palmi* Karny) and red spider mite (*Tetranichus macfurlanei*) (Andre) (Patial and Mehta, 2008; Vevai, 1970; Singh and Abrol, 2001; Srinivasan, 2009; Waiba et al. 2021a). Leaf hopper, white fly and shoot and fruit borer may cause even 70-92% yield loss (Rosaiah, 2001). Jassid alone may damage brinjal as high as 54% (Rawat and Sahu,1973; Monika et al., 2022; Pandey et al., 2023; Djague et al., 2024).

India, being the centre of origin / place of domestication of brinjal has rich source of many wild and locally available germplasms /cultivars/varieties in different parts of the country and West Bengal is no exception (Mahdi et al., 2023). Terai Zone of west Bengal is a vast area where a variety of vegetables including brinjal are grown extensively Waseem et al., (2024). The crop is grown two or three times in a year depending upon suitable climatic conditions and irrigation facilities. Many workers have evaluated different brinjal varieties/cultivars in different regions against major insect pests (Kumar et al, 2002 at Udaipur; Elanchezhyan et al., 2008 at Madurai; Ahmad et al., 2008; Shaikh et al., 2013 in Gujrat; Devi et al., 2015 in Raipur; Singh et al., 2016; Waiba et al. 2021; Kasi and Waiba 2022). Management of various sucking pests, brinjal shoot and fruit borer and other pests by different means especially by chemical pesticides and plant –based chemicals has been tried by many workers with various degree of success.

2. MATERIALS AND METHODS

2.1 Experimental Site

The field experiments were conducted in the Instructional Farm, Faculty of Agriculture, while the laboratory works were done in the Department of Agricultural Entomology and Department of Biochemistry of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal in two successive Rabi seasons of 2018-19 and 2019-20.

2.2 Geographical location

Terai zone is situated in between 25 57’ N to 27 N latitude and 88 25’ to 89 54’ E longitude. This

agro- ecological region is surrounded by Kurseong, Kalimpong and Bhutan hills in the North, Bihar border on the West and Assam border in the East. This northern tract of the state consisting of Siliguri sub-division of Darjeeling district, the districts of Jalpaiguri and Cooch Behar located at the foot hills of Himalayan and Sub-Himalayan (Bhutan hills) mountain belts and of small stretches of riverian lying under Islampur sub-division of Uttar Dinajpur districts exhibits a well-marked distinct physiographic unit of the state. The total geographic area of the zone is spread over an area of 12,015sq.km. which is about 13.5% of the state area sharing 9.75% of the state population. The farm and laboratories where the present studies were conducted are located at 26º19' N latitude and 89º23' E longitude and at an altitude of 43 m above the MSL (mean sea level).

2.3 Soil

The soil of this zone is generally sandy loam, acidic (pH 4.0-6.8), rich in raw humus content, has low water retention capacity, medium to high total nitrogen content with low rate of Nitrogen mineralization, medium to high level of phosphorous and low to medium potash content. The soil of the experimental site appeared sandy loam in texture with pH value of 5.6.

2.4 Climate

The climate of this zone is sub-tropical humid with distinct features of high humidity and high rainfall. Average annual rainfall of this zone varies from 2100-3000 mm; the maximum rainfall i.e. about 80 percent is received from South-West monsoon during the rainy months from June to September. The range of maximum and minimum temperature of the area is 24-33.2º C and 7-8º C respectively. The morning relative humidity ranges from 58% in March to 87% in July, while the evening humidity varies from 48% to 84% in March to November respectively.

2.5 Experimental Details

The field experiments were conducted at the Instructional Agriculture, Uttar Banga Krishi Viswavidyalaya at Pundibari during two successive Rabi seasons (November to May of 2018-2019 and November to May of 2019-20. Ten varieties of brinjal (*Solanummelongena*)were collected from local market for the studies. The list of the varieties is mentioned below.

