International Journal of Advanced Biochemistry Research 2024; SP-8(5): 99-108

International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; SP-8(5): 99-108
www.biochemjournal.com
Received: 15-02-2024
Accepted: 20-03-2024

Hubballi Aravinda
Department of Agricultural Entomology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

GT Shruthi
Department of Agricultural Entomology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

SN Nandini
Department of Agricultural Entomology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

AN Shylesha
Principal Scientist, ICAR-National Bureau of Agricultural Insect Resources, Bangaluru, Karnataka, India

TM Shivalingaswamy
Principal Scientist, ICAR-National Bureau of Agricultural Insect Resources, Bangaluru, Karnataka, India

Amit Umesh Paschapur
Scientist, Department of Entomology, ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora Uttarakhand, India

Corresponding Author:
Hubballi Aravinda
Department of Agricultural Entomology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

Benevolent battlers: Exploring the population dynamics of natural enemies in managing key sucking pests of okra

Hubballi Aravinda, GT Shruthi, SN Nandini, AN Shylesha, TM Shivalingaswamy and Amit Umesh Paschapur

DOI: https://doi.org/10.33545/26174693.2024.v8.i5Sb.1135

Abstract
Background: Okra also known as Lady's finger (*Abelmoschus esculentus* L. Moench) is an important vegetable crop. Among the pests menace, sucking pests are the most destructive and primary limiting factor in okra cultivation. This study probes into the crucial realm of insect natural enemies and their pivotal role in managing the prevalent sucking pests of Okra (*Abelmoschus esculentus* L. Moench). Sucking pests such as aphids, leafhoppers, and whiteflies instinct 54-66% economic damage and the crop cultivated during *Kharif* and summer seasons are more susceptible to insect infestation.
Results: In the present study, 17 species of predatory spiders, 11 species of coccinellids, 12 other predatory insects belonging to six orders and four species of hymenopterans were seen parasitizing on sucking pests of okra, which were morphologically characterized up to species level and their species dominance over a period of two years was assessed. A comprehensive assessment of natural enemy diversity and abundance was conducted using a variety of diversity indices, including Shannon-Wiener, Simpson's, Pielou's, and others. The diversity indices calculated for predatory spiders and coccinellids showed that all the species were evenly distributed and no single species was dominating the ecosystem during all three seasons. However, with respect to other predatory insects and parasitoids, a few individuals like Syrphids, *Geocoris* spp., *Pachyneuron aphidis* and *Aphytis* sp. dominated the okra crop and caused an imbalance in the diversity of other predators and parasitoids in the cropping system.
Conclusion: The significance of the study extends beyond agrarian systems, emphasizing the broader ecological role of natural enemies and promoting sustainable agricultural practices that harmonize with the ecosystem. Overall, this research advances our knowledge of bio-intensive pest management, advocating for the conservation and augmentation of biodiversity enhancing agricultural sustainability and ecological well-being.

Keywords: Okra (*Abelmoschus esculentus* L. Moench), sucking pests, natural enemies, predatory spiders, diversity indices, bio-intensive pest management

Introduction
Okra also known as Lady's finger (*Abelmoschus esculentus* L. Moench) is an important vegetable crop belonging to the Malvaceae family. It is grown commercially in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malaysia, Brazil, Ghana, Ethiopia and the Southern United States (Anonymous, 2010; Azo'o *et al*. 2011; Patil *et al*. 2013; Patil 2017) [5, 8, 5, 27]. Okra is cultivated globally in an area of 1.26 million ha with production and productivity of 22.29 million tonnes and 15.10 t/ha, respectively (Ray *et al*. 2020; Janu and Kumar, 2022) [16].
There are several constraints in the cultivation of okra; among them, pest menace is a major one (Kumawat *et al.*, 2000; Singh and Joshi, 2004; Singh *et al*., 2013; Ali *et al.*, 2016; Bhatt *et al*., 2018) [19, 43, 44, 1, 10]. Several species of insects have been recorded to infest okra plants (72 species), of which shoot and fruit borer (*Earias* spp.) Aphids (*Aphis gossypii* (Glover)) Leafhoppers (*Amrasca biguttula biguttula* (Ishida)) and Whiteflies (*Bemisia tabaci* (Gennadius)) cause considerable economic damage and are regarded as serious pests of okra in southern Indian states (Srinivas Rao and Rajendra, 2002; Anitha and Nandihalli, 2008; Deevaraj *et al.*, 2020) [45, 4, 13].
Among major insect pests, the sucking pests are the most destructive and primary limiting factor in okra cultivation with 23-54 percent of yield loss (Rai *et al*, 2014) [36].

The okra crop is mainly infested with leafhoppers and aphids which are important sucking pests in the early stage of the crop. They are capable of transmitting viral infections on several host plants, in addition to causing direct yield losses of 54-66% (Rai *et al*., 2014; Sanwal *et al*., 2016 and Kavinilavu *et al*., 2018) [36, 39, 18]. Whitefly is another important sucking pest, where, the nymphs and adults suck the cell sap and cause curling and drying of leaves, stunted growth of the plant. Whiteflies also act as vectors of the yellow vein mosaic virus of Okra, which leads to a yield loss of 50-90% (Mandal *et al.*, 2006; Rai *et al.*, 2014) [21, 36].

It is very important to mitigate the losses caused by major insect pests of okra and the most affordable and accessible technique is the use of toxic insecticides for immediate and effective pest control (Patil *et al*., 2014; Suman *et al*., 2021) [29, 46]. However, chemical pest management techniques are associated with several environmental hazards like residues in the crops, resistance development and resurgence of insect pests (Ansari *et al*., 2014; Maurya *et al*., 2022) [6, 24]. The studies conducted by Puvvala *et al*, (2020) [33] at Pesticide Residue and Food Quality Analysis Laboratory (PRFQAL), University of Agricultural Sciences, Raichur, Karnataka reported the presence of high amounts of residues of imidachloprid (6.7 ppm), thiomethoxam (3.8 ppm), flubendiamide (7.9 ppm), chlorantraniliprole (6.5 ppm) in the harvested okra fruits, which are far above the maximum residue limits (MRL).

The best alternative to tackling these pest problems is to develop a biocontrol strategy involving potential natural enemies which can be successfully incorporated into a sound Integrated Pest Management (IPM) program (Narayanan and Muthiah, 2017; Bhatt *et al*. 2018) [25, 10]. In this direction, several aphidophagous predators like *Coccinella septumpunctata*, *Coccinella transversalis*, *Menochilus sexmaculata*, *Harmonia axyridis* etc., have been identified as major natural regulatory factors in managing aphids, mites, whiteflies and other sucking pests (Satti and Bilal, 2012; Amin *et al*., 2019) [40, 2]. Moreover, the Hymenopteran parasitoids are potential biocontrol agents against several groups of sucking pests (Gandhi *et al*. 2019) [15]. Further, the knowledge of the diversity and abundance of these natural enemies is a pre-requisite for the successful implementation of bio-intensive Pest Management (IPM) program.