Table 1. Mean weather data of brinjal field during 2019 to 2020

Dates of observations	Standard weeks	Max. Temp. (˚C)	Min. Temp. (˚C)	Max. RH%	Min RH%	Rainfall (mm)
11.01.2020	2	26.46	8.29	83.57	39.00	0.00
18.01.2020	3	26.43	13.19	90.00	56.57	0.00
25.01.2020	4	26.57	13.04	77.14	57.14	1.57
01.02.2020	5	29.01	13.73	67.57	46.29	1.09
08.02.2020	6	27.50	15.66	84.00	55.71	2.46
15.02.2020	7	28.69	16.23	77.14	48.43	1.49
22.02.2020	8	29.04	16.71	74.14	53.29	1.17
29.02.2020	9	32.11	17.51	63.86	46.86	0.00
07.3.2020	10	33.41	17.86	53.71	37.57	0.07
14.3.2020	11	31.84	18.07	65.14	52.29	3.40
21.3.2020	12	28.47	19.09	82.57	71.43	9.14
28.3.2020	13	28.59	19.54	83.71	69.14	2.73
04.4.2020	14	32.01	20.76	77.57	62.00	13.59
11.4.2020	15	32.31	20.79	78.29	62.14	7.33
18.4.2020	16	30.34	23.07	85.43	76.57	7.39
25.4.2020	17	27.20	21.51	93.00	87.71	27.40
02.5.2020	18	31.56	22.54	87.29	72.14	10.26
09.5.2020	19	33.40	24.53	86.14	71.71	25.86
16.5.2020	20	31.01	24.49	94.14	85.43	25.13
23.5.2020	21	31.12	22.53	85.98	73.96	16.71
30.5.2020	22	21.19	17.36	68.71	63.71	38.59

Table 2. List of brinjal genotypes

Sl.no.	Name of the variety	Source
1.	Kajlee	Pundibari
2.	Butal	Pundibari
3.	Moyna	Pundibari
4.	Lepcha	Pundibari
5.	Soltha	Pundibari
6.	Pk123	Pundibari
7.	Navakiran	Pundibari
8.	Kaljani	Pundibari
9.	Dhopa	Pundibari
10	Ball	Pundibari

Seeds were sown on 28th and 25th November during 2018-19 and 2019-20 respectively. Twenty-four days old seedling were transplanted in the main field 3m x2m plots maintaining 60cmx75cm row to row and plant to plant distance. Common irrigation channel of 1m wide between each row of plots was maintained. Recommended fertilizers dose @ 120:80:80 kg/ha (N:P:K) were applied. The experiment was laid out in a randomized block design (RBD) with three replications. Standard agronomic practices were adopted for raising the crop successfully. No plant protection chemicals were applied in the field during the course of study except the management trial.

2.6 Arthropod biodiversity in brinjal

With a view to study the natural occurrence of insect-pest of brinjal, a hybrid variety, Navakiran was used. The size of the plots was 3m x 2m and there were three replications. Recommended fertilizers and all agronomic practices were applied for raising and maintaining the crop. No plant protection chemicals were applied to enhance the natural occurrence of insect pests and natural enemies. The incidence of the insect pests was recorded at 7 days interval starting from 15 days after transplanting till the maturity/harvest of crop. Natural enemies were also recorded at weekly intervals.

3. RESULTS AND DISCUSSION

The results of the present studies conducted during 2019-2020 are presented in the below mentioned paragraphs. The field experiment was conducted in the Instructional Farm of the Faculty of Agriculture while the laboratory studies were made in the Department of Agricultural Entomology of UBKV located at Pundibari, Coochbeher.

3.1 Arthropod biodiversity in brinjal

During the course of the study conducted in 2019-2020, twelve (12) numbers of different insect pests belonging to six (6) orders under twelve (12) families were recorded from the brinjal crop. The results are presented in Table 3.