The studies conducted by Anbalagan *et al*., (2016) [3] on the diversity of natural enemies in okra at Kanchipuram and Tiruvallur districts of Tamil Nadu showed that a total of 129 species of predatory and parasitic insects were recorded in the study. Order Hymenoptera contained the highest number of parasitic insect species and the family Coccinellidae (ladybird beetles) was found to be the dominant group with the highest number of insect predators. Raghuwanshi *et al*., (2019) [34] studied the pest succession and incidence of insect pests and their natural enemies in okra. Their results revealed those insect pests and their natural enemies belonged to three orders (Hemiptera, Lepidoptera and Coleoptera) and six families (Cicadellidae, Aphididae, Aleyrodidae, Pyrrhocoridae, Noctuidae and Coccinellidae).

The utilization of diversity indices in the study of insect natural enemies is of paramount importance due to the nuanced insights they provide into the complexity of ecological systems (Thukral, 2017) [47]. These indices, such as the Shannon-Wiener index, Simpson's index of diversity, Pielou's evenness index, dominance index, Margalef Index, Menhinick's index, Fisher's alpha index, and Berger-Parker indices, offer quantitative measures of species richness, abundance distribution, and community evenness (Pathania *et al*., 2015) [26]. By applying these indices, researchers can gauge the stability, resilience, and overall health of natural enemy populations within agroecosystems. Moreover, these metrics enable the assessment of the impact of environmental changes, such as land use modifications or climate fluctuations, on the diversity and structure of natural enemy communities (Bhatt *et al*., 2018) [10]. Understanding the intricacies of diversity through these indices informs effective pest management strategies, underscores the significance of preserving biodiversity, and emphasizes the essential role of natural enemies in maintaining ecosystem balance and sustainable agriculture.

Considering the above insights, it was noticed that in the okra crop, the information on the diversity of natural enemies attacking sucking pests is very scarce. Therefore, the present investigations were made to assess the diversity of natural enemies of okra sucking pests, taxonomically identify them, estimate their species dominance in different cropping seasons and analyze various diversity indices in order to quantitatively characterize population dynamics over a period of two years (2019-2020) in the southern state of Karnataka, India.

Methods

Study location and crop cultivation

The documentation of diversity and abundance of the natural enemy complex of okra was carried out for three seasons during two consecutive years (2019 and 2020) at Attur research farm, ICAR-National Bureau of Agricultural Insect Resources, Bangalore, Karnataka (Latitude: 13.097221 Longitude:77.568291). Okra variety, Arka Nikita (IIHR) was sown in an area of 20x20 m^2 with 45x30 cm spacing on 1st October 2019 during *Rabi* season (40th standard meteorological week (SMW)), 1st January 2020 during summer season (1st SMW) and 2nd July 2020 during *Kharif* season (27th SMW). All the recommended agronomic practices were followed to raise the crop except plant protection measures.

Surveillance and monitoring of sucking pests and their natural enemies

To record the population dynamics of natural enemies attacking sucking pests of Okra crop, observations on 100 randomly selected plants were noted every 10th day interval during all three seasons. The sucking pests were classified according to Jasrotia (1999) [17], wherein, 5 to 10 percent damaged plants were considered as minor pests and more than 10 percent infestation was classified as major pests. Further, the identification of the insects up to species level was carried out at the Department of Entomology, GKVK, UAS, Bengaluru.

To study the dynamics of natural enemies, individual predators and parasitoids were counted manually through the absolute method of sampling, like, visual searching. The same 100 plants selected previously to record the insect pest population were sampled to monitor the natural enemy population during three seasons and at every 10th day interval. Further, the parasitized and sluggish or morbid specimens of insect pests from the selected 100 plants were collected from the field and maintained under laboratory conditions at 25±2 °C temperature and 65±5% relative humidity until the emergence of parasitoids from the insect host. The emerged parasitoids from the laboratory and other parasitoids and predators collected from the field were mounted and taxonomically characterized. The relative abundance of predators and parasitoids was worked out by the formula given by Rahaman *et al,* (2014) [35]. (Formula 1)

$$\text{Relative abundance of species A} = \frac{\text{Number of Species-A}}{\text{Total number of all species in the crop}} \times 100 \quad \text{-Formula 1}$$

Diversity indices and data analysis

For quantitative characterization of population dynamics of natural enemies in Okra crop, the data from all three seasons was pooled and diversity indices were calculated. The most commonly used diversity indices like Shannon-Wiener index, Simpson's index of diversity, Pielou's evenness index, dominance index, Margalef Index, Menhinick's index, Fisher's alpha index and Berger-Parker indices were calculated by the software Past 4.03 (version 2018). Detailed formulae of all the indices are furnished in Table 1.

Results

Population dynamics of sucking pests

The population dynamics of sucking pests in okra was estimated for three seasons and details are presented graphically (Fig 1a to 1c). In all three seasons, aphid (*Aphis gossypii*) was identified as the most dominant sucking pest with a population ranging from as high as 120.6 aphids/three leaves/plant during *Kharif* 2020 to as low as 93.71 aphids/three leaves /plant during summer 2020. Whereas, the population of whiteflies ranged between 12.86 whiteflies /three leaves/plant during *Rabi* 2019 to 27 Whiteflies /three leaves/plant during summer 2020. Thus, indicating the suitability of the summer season for the rapid multiplication of whiteflies. Moreover, the leafhoppers population ranged from 24.07 leafhoppers/three leaves/plant during the summer 2020 to 38.57 leafhoppers/three leaves/plant during *Kharif* 2020. These results indicate that *Kharif* season is ideal for the rapid multiplication of leafhoppers in okra.

Diversity and abundance of a natural enemy complex

The estimation of population dynamics of natural enemies of sucking pests infesting okra crops in the southern state of karnataka was carried out for three seasons. The predatory fauna included spiders, coccinellids, green lacewings, praying mantids and earwigs etc. Among parasitoids, the hymenopterans were the dominant group infesting the sucking pests of okra. The diversity and relative abundance of individual predators and parasitoids are elaborated in the following sections.

Diversity and relative abundance of predatory spiders

A total of 17 species of predatory spiders belonging to seven families were recorded in okra crop and they were taxonomically characterized (Table 2). Their relative abundance was calculated in three seasons and the data is furnished in table 3. The highest number of spiders was reported in *Kharif 2020* (1828) followed by the summer 2020 (1811) and *Rabi* 2019 (1504). In *Rabi*-2019, *Oxyopes naliniae* (11 spiders/10 plants) was the most dominant species with a species composition of 8.78%. Whereas, in summer-2020 and *Kharif-2020*, *Oxyopes pankaji* (10.92 spiders/10 plants) and *Pardosa* sp (12.25 spiders/10 plants) were the dominant ones, with species composition of 7.23% and 8.04% respectively. Moreover, the data on the population density of predatory spiders obtained during three seasons was pooled and various diversity indices were calculated (Table 4). The diversity indices showed that all 17 species of spiders were reported during all three seasons and they were evenly distributed throughout the cropping period of 120 days. Shannon diversity index (H), Evenness index, Margalef's index, equitability index and Menhinick's index concluded that no single species of spider is dominating the ecosystem and their population is evenly distributed in all three seasons.