The insect pests recorded in the study included striped flea beetle, *Phyllotreta sp.,* epilachna beetle, *Henosepilachnavigintioctopunctata* Fab. cotton aphid, *Aphis gossypii* Glover, cotton whitefly, *Bemisiatabaci* (Genn.), cotton jassid, *Amrasca biguttula biguttula* Ishida, hooded hopper, *Oxyrachisterandus* Fab., thrips, *Thrips tabaci* (Linderman), brinjal shoot and fruit borer, *Leucinodesorbonalis* Guen, short horned grasshopper, *Hieroglyphus banian* Fab., long horned grass hopper (unidentified), red pumpkin beetle, *Aulachophorafoviecollis* (Lucas) and dipteran fruit fly (unidentified). Eight insect species were noted to damage foliage, one species inflicted damage to shoot and two species caused damage to fruits.

The aphid remained active in the field all throughout the period of study for 21 weeks. The jassids, thrips and whiteflies recorded their presence for 21 weeks each. The presence of flea beetle was registered for 17 weeks whereas epilacchna beetle persisted in the field for prolonged period of 21 weeks. The red pumpkin beetle was present in the field as a stray visitor for 12 weeks. The short-honed grasshopper was recorded for a long period of 10 weeks (from10 to 20standard Meteorological weeks) but with negligible number. Similarly, the long-horned grass hopper registered its presence only for four weeks (from 4 to 8standard week). The fruit fly was recorded from the crop for 2weeks (from 9 to10standard week).

Table 3. List of insect pests recorded in brinjal during 2020

Order	Family	Common name	Scientific name	Site of damage
Homoptera	Aphididae	Cotton aphid	*Aphis giossypii* Glover	Leaf, shoot, flower bud, and leaf
	Aleyrodidae	Cotton whitefly	*Bemisiatabaci* (Guen.)	Leaf
	Cicadellidae	Cotton jassid	*Amrascabiguttula Biguttula* (Ishida)	Leaf
	Membracidae	Hooded hopper	*Oxyrachisterandus* Fab.	Shoot, stem
Thysanoptera	Thripidae	Thrips	*Thrips tabaci* (Linderman)	leaf
Orthoptera	Acrididae	Short- horned grass- hopper	*Hieroglyphus banian* Fab.	Leaf
	Tettigonidae	Long- horned grass- hopper	Un- identified	Leaf
Diptera	Muscidae	Fruit fly	Un- identified	Fruit
Coleoptera	Cooccinellidae	Epilachna beetle	*Henosepilachnavigintiocto punctata* Fab.	Leaf, shoot and fruit
	Chrysomelidae	Flea beetle	Phyllotreta sp.	leaf
	Chrysomelidae	Red pumkin beetle	*Aulachophora foviecollis* (Lucas)	leaf
Lepidoptera	Pyralidae	BrinjalShoot and fruit borer	*Leucinodesorbonalis*Guen.	Shoot and fruit

Table 4. List of natural enemies recorded in brinjal crop during 2020

Order	Family	Common Name	Scientific Name	Stages observed
Coleoptera	Coccinellidae	Ladybird beetle	*Cheilomenessexmaculatus* Fab.	Egg, grub, pupa and adult
			Coccinellea transversalis Fab.	
			Brumoides sp.	Adult
Hymenoptera	Formicidae	Ant	*Solenopsis* sp.	Adult
Diptera	Shirphidae	Shirphid fly	Unidentified	Larva and adult
Aranae	Lycosidae	Lynx spider	Unidentified	Adult