Diversity and relative abundance of predatory coccinellids

11 species of coccinellids belonging to three sub-families were recorded (Table 5) and their relative abundance was calculated in three seasons (Table 6). The population density studies showed that the highest population was recorded in *Kharif* season (1158) followed by the summer season (1093) and the least population was in the *Rabi* season (968). *Coccinella transversalis* was the most dominant species in both the *Rabi* and *Kharif* seasons with a percent species composition of 11.78% and 11.57% respectively. Whereas, *Coccinella septempunctata* was the dominant species in the summer season with a percent species composition of 10.61%. Further, several diversity indices were calculated after pooling the data (Table 7). It was observed through various diversity indices that all 11 species of coccinellids were recorded in all three cropping seasons in Okra. The Shannon diversity index (H), Evenness index, Margalef's index, equitability index and Menhinick's index concluded that all the species were evenly distributed and no single species was dominating the ecosystem.

Diversity and relative abundance of other predators

A total of 12 other predatory insects belonging to six orders and 12 families were recorded (Table 8) and their relative abundance was calculated for three seasons (Table 9). The highest number of general predators was recorded in the *Kharif* season (309) followed by the *Rabi* season (230) and the summer season (177). Syrphids were the most dominant predators during *Rabi* (3.42 adults /10 plants) and summer season (2.75 adults /10 plants) with percent species dominance of 17.83% and 18.64% respectively. Whereas, in the *Kharif* season, *Geocoris* spp. (4.92 adults /10 plants) was the dominant species with and percent species composition of 19.09%. Further, the diversity indices of these predatory fauna were calculated and furnished in Table 10. The diversity indices like Evenness_e^H/S, Equitability (J) and Fisher-alpha index show the uneven distribution of predators in the okra crop. Moreover, the Dominance (D) index, Simpson (1-D), Shannon (H) values indicate that few species of predators are dominant and cause imbalance in the diversity of other predators in the ecosystem.

Diversity and relative abundance of parasitoids

Four species of hymenopterans belonging to four families were recorded to parasitize on sucking pests of Okra (Table 11). Their relative abundance was calculated for three seasons (Table 12), and it was observed that *Pachyneuron* *aphidis* was the most dominant parasitoid with 46.67% species composition in *Kharif* season, followed by 51.68% in *Rabi* season and 59.78% in the summer season. However, *Aphytis sp.* had the least species composition with less than 5% values in the *Kharif* and *Rabi* seasons and 5.43% in the summer season. The diversity indices of these parasitoids were calculated and values are furnished in Table 13. The diversity indices like Evenness_e^H/S, Equitability (J) and Fisher-alpha index show the uneven distribution of parasitoids in okra crop. Moreover, the Dominance (D) index, Simpson (1-D), Shannon (H) values indicate that few species of parasitoids dominated and caused an imbalance in the diversity of other predators in the ecosystem.

Discussion

Okra (*Abelmoschus esculentus* (L.) Moench) is an important vegetable crop cultivated throughout the world in tropical and sub-tropical climatic conditions (Azo'o *et al*. 2011; Patil *et al*. 2013; Patil 2017) [8, 28, 27]. The crop suffers from several biotic and abiotic constraints, during its entire cropping period. Among them, pest menace is a major one (Picanco, 2000) [30]. Sucking pests of okra are known to cause considerable economic loss along with acting as vectors of several viral diseases (Singh *et al*., 2013; Sanwal *et al*., 2016) [44, 39]. Authors like Preetha *et al*. (2009) [32], Sanwal *et al*. (2016) [39] and Kavinilavu *et al*. (2018) [18], extensively studied the impact of sucking pests like, *Amrasca biguttula biguttula, Aphis gossypii* and *Bemisia tabaci* on crop growth and yield. Our findings formed close corroboration with the studies of Anitha and Nandihalli (2008) [4] who reported, that the *Kharif* crop is more susceptible to attack by aphids. Moreover, Mani and Singh (2012) [22] and Deevaraj *et al.* (2020) [13] reported the severe incidence of leafhoppers and whiteflies in *Kharif* and summer seasons respectively in southern parts of India. These studies also formed close conformity with our results, thus indicating the seasonal incidence of sucking pests in the okra crop.

Natural enemies play an important role in maintaining the pest population density below economic threshold levels and reducing the economic damage caused by the pests (Raghuwanshi *et al*., 2019) [34]. Several authors like, Leite (2005), Ali *et al.* (2016) [1], Bhatt*et al*. (2018) [10] and Amin *et al*., (2019) [2], studied the population dynamics of predators and parasitoids in okra crop. Ali *et al.*, (2016) [1] reported that Aphid parasitoids (*Trioxys* spp., *Aphidius gifuensis*), Coccinellids and spiders were the key natural enemies of sucking pests in cotton. In Brazil, Leite (2005) [20] observed *Encarsia* sp. (Hymenoptera: Aphelinidae) parasitizing whiteflies on okra plants. Amin *et al*., (2019) [2] recorded natural enemies belonging to 50 families under eight different orders. Order Hymenoptera contained the highest number of families and species acting as parasitoids. Among the predators, Coccinellidae (ladybird beetles) was found to be the dominant group with the highest number of species. Similar results were recorded in our studies, wherein, 17 species of predatory spiders, 11 species of coccinellids, 12 other predatory insects belonging to six orders and four species of hymenopterans were seen parasitizing on sucking pests of okra.

Furthermore, studies of Sahito *et al.* (2013) [38] showed that four prominent predatory spider species like, *Hippa saagelenoides*, *Cheiracanthium danieli*, *Argyrodes argentatus* and *Drassodes sp*. were observed in okra, which was actively predating on sucking pests like Jassids, whiteflies, aphids and thrips. Similarly, in our studies, we observed *Oxyopes naliniae*, *Oxyopes pankaji* and *Pardosa* sp. actively predating on *A. biguttula biguttula, A.gossypii* and *B. tabaci.* Authors like Anbalagan *et al*. (2016) [3] reported the dominance of *Coccinella transversalis* (Fab.), *Cheilomenes sexmaculata* (Fab.), *Micraspis discolour* (Fab.) and *Anisolemnia dilatata* (Fab.) in okra and their voracious feeding habit on major sucking pests of okra. Gandhi *et al.* (2019) [15] also reported the presence of aphid-hunting wasp *Carinostigmus tsuneki* (Hymenoptera: Crabronidae: Pemphredoninae) in okra. Our studies also yielded similar results, wherein, coccinellids like, *Coccinella transversalis* and *Coccinella septempunctata* dominated the predatory guild and parasitoids like, *Pachyneuron aphidis* and *Aphytis sp.* dominated the parasitoid guild in the okra crop.

For quantitative characterization of the natural enemies in okra, a number of indices were assessed to calculate the diversity and abundance of predators and parasitoids of sucking pests infesting okra. The diversity indices calculated for predatory spiders and coccinellids showed that all the species were evenly distributed and no single species was dominating the ecosystem during all three seasons. However, with respect to other predatory insects and parasitoids, few individuals like, Syrphids, *Geocoris* spp., *Pachyneuron aphidis* and *Aphytis* sp. dominated in the okra field and caused imbalance in the diversity of other predators and parasitoids in the cropping system. Similar results were reported by several authors like, Amin *et al*., (2019) [2] reported the dominance of *Coccinella septempunctata* (25.8%) in okra, followed by ground beetles (13.8%) and *Chrysoperla* spp. (9.9%). Further, Satti and Bilal, (2012) [40] reported the dominance of *Hippodamia variegata*, *Chrysoperla zastrowi sillemi*, *Ischiodon aegyptium* and *Mantis* spp. in okra crop. They also observed that eggs of *Chrysoperla carnea* and syrphids were generally found laid among the immature stages of whitefly and the aphid colonies, respectively. Moreover, authors like Narayanan and Muthiah (2017) [25], Bhatt *et al*. (2018) [10], Raghuwanshi *et al*. (2019) [34], Deevaraj *et al.* (2020) [13] and Archunan and Pazhanisamy (2020) [7] suggested the use of these natural enemies for comprehensive bio-ecological studies to encourage the natural control of vegetable pests and minimize the need for chemical control.

Table 1: Alpha diversity indices used to estimate the population dynamics of the insect pests and natural enemies in bhendi crop

Alpha diversity index	Formula	Reference
Berger-Parker dominance index	Number of individuals in the dominant taxon relative to n.	Berger and Parker (1970) [9]
Brillouin's index	$= \frac{\mathrm{In}(n!) - \sum_i \mathrm{In}(n_i!)}{n}$	Brillouin (1962) [11]
Chao-1 index	$= S + \left(\frac{n-1}{n}\right)\frac{F_1^2}{2F_2}$	Chao (1984) [12]
Dominance	$= \sum_i \left(\frac{n_i}{n}\right)^2$	Simpson (1949) [42]
Fisher's alpha diversity index	$=\alpha * \mathrm{In}(1+n/\alpha)$	Fisher *et al.* (1943) [14]
Margalef's richness index	$= (S-1)/\mathrm{In}(n)$	Margalef (1958) [23]
Menhinick's richness index	$= \frac{S}{\sqrt{n}}$	Whittaker (1977) [48]
Pielou's evenness index	$= \frac{H}{H_{max}}$	Pielou (1975) [31]
Shannon diversity index	$H = -\Sigma pi * \ln(pi)$	Shannon (1948) [41]
Simpson's diversity index	$D = \frac{1 - \Sigma\, n(n-1)}{N(N-1)}$	Simpson (1949) [42]

Where, n: number of individuals, n_i: number of individuals of taxon i, S: number of taxa, F_1: number of singleton species, F_2: number of doubleton species, α: Fisher's alpha, H: Shannon index, H_{max}: logarithm of number of taxa and D: dominance

Table 2: Predatory Spider fauna in bhendi fields at NBAIR Attur farm during 2019-20

Sl. No	Family	Predatory spider species
1	OxyopidaeThorell,1870 (Lynx spiders)(4)*	*Oxyopes hindostanicus* (Pocock, 1901)
2		*Peucetia* sp (Thorell, 1869)
3		*Oxyopes naliniae* (Gajbe, 1999)
4		*Oxyopes pankaji* (Gajbe & Gajbe,2000)
5	Cheiracanthiidae (2)*	*Cheiracanthium approximatum* (O.Pickard-Cambridge, 1885)
6		*Cheiracanthium* sp (C. L. Koch, 1839.)
7	Thomisidae Sundevall, 1833 (2)*	*Thomisus* sp (Walckenaer, 1805)
8		*Runcinia* sp (Simon, 1875)
9	Salticidae Blackwall, 1841 (Jumping spiders) (3)*	*Rhene flavigera* (Koch 1846)
10		*Phintella* sp (Strand, 1906)
11		*Myrmarachne* sp(MacLeay, 1839)
12	Araneidae Simon, 1895 (1)*	*Neoscona* sp(E. Simon, 1864)
13	Lycosidae Sundevall,1833 (3)*	*Pardosa* sp (C. L. Koch, 1847)
14		*Draposa lyrivulva* (Bösenberg& Strand, 1906)
15		*Lycosa* sp (Latreille, 1804)
16		*Draposa* sp (Kronestedt, 2010)
17	Theridiidae Sundevall,1833 (1)*	*Chrysso* sp

Note:* Values in parentheses are total number of species in that group

Table 3: Relative abundance of predatory spiders in bhendi crop at NBAIR Attur farm during three cropping season

Predatory spiders species	***Kharif*- 2020**			***Rabi*- 2019**			**Summer- 2020**		
	Total	**Mean±SD (Per 10 plants)**	**% SC**	**Total**	**Mean±SD (Per 10 plants)**	**% SC**	**Total**	**Mean±SD (Per 10 plants)**	**% SC**
Cheiracanthium approximatum O. Pickard-Cambridge, 1885.	122	10.17±2.12	6.67	75	6.25±2.09	4.99	98	8.17±1.90	5.41
Cheiracanthium sp C. L. Koch, 1839.	137	11.42±1.73	7.49	101	8.42±1.38	6.72	120	10.00±1.41	6.63
Draposa lyrivulva (Bösenberg& Strand, 1906)	127	10.58±1.93	6.95	94	7.83±1.90	6.25	122	10.17±1.59	6.74
Draposa sp Kronestedt, 2010	125	10.42±1.78	6.84	92	7.67±1.92	6.12	114	9.50±1.62	6.29
Lycosa sp Latreille, 1804	129	10.75±2.05	7.06	82	6.83±1.95	5.45	112	9.33±1.78	6.18
Myrmarachne sp MacLeay, 1839	48	4.00±2.13	2.63	37	3.08±1.16	2.46	45	3.75±1.36	2.48
Neoscona sp E. Simon, 1864	100	8.33±1.87	5.47	80	6.67±1.44	5.32	90	7.50±1.68	4.97
Oxyopes hindostanicus Pocock, 1901	125	10.42±1.44	6.84	112	9.33±1.30	7.45	111	9.25±1.96	6.13
Oxyopes naliniae Gajbe, 1999	130	10.83±1.40	7.11	132	11.00±1.41	8.78	118	9.83±1.59	6.52
Oxyopes pankaji Gajbe& Gajbe,2000	137	11.42±1.62	7.49	125	10.42±1.51	8.31	131	10.92±1.38	7.23
Pardosa sp C. L. Koch, 1847	147	12.25±1.66	8.04	126	10.50±1.45	8.38	114	9.50±1.45	6.29
Peucetia sp Thorell, 1869	82	6.83±1.95	4.49	60	5.00±2.04	3.99	107	8.92±1.38	5.91
Phintella sp Strand, 1906[	55	4.58±1.56	3.01	67	5.58±1.88	4.45	87	7.25±2.09	4.80
Rhene flavigera, Koch 1846	79	6.58±2.02	4.32	61	5.08±2.35	4.06	86	7.17±2.44	4.75
Runcinia sp Simon, 1875	61	5.08±1.93	3.34	64	5.33±1.97	4.26	88	7.33±1.61	4.86
Thomisus sp Walckenaer, 1805	56	4.67±1.30	3.06	62	5.17±2.37	4.12	85	7.08±1.51	4.69
Chrysso sp	96	8.00±2.00	5.25	74	6.17±1.99	4.92	99	8.25±0.87	5.47
Others	72	6.00±1.35	3.94	60	5.00±2.00	3.99	84	7.00±1.60	4.64
Total	1828		100.00	1504		100.00	1811		100.00