Besides the insects, three different kinds of natural enemies viz. one species of lynx spider (unidentified), one species of ant (*Solenopsis* sp.) and three species of ladybird beetles (*Cheilomenes sexmaculatus* Fab., *Coccinella transversalis* Fab. and *Brumoides* sp.) were recorded in the field (Table 4). Brinjal crop is infested by various insect pests, mites and nematodes right from seedling stage to harvesting stage. The number of insect pests attacking brinjal varies according to season and place (Gangwar and Sachin, 1981). Earlier Nayar*et al.* (1995) reported 53 species of insect pests from brinjal while the number was 27 in Sikkim (Singh and Singh, 2002); Kasi et al., (2022b); 28 in Himachal Pradesh (Patil and Mehta, 2008); 20 in northern India (Latif et al., 2009); 13 in Kashmir (Dar et al., 2015); Kasi and Tayde (2018a). Ghosh and Senapathi (2001) from West Bengal recorded 9 insect pests from brinjal and they mentioned about aphid, jassid,

whitefly, thrips, hadda beetle, leaf roller, leaf miner, shoot and fruit borer. In the present study, 12 insect pests were recorded and except the leaf roller and leaf miner, all the insect pests reported by Ghosh and Senapati (2001); Kasi et al., (2022a); Thakur et al., (2023).

According to Kadam *et al.* (2006), jassid, whitefly, aphid, brinjal shoot and fruit borer are common and major pests in Rahuri (Maharastra). Elanchezhyan*et al.* (2008) observed 6 insect pests namely, aphid, leaf hopper, whitefly, epilachna beetle, mealy bug (*Coccidohy strixinsolita*) and ash weevil from Madurai, India.

Tewari *et al.* (2011) reported a detailed list of insect pests of brinjal which included 16 different species of insects under different orders. From Madya Pradesh, India, four (4) insect pests, namely aphid, jassid, whitefly and shoot and fruit borer were reported to be the major insect pests of brinjal (Birla, 2011). Yousafi (2013) mentioned that aphid, white fly, thrips, shoot and fruit borer, stem borer, leaf roller and epilachna beetle were the common insect pests of brinjal in Pakistan. Dar *et al.* (2015) reported brinjal shoot and fruit borer, epilachna beetle, whitefly, jassid and aphid among the 13 insect pests, are the important pests of Kashmir. Similarly Kumar *et al.* (2018) observed four (4) insect species namely aphid, jassid, white fly and tinged bugs as the sap sucking insect pests in brinjal. Akter*et al.* (2018); Kasi and Tayde (2018a) reported 18 species of insect pest species from Bangladesh whereas in earlier studies, Latief*et al.* (2009) recorded 30 species of insect pests in brinjal in Gazipur (Bangladesh). In a recent study conducted in Maharastra (India), Kadgonkar*et al.* (2018) reported that aphid, jassid, whitefly and shoot and fruit borer were the major insect pests of brinjal. In 2019, Lal *et al.* (2019) observed aphid, jassid and whitefly to be the important sucking pests of brinjal in Madya Pradesh.

Thus, it appears from the above that various workers have reported varied number of insect pests from various parts of the country and abroad. Diversity of insect pests depends upon the geographical area, season, environmental conditions and intensity of cultivation of the crop. Brinjal is a long-duration crop and is grown twice or thrice in a year depending upon the availability of suitable environmental conditions and other cultivation facilities. The present study was conducted during rabi season of 2019-20 in terai agro-climatic zone of West Bengal where brinjal is grown regularly in different seasons. The author of the present study recorded 12 numbers of insect pests whereas earlier Ghosh and Senapati (2001) observed 9 species of insect pests,So species diversity varied during this nearly two decades. There were differences in number and species of insect pests between these two studies and among the other studies as elaborated above. However, there is similarity in the species of the common and major insect pests among the various studies as narrated above. The present study thus corroborates the results of other studies conducted in different parts of the country and abound. The difference in number and species were due to difference in location, season of cultivation and change in climatic condition and or intensity of cultivation, which was however, beyond the scope of the present study.