% SC: percent Species composition, SD: Standard deviation

Table 4: Various diversity indices of predatory spiders in bhendi crop during 2019-2020 (Pooled data of three seasons)

Diversity Indices	Month 1 (0-30 days)			Month 2 (30-60 days)			Month 3 (60-90 days)			Month 4 (90-120 days)		
	10th day	20th day	30th day	10th day	20th day	30th day	10th day	20th day	30th day	10th day	20th day	30th day
Taxa_S	18	18	18	18	18	18	18	18	18	18	18	18
Individuals	388	391	414	446	439	433	440	466	423	427	422	454
Dominance_D	0.064	0.062	0.063	0.061	0.062	0.063	0.062	0.062	0.063	0.063	0.063	0.061
Simpson_1-D	0.936	0.938	0.937	0.939	0.938	0.937	0.938	0.938	0.937	0.937	0.937	0.939
Shannon_H	2.807	2.827	2.821	2.841	2.827	2.823	2.819	2.821	2.820	2.821	2.822	2.839
Evenness_e^H/S	0.920	0.939	0.933	0.952	0.939	0.936	0.932	0.933	0.933	0.933	0.935	0.950
Brillouin	2.572	2.590	2.595	2.626	2.611	2.604	2.604	2.615	2.597	2.600	2.600	2.627
Menhinick	1.586	1.584	1.537	1.480	1.492	1.506	1.489	1.447	1.528	1.514	1.523	1.466
Margalef	3.499	3.497	3.454	3.402	3.413	3.426	3.410	3.372	3.445	3.434	3.441	3.389
Equitability_J	0.971	0.978	0.976	0.983	0.978	0.977	0.975	0.976	0.976	0.976	0.977	0.982
Fisher_alpha	5.694	5.693	5.545	5.375	5.409	5.457	5.400	5.279	5.524	5.478	5.503	5.332
Berger-Parker	0.091	0.088	0.092	0.080	0.089	0.089	0.087	0.084	0.088	0.093	0.088	0.084
Chao-1	18	18	18	18	18	18	18	18	18	18	18	18

Table 5: Predatory Coccinellid fauna recorded in bhendi crop at NBAIR Attur farm during 2019-20

Sl. No	Family and subfamily	Predatory Coccinellids species
1	Coccinellidae: Coccinellinae (7)*	*Coccinella septempunctata* (Linnaeus, 1758)
2		*Coccinella transversalis* (Fabricius, 1781)
3		*Harmonia octomaculata* (Fabricius, 1781)
4		*Coccinella undecimpunctata* (Linnaeus, 1758)
5		*Cheilomenes sexmaculata* (Fabricius, 1781)
6		*Propylea* Sp (Mulsant, 1846)
7		*Coelophora bissellata* (Mulsant, 1850)
8	Coccinellidae: Chilocorinae (1)*	*Brumoides suturalis* (Fabricius, 1789)
9	Coccinellidae: Scymninae (3)*	*Pseudaspidimerus trinotatus* (Thunberg, 1781)
10		*Scymnus castaneus* (Sicard 1929)
11		*Scymnus latemaculatus* (Motschulsky, 1858)

Note:* Values in parentheses are the total number of species in that group

Table 6: Relative abundances of predatory coccinellids in bhendifield during three cropping seasons

Predatory coccinellid species	*Kharif*			*Rabi*			Summer		
	Total	Mean± SD (Per 10 plants)	% SC	Total	Mean± SD (Per 10 plants)	% SC	Total	Mean±SD (Per 10plants)	% SC
Coccinella septempunctata (Linnaeus, 1758)	130	10.83±1.19	11.23	112	9.33±1.78	11.57	116	9.67±1.15	10.61
Coccinella transversalis Fabricius, 1781	134	11.17±2.08	11.57	114	9.50±1.88	11.78	115	9.58±1.31	10.52
Harmonia octomaculata (Fabricius, 1781)	117	9.75±1.76	10.10	100	8.33±1.97	10.33	115	9.58±1.16	10.52
Coccinella undecimpunctata (Linnaeus, 1758)	100	8.33±1.37	8.64	93	7.75±1.60	9.61	112	9.33±2.53	10.25
Cheilomenes sexmaculata Fabricius, 1781	124	10.33±1.61	10.71	110	9.17±1.40	11.36	115	9.58±1.88	10.52
Propylea Sp Mulsant, 1846	98	8.17±1.11	8.46	74	6.17±1.64	7.64	96	8.00±2.09	8.78
Coelophora bissellata Mulsant, 1850	70	5.83±1.34	6.04	50	4.17±1.03	5.17	36	3.00±1.54	3.29
Brumoides suturalis (Fabricius, 1789)	117	9.75±1.60	10.10	82	6.83±1.80	8.47	101	8.42±0.90	9.24
Pseudaspidimerus trinotatus (Thunberg, 1781)	54	4.50±1.51	4.66	65	5.42±1.51	6.71	70	5.83±1.85	6.40
Scymnus castaneus Sicard 1929	75	6.25±1.60	6.48	64	5.33±1.44	6.61	81	6.75±1.60	7.41
Scymnus latemaculatus Motschulsky, 1858	60	5.00±1.41	5.18	56	4.67±1.23	5.79	69	5.75±1.22	6.31
Others	79	6.58±1.68	6.82	48	4.00±0.74	4.96	67	5.58±2.07	6.13
Total	1158		100.00	968		100.00	1093		100.00

SC: Species composition, SD: Standard deviation

Table 7: Various diversity indices of predatory coccinellids in bhendi crop during 2019-2020 (Pooled data of three seasons)

Diversity Indices	Month 1 (0-30 days)			Month 2 (30-60 days)			Month 3 (60-90 days)			Month 4 (90-120 days)		
	10th day	20th day	30th day	10th day	20th day	30th day	10th day	20th day	30th day	10th day	20th day	30th day
Taxa_S	12	12	12	12	12	12	12	12	12	12	12	12
Individuals	245	260	256	263	287	260	255	278	275	285	277	278
Dominance_D	0.094	0.093	0.092	0.094	0.092	0.094	0.097	0.092	0.092	0.092	0.092	0.093
Simpson_1-D	0.906	0.907	0.908	0.906	0.908	0.906	0.903	0.908	0.908	0.908	0.908	0.907
Shannon_H	2.420	2.427	2.430	2.416	2.433	2.417	2.399	2.432	2.428	2.423	2.429	2.417
Evenness_e^H/S	0.937	0.944	0.947	0.934	0.949	0.935	0.918	0.948	0.945	0.940	0.945	0.934
Brillouin	2.184	2.201	2.200	2.191	2.223	2.192	2.173	2.216	2.211	2.213	2.212	2.203
Menhinick	1.331	1.290	1.306	1.289	1.227	1.293	1.304	1.250	1.258	1.234	1.257	1.249
Margalef	2.502	2.466	2.480	2.465	2.413	2.469	2.478	2.431	2.438	2.418	2.437	2.431
Equitability_J	0.974	0.977	0.978	0.972	0.979	0.973	0.966	0.979	0.977	0.975	0.977	0.973
Fisher_alpha	3.892	3.782	3.829	3.785	3.627	3.794	3.819	3.684	3.704	3.644	3.704	3.681
Berger-Parker	0.143	0.135	0.133	0.136	0.129	0.127	0.142	0.126	0.131	0.120	0.120	0.123
Chao-1	12	12	12	12	12	12	12	12	12	12	12	12

Table 8: Other predatory fauna recorded in bhendicropat NBAIR Attur farm during 2019-20

Sl no	Other predatory species	Taxonomic position	
		Order	Family
	Geocoris sp.	Hemiptera	Geocoridae (1)*
	Lisarda uniformis Distant, 1903		Reduviidae (1)*
	Campyloneura sp		Mirridae (1)*
	Orius sp		Anthocoridae (1)*
	Eocanthecona furcellata Wolf, 1811		Pentatomidae (1)*
	Creobroter apicalis Saussure, 1869	Mantodea	Hymenopodidae (2)*
	Euantissa sp		
	Pantala flavescens Fabricius, 1798	Odonata	Libellulidae (1)*
	Chrysoperla spp.	Neuroptear	Chrysopidae (1)*
	Earwig	Dermaptera	Dermaptera (1)*
	Robber fly	Diptera	Asilidae (1)*
	Syrphid fly		Syrphidae (1)*

Note: ( )* values in parentheses are total number of species in that group

Table 9: Relative abundances of other predatory insects in bhendifield during three cropping seasons

Other predatory fauna	*Kharif*			*Rabi*			Summer		
	Total	Mean± SD (Per 10 plants)	% SC	Total	Mean± SD (Per 10 plants)	% SC	Total	Mean± SD (Per 10 plants)	% SC
*Geocoris*sp.	**59**	**4.92±156**	**19.09**	31	2.58±1.38	13.48	16	1.33±1.15	9.04
Lisardauniformis Distant,1903	15	1.25±0.97	4.85	11	0.92±0.67	4.78	8	0.67±0.65	4.52
*Orius*sp	20	1.67±1.15	6.47	8	0.67±0.65	3.48	7	0.58±0.67	3.95
Eocantheconafurcellata Wolf, 1811	13	1.08±1.08	4.21	8	0.67±0.65	3.48	8	0.67±0.78	4.52
Creobroterapicalis Saussure,1869	14	1.17±1.34	4.53	12	1.00±1.04	5.22	9	0.75±0.97	5.08
Euantissasp	9	0.75±1.06	2.91	7	0.58±0.79	3.04	7	0.58±0.67	3.95
Pantalaflavescens Fabricius,1798	56	4.67±2.39	18.12	33	2.75±1.54	14.35	33	2.75±2.30	18.64
Chrysoperla spp.	29	2.42±1.68	9.39	22	1.83±1.47	9.57	14	1.17±0.94	7.91
Earwig	13	1.08±1.08	4.21	13	1.08±1.00	5.65	14	1.17±1.19	7.91
Robber fly	12	1.00±1.41	3.88	17	1.42±1.24	7.39	13	1.08±1.16	7.34
Syrphid fly	36	3.00±2.09	11.65	41	3.42±2.43	17.83	33	2.75±2.70	18.64
other	33	2.75±1.91	10.68	27	2.25±0.97	11.74	15	1.25±1.06	8.47
Total	309		100.00	230		100.00	177		100.00

SC: Species composition, SD: Standard deviation

Table 10: Various diversity indices of other predatory insects in bhendi crop during 2019-2020 (Pooled data of three seasons)

Diversity Indices	Month 1 (0-30 days)			Month 2 (30-60 days)			Month 3 (60-90 days)			Month 4 (90-120 days)		
	10th day	20th day	30th day	10th day	20th day	30th day	10th day	20th day	30th day	10th day	20th day	30th day
Taxa_S	5	6	8	9	10	8	9	9	10	7	10	8
Individuals	40	42	52	63	78	58	62	69	75	63	64	50
Dominance_D	0.313	0.226	0.183	0.146	0.133	0.159	0.149	0.147	0.134	0.201	0.138	0.162
Simpson_1-D	0.687	0.774	0.817	0.854	0.867	0.841	0.851	0.853	0.866	0.800	0.862	0.838
Shannon_H	1.400	1.615	1.840	2.043	2.166	1.948	2.043	2.052	2.151	1.744	2.115	1.944
Evenness_e^H/S	0.777	0.860	0.837	0.875	0.850	0.890	0.861	0.870	0.863	0.845	0.862	0.878
Brillouin	1.029	1.213	1.387	1.568	1.722	1.497	1.587	1.620	1.715	1.390	1.639	1.455
Menhinick	1.516	1.625	1.899	2.039	2.057	1.889	1.997	1.913	1.998	1.527	2.123	2.017
Margalef	1.732	1.917	2.399	2.702	2.893	2.436	2.658	2.585	2.794	1.967	2.862	2.549
Equitability (J)	0.837	0.915	0.913	0.939	0.930	0.944	0.931	0.936	0.936	0.912	0.933	0.937
Fisher_alpha	4.345	4.820	6.252	7.030	6.774	6.594	6.267	5.911	6.195	3.704	7.394	7.319
Berger-Parker	0.457	0.312	0.273	0.225	0.213	0.241	0.250	0.240	0.239	0.270	0.213	0.267
Chao-1	6.611	11.167	9.917	9.922	11.943	9.733	10.750	9.900	10.713	7.611	17.167	9.983

Table 11: Hymenopteran parasitoids parasitizing on sucking pests ofbhendicrop at NBAIR Attur farm during 2019-20

1.	*Carinostigmus costatus Krombein*, 1984	Adult &Nympal parasitoids	Crabronida**e**(1)
2.	*Aphytis* sp.	Egg&Nympal parasitoids	Aphelinidae(1**)**
3.	*Tetrastichinae* sp	Pupal parasitoid	Eulophidae (1**)**
4.	*Pachyneuron aphidis*	Hyperparasitoid	Pteromalidae (1**)**

Note: ( )* values in parentheses are total number of species in that group

Table 12: Relative abundances of hymenopteran parasitoids in bhendi field during three cropping seasons

Hymenopteran parasitoid/ predatory species	*Kharif*			*Rabi*			Summer		
	Total	Mean± SD (Per 10 plants)	% SC	Total	Mean± SD (Per 10 plants)	% SC	Total	Mean± SD (Per 10 plants)	% SC
Carinostigmus costatus Krombein, 1984	52	4.33±1.78	21.67	23	1.92±1.38	12.92	14	1.17±1.19	15.21
Aphytis sp.	10	0.83±0.83	4.16	7	0.58±0.67	3.93	5	0.42±0.51	5.43
Tetrastichinae sp	66	5.50±1.45	27.50	56	4.67±1.87	31.46	18	1.50±1.17	19.56
Pachyneuron aphidis	112	9.33±2.35	46.67	92	7.67±4.05	51.68	55	4.58±3.40	59.78
Total	240		100.00	178		100.00	92		100.00

Table 13: Various diversity indices hymenopteran parasitoidsin bhendi crop during 2019-2020 (Pooled data of three seasons)