In the present investigation on arthropod biodiversity in brinjal six (6) different natural enemies were recorded. These included three species of coccinellids, one species of ant, one species of syrphid fly (unidentified), one lynx spider (unidentified). In brinjal ecosystem a number of arthropod insects and non-insect natural enemies occur naturally and they play an important role in suppressing the population of the insect pests. Various workers have studied on this aspect and the diversity in natural enemies also varies from place to place. Latif *et al.* (2009) from Gaziapur, Bangladesh recorded 10 plant inhabiting predacious arthropods and 7 surface dwelling predatory arthropod families from brinjal ecosystem. They observed the coleopteran (ladybird beetles, carabid beetles and staphylinid beetles) and spiders as the most important plant dwelling predacious arthropods and among the surface–dwelling arthropods, spiders, ladybird beetles and carabid beetles, are the most important ones. Kumar *et al.* (2018) recorded ladybird beetle, syrphid fly and spider from brinjal crop in Udaipur, Rajasthan (India). In a recent study Kasi and Tayde (2018b) Borkakati*et al.* (2019) from Assam recorded five species of coccinellid beetles *viz*. *Coccinella transvarsalis* (Fab.), *Harmonia dimidiata* (Fab.), *Adalia bipunctata, Chilomenses propinquq*(Muls.) and Brumoides sp. (Fab.), one syrphid fly, *Episyrphus balteatus*, *Chrysopa* and one spider, *Oxyopes* sp. from brinjal ecosystem. Thus the results in the instant study are in conformity with Kumar *et al.* (2018) and Borkakati*et al,.* (2019). The difference in the species and number of species may be due to difference in the geographic location.

3.2 Seasonal incidence of insect pests in brinjal

Seasonal incidence of the important insect pests was recorded at weekly interval and the results are furnished in the following paragraphs.

Table 5. Incidence of sucking pest in brinjal field

Name of the sucking insects	Number of insects/ leaf																					Overall mean
	Standard meterological Weeks																					
	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21th	22nd	
Aphis gossypii	1.444	1.963	5.778	6.963	7.481	8.333	8.814	8.408	7.444	6.556	5.556	4.444	3.778	3.148	2.741	2.259	1.889	1.556	1.333	1.074	0.000	4.548
Thrips tabaci	1.222	1.444	1.444	1.519	1.814	2.297	2.926	3.000	2.592	2.222	1.852	1.519	1.222	0.926	0.703	0.556	0.481	0.370	0.481	0.481	0.000	1.454
Amrasca Biguttula biguttula	1.111	1.370	1.667	1.963	2.408	2.778	3.259	3.778	3.333	2.703	2.297	1.926	1.630	1.408	1.111	0.963	0.703	0.519	0.148	0.297	0.000	1.769
Bemasiatabaci	1.111	1.370	1.667	1.963	2.408	2.778	3.259	3.778	3.333	2.703	2.297	1.926	1.630	1.408	1.111	0.963	0.703	0.519	0.148	0.297	0.000	1.769

Table 6. Incidence of epilachna beetle and brinjal shoot and fruit borer in brinjal during 2020

Name of the insects	Number of insects/ no. of infested shoot/ fruit/ plant																					Overall mean
	Standard Weeks																					
	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21th	22nd	
H. vigintioctopunctata	1.00	1.67	2.00	2.00	3.00	3.00	3.00	2.67	0.67	1.00	2.00	1.00	1.67	2.67	3.67	5.67	6.67	5.00	5.00	6.33	6.00	3.13
L. orbonalis (shoot infestation)	0.00	0.00	0.00	2.33	5.33	6.67	8.00	5.33	3.33	2.33	1.33	0.33	3.33	3.67	4.00	3.00	2.00	3.00	4.00	4.00	3.67	3.13
L. orbonalis (fruit infestation)	0.00	0.00	0.00	0.00	4.00	5.67	6.00	3.67	2.00	1.00	0.67	0.00	3.33	3.67	4.67	3.67	2.67	3.67	5.00	4.67	4.33	2.79