Diversity Indices	Month 1 (0-30 days)			Month 2 (30-60 days)			Month 3 (60-90 days)			Month 4 (90-120 days)		
	10th day	20th day	30th day	10th day	20th day	30th day	10th day	20th day	30th day	10th day	20th day	30th day
Taxa_S	4	4	4	4	4	4	4	4	4	4	4	4
Individuals	54	54	36	35	47	57	32	48	32	51	40	24
Dominance_D	0.0782	0.0720	0.1019	0.1314	0.1172	0.1628	0.1191	0.1076	0.0938	0.1142	0.1188	0.1458
Simpson_1-D	0.9218	0.928	0.8981	0.8686	0.8828	0.8372	0.8809	0.8924	0.9063	0.8858	0.8813	0.8542
Shannon_H	2.769	2.82	2.561	2.338	2.435	2.214	2.41	2.56	2.617	2.501	2.322	2.163
Evenness_e^H/S	0.797	0.7987	0.7615	0.7398	0.7138	0.5722	0.742	0.7186	0.8059	0.6774	0.7845	0.7903
Brillouin	2.321	2.358	2.055	1.897	2.037	1.888	1.919	2.126	2.062	2.094	1.937	1.692
Menhinick	2.722	2.858	2.833	2.366	2.334	2.119	2.652	2.598	3.005	2.521	2.055	2.245
Margalef	4.763	5.014	4.465	3.656	3.896	3.71	4.04	4.391	4.617	4.324	3.253	3.147
Equitability_J	0.9243	0.9262	0.9038	0.8858	0.8784	0.7987	0.8898	0.8857	0.9239	0.8653	0.9054	0.9019
Fisher_alpha	11.49	12.62	12.59	8.648	8.55	7.391	11.01	10.46	14.72	9.915	6.692	7.859
Berger-Parker	0.1667	0.1481	0.2222	0.2857	0.234	0.3158	0.25	0.2292	0.2188	0.2353	0.225	0.2917
Chao-1	4	4	4	4	4	4	4	4	4	4	4	4

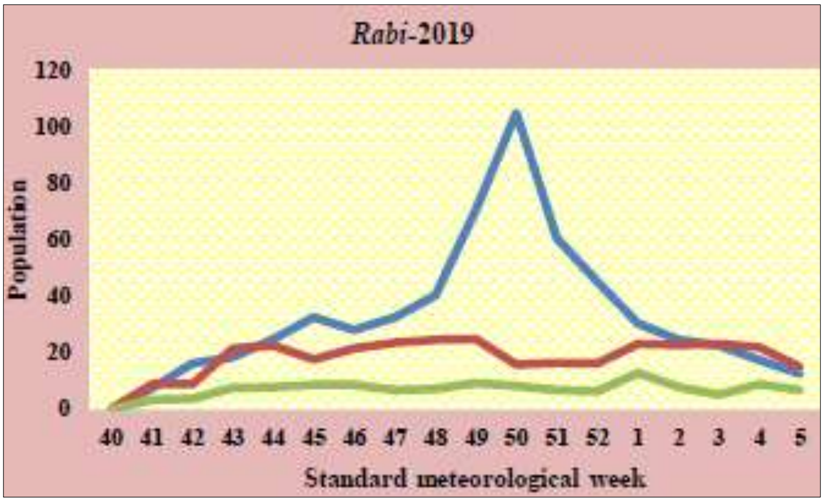

Fig 1a: Population dynamic of sucking pets of bhendi during Rabi-2019

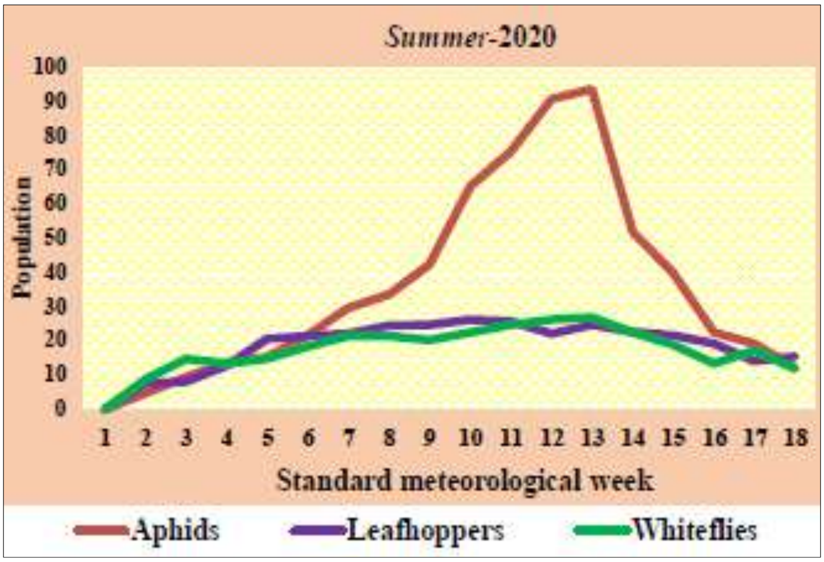

Fig 1B: Population dynamic of sucking pets of bhendi during summer-2020

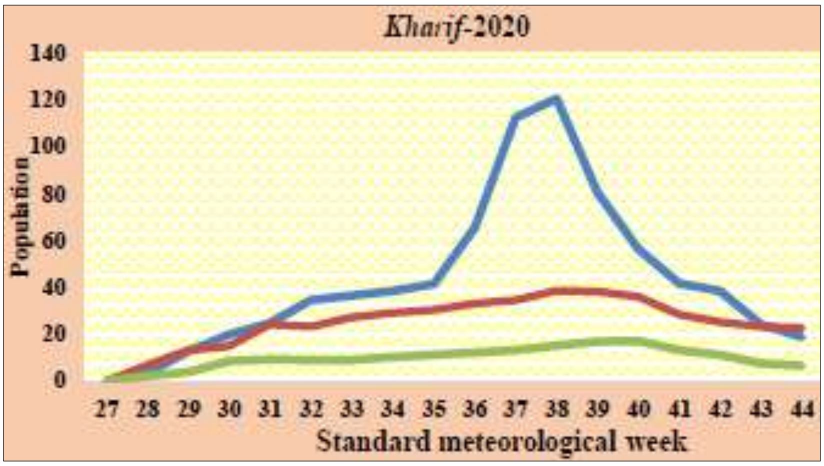

Fig 1c: Population dynamic of sucking pets of bhendi during Kharif-2020

Conclusion

In conclusion, this research sheds light on the intricate population dynamics of natural enemies and their role in effectively managing key-sucking pests of okra. Through rigorous field investigations and comprehensive data analysis, we have elucidated the multifaceted interactions among the various organisms within this agroecosystem. The findings underscore the significance of maintaining a balanced and bio-diverse environment to promote the natural enemies' population and enhance their pest control services. By elucidating the mechanisms driving the success of these benevolent battlers, our study provides valuable insights for sustainable pest management strategies that minimize the reliance on chemical interventions. As we navigate the challenges of modern agriculture, harnessing the potential of these natural predators stands as a promising avenue for promoting both ecological health and crop productivity. This research not only contributes to our understanding of integrated pest management but also highlights the importance of preserving and enhancing biodiversity for the betterment of agricultural systems and the broader ecosystem.