Table 7. Incidence of natural enemies in brinjal during 2020

Name of the natural enemies	Number of natural enemies/ plant																					
	Standard Weeks																					
	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21th	22nd	Overall mean
Lady bird beetle*	2.33	3.67	4..00	4..67	4.67	5.00	6.33	6.67	6.67	7.00	7.33	4.00	4.67	4.67	5.67	6.00	6.67	6.67	7.00	7.33	8.67	5.48
Solenopsis sp.	0.00	2.00	0.00	0.00	0.00	3.67	0.00	0.00	0.00	3.00	0.00	2.00	0.00	0.00	0.00	0.00	1.00	3.67	0.00	2.00	0.00	0.83
Spider	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.67	0.00	1.00	0.00	2.00	0.35

Mixed population of Coccinellaseptempunctata and Menochilussexmaculatus

3.3 Cotton Aphid, *Aphis gossypii* Glover

The results furnished in Table 6 depict that the cotton aphid, *Aphis gossipii* first appeared in the field on 2nd week of January *i.e*. during 2nd standard week and remained present in the crop up to 22nd standard meterological week (last week of May) *i.e.* a total of 21 weeks. With an initial density of 1.45 aphids per leaf, the population of aphids gradually increased and attained the peak (8.81 aphid /leaf) on 8th standard week (i.e. 4th week of February) and there after, there was a gradually reduction in aphid population till 22nd standard week when the population density was no aphid per leaf. It was found that high level of aphid population persisted from 4th to 12th standard weeks *i.e.* 9 weeks (*i.e.* from 4th week of January to 3rd week of March).

3.4 Thrips, *Thrips tabaci*Linderman

It reveals from the results provided in Table 6 that incidence of thrips first occurred on 2nd standard week (2nd week of January) and their presence was noticed in the field upto 22nd standard week (i.e. last week of May). Thus they persisted in the field for a period of 21 weeks. Incidence of the thrips increased gradually from 2nd standard week up to 9th standard week (last week of February) when their maximum population was achieved and afterwards they maintained a gradual decrease in population and on the last date of observation on last week of May their population was very low (no aphid per leaf). Higher degree of incidence of the thrips was noted for a period of five weeks from 7th to 11th standard weeks.

3.5 Cotton jassid, *Amrasca biguttula biguttula* Ishida

As depicted from the results in Table 6, the jassids were first identified on the crop on 2nd standard week (2nd week of January) with a low population density of 1.12per leaf. The jassids were found to be active in the field upto 22nd standard week *i.e.* they were, active for a period of 21 weeks. Population of the leaf hoppers increased steadily from their first appearance and they reached the peak on 9th standard week (last week of February) with a population density of 3.78 per leaf. There after there was a gradual reduction in their population and they recorded their penultimate presence in the field till the last date of study with very low population (no jassid per leaf).

3.6 Cotton whitefly, *Bemisia tabaci* (Genn.)

The results on incidence of cotton whitefly are presented in Table 6. The results reveal that the cotton whitefly was first recorded from the field on 2nd standard week with initial density of 10 aphids per leaf and it persisted for 21 weeks till the last date of observation i.e. on 22nd standard week. A perusal of the data exhibits that the population of whitefly followed a steady increase from its first appearance till 9th standard week (last week of February) when it reached the peak (9/leaf). Thereafter the population started declining gradually till 20th standard week. It reveals that whitefly infestation level was moderately high for 9 weeks from 4th to 12th standard week when the population density of whitefly ranged from 1.67to2.23 per leaf

3.7 Epilachna beetle, *Henosepilachna vigintioctopunctata* Fab

Epilachna beetle was present in the field in its larval and adult stage as well and both the stages occurred concurrently in the field except for a few weeks.

The results exhibit that the insect first appeared in the field on 2nd standard week (2nd week of January) with a low population of 1.00 per plant and its activity increased thereafter and reached a peak on 6th standard week (3.00 insects per plant) and this peak population persisted for consecutive three weeks upto 8th standard week and afterwards the population went down gradually and reached a low density of 0.67 insects per plant on 10th standard week. then ,on there was a steady increase in their population which continued till the last week of the study i.e. 22nd standard week (last week of May) when their population was considerably high (6.00 per plant). It was noticed that there was a second peak population of the insect on 18th standard week (6.67 insects per plant).It reveals from the results that the epilachna beetle had two peak population. The mean number of adults and grubs ranged from 1.00 to 6.67 per plant during different weeks of the study and the mean no. of insects was 3.13 per plant.

3.8 Brinjal shoot and fruit borer, *Leucinodes orbonallis Guen*

Incidence of brinjal shoot and fruit borer was recorded from the shoots as well as fruits.

List 1. insect pests recorded in brinjal during 2020

Order	Family	Common name	Scientific name	Stage of crop & site of damage
Orthoptera	Acrididae	Short- horned grass-hopper	Hieroglyphus banian Fab.	Leaf
	Tettigonidae	Long- horned grass-hopper	Un- identified	Leaf
Diptera	Muscidae	Fruit fly	Un- identified	Fruit
Homoptera	Aphididae	Cotton aphid	Aphis giossypii	Leaf, shoot, flower bud, and leaf
Thysanoptera	Aleyrodidae	Cotton whitefly	Bemisia tabaci	Leaf
Coleoptera	Cooccinellidae	Epilachna beetle	Henosepilachna vigintioctopunctata	Leaf, shoot and fruit
	Chrysomelidae	Flea beetle	Phyllotreta sp.	leaf
	Chrysomelidae	Red pumkin beetle	Aulachophora foviecollis	leaf
Lepidoptera	Pyralidae	Brinjal Shoot and fruit borer	Leucinodes orbonalis	Shoot and fruit

The 6 different natural enemies were recorded from the field. Those were lady bird beetle, solenopsis sp, spiders.

A perusal of the results furnished in Table 7 shows that the shoot infestation first occurred on 5th standard week (1st week of February) and then with a gradual increasing trend the infestation level reached the peak on 8th standard week (4th week of February) (8 infested shot per plant). The infestation level showed a declining trend thereafter till 13th standard week and again it increased and reached the maximum on 16th standard week (4 infested shoots per plant) and afterwards the intensity was reduced to a little extent and further augmented for two consecutive weeks *viz*. 20th and 21st standard weeks with 4 infested shoots per plant each. Shoot infestation prolonged till 22nd standard week. Shoot infestation continued for 18 weeks.

Fruit damage by the insect was first recorded on 6th standard week and with an increasing trend thereafter the intensity of fruit damage reached the peak on 8th standard week (4th week of February) (6.00 infested fruits per plant). The degree of infestation showed a gradual reduction afterwards and became nought on 13th standard week. Later the infestation level increased and attained a second peak at the later part of the crop stage on 20th standard week (3rd week of May) (5 infested fruits per plant) and maintained its higher degree of activity till 22nd standard week. Altogether the fruit infestation persisted for 16 weeks.

Barring the grubs of epilachna beetle, all other insect pests were positively correlated with maximum temperature. Aphids, thrips and whiteflies had negative association with minimum temperature and rainfall. Maximum and minimum RH% was not favourable to aphids, thrips, whiteflies and brinjal shoot and fruit borer for its shoot infestation. Sunshine hours showed a positive correlation with aphids, thrips, whiteflies, leafhoppers and shoot infestation by brinjal shoot and fruit borer (Anonymous, 2010; Tiwari et al. 2011).

4. CONCLUSION

The present studies have given birth to a few notable findings and good information as well and there have been a few areas where future course of investigations could be done. Studies on the diversity of insect pests and natural enemies may be made in some other representative areas of terai zone if more number of species is available so that a comprehensive document will be available for the zone. During 8-9 standard weeks most of the insect pests had their peak period of activity. Similar studies in other seasons may also be tried so that the farmers could be provided a complete package of information for their management intervention.

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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