References

1. Ali A, Desneux N, Lu Y, Liu B, Wu K. Characterization of the natural enemy community attacking cotton aphid in the Bt cotton ecosystem in Northern China. Scientific Reports. 2016;6:24273.
2. Amin MR, Tripura K, Miah MRU, Kayesh E, Khan MAR. Diversity of insects in okra Agro-ecosystem at Gazipur in Bangladesh. Indian Journal of Ecology. 2019;46(1):214-216.
3. Anbalagan V, Paulraja MG, Ignacimuthua S, Baskara SC, Gunasekaran J. Natural enemy (Arthropoda-Insecta) biodiversity in vegetable crops in Northeastern Tamil Nadu, India. International Letters of Natural Sciences. 2016;53:28-33.
4. Anitha KR, Nandihalli BS. Utilization of botanicals and mycopathogens in the management of sucking pests of okra. Karnataka Journal of Agricultural Sciences. 2008;21(2):231-233.
5. Anonymous. Biology of okra. Department of Biotechnology, Ministry of Science and Technology, Government of India; c2010. p. 29.
6. Ansari MS, Moraiet MA, Ahmad S. Insecticides: impact on the environment and human health. In: Environmental deterioration and human health: natural and anthropogenic determinants; c2014. p. 99-123.
7. Archunan K, Pazhanisamy M. Field Evaluation of biorational insecticides against shoot and fruit Borer *Earias vittella* (Fabricious) on Okra. Plant Archives. 2020;20:2587-2590.
8. Azo'o ME, Fohouo FNT, Messi J. Influence of the Foraging Activity of the Entomofauna on Okra (*Abelmoschus esculentus*) Seed Yield. International Journal of Agricultural Biology. 2011;13(5):761-765.
9. Berger WH, Parker FL. Diversity of planktonic foraminifera in deep-sea sediments. *Science*. 1970;168(3937):1345-1347.
10. Bhatt B, Joshi S, Karnatak AK. Biodiversity of insect pests and their predators on okra agroecosystem. Journal of Pharmacognosy and Phytochemistry. 2018;7:84-86.
11. Brillouin L. Science and information theory. Academic Press, New York; c1962.
12. Chao A. Non parametric estimation of the number of classes in a population. Scandinavian Journal of Statistics. 1984;11:265-270. Available from: http://www.jstor.org/stable/4615964.
13. Deevaraja NS, Ashoka J, Sreenivas AG, Aswathanarayana DS. Seasonal incidence of insect pests of okra. International Journal of Chemical Studies. 2020;8(4):223-226.
14. Fisher RA, Corbet AS, Williams CB. The relation between the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology. 1943;12:42-58. https://doi.org/10.2307/1411.
15. Gandhi GR, Srinivasa MK, Venkatesan T. New Record of *Carinostigmus* Tsuneki (Hymenoptera: Crabronidae: Pemphredoninae) species in India and identity of its species using DNA barcoding. Journal of Biological Control. 2019;33(1):70-75.
16. Janu R, Kumar A. Field efficacy of selected insecticides against okra shoot and fruit borer *Earias vittella* (Fabricius). Journal of Pharmaceutical Innovation. 2022;11(4):1549-1551.
17. Jasrotia P. Insect-pest complex of cabbage and their management. M.Sc. Thesis. Himachal Pradesh Krishi Vishvavidyalaya, Palampur; c1999.
18. Kavinilavu M, Vishnupriya R, Chitra N. Population Dynamics of Sucking Pests on Okra, *Abelmoschus*

esculentus L. (Moench). Madras Agricultural Journal. 2018;105(March):1-3.
19. Kumawat RL, Pareek BL, Meena BL. Seasonal incidence of jassid and whitefly on okra and their correlation with abiotic factors. Annals of Biology. 2000;16(2):167-169.
20. Leite GLD. Whitefly population dynamics in okra plantations. Pesquisa Agropecuaria Brasileira. 2005;40:19-25.
21. Mandal SR, Sah SB, Gupta SC. Efficacy and economics of biopesticide and insecticide combinations against okra pests. International Journal of Agriculture Sciences. 2006;2(2):377-380.
22. Mani, Singh. Pest complex of okra and population dynamics under Bundelkhand region, Uttar Pradesh. Annals of Plant Protection Sciences. 2012;20(2):314-317.
23. Margalef R. Temporal succession and spatial heterogeneity in natural phytoplankton. In: Perspectives in Marine Biology; c1958. p. 323-349.
24. Maurya RP, Koranga R, Samal I, Chaudhary D, Paschapur AU, Sreedhar M, *et al*. Biological control: A global perspective. International Journal of Tropical Insect Science. 2022;42(5):3203-3220.
25. Narayanan US, Muthiah C. *In vivo* screening of okra (*Abelmoschus esculentus* L.) germplasm collections against sucking pests. Electronic Journal of Plant Breeding. 2017;8(1):187-192.
26. Pathania M. Diversity and population dynamics of phytophagous scarabaeid beetles (Coleoptera: Scarabaeidae) in different landscapes of Himachal Pradesh, India. Arthropods. 2015;4(2):46.
27. Patil PD. Pollination biology of okra (*Abelmoschus esculentus* L. Moench). International Journal of Advanced Innovative Research. 2017;4(1):109.
28. Patil P, Malik SKK, Negi S, John J, Yadav S, Chaudhari G, *et al*. Pollen germination characteristics, pollen-pistil interaction and reproductive behaviour in interspecific crosses among *Abelmoschus esculentus* Moench and its wild relatives. Grana. 2013;52(1):1-14.
29. Patil SR, Lande GK, Awasthi NS, Barkhade UP. Effect of different doses of newer insecticides against sucking pests of okra. The Bioscan. 2014;9(4):1597-1600.
30. Picanco MC. Manejo integrado de pragas de hortalicas. In: ZAMBOLIM, L. Manejo integrado - doencas, pragas e plantas daninhas. Viçosa: UFV; c2000. p. 275-324.
31. Pielou EC. Ecological Diversity. Wiley & Sons, New York; c1975.
32. Preetha G, Manoharan T, Stanley J, Kuttalam S. Persistent Toxicity of IMIDACLOPRID 17.8 SL TO APHID, *Aphis gossypii* Glover and Leafhopper, *Amrasca biguttula biguttula* Ishida in Okra. Pest management in horticultural ecosystems. 2009;15(2):121-125.
33. Puvvala VR, Emmanuel N, Hemadri T. Determination of pesticide residue levels in okra (*Abelmoschus esculentus* (L.) Moench) plots by LC-MS/MS. Journal of Pharmacognosy and Phytochemistry. 2020;9(4):1002-1007.
34. Raghuwanshi PK, Singh UC, Bhadoria NS, Tomar SPS, Bharti OP. Succession and incidence of insect pests and their natural enemies in okra. International Journal of Current Science. 2019;7(5):4442-4445.
35. Rahaman MM, Islam KS, Jahan M, Mamun MAA. Relative abundance of stem borer species and natural enemies in rice ecosystem at Madhupur, Tangail, Bangladesh. Journal of Bangladesh Agricultural University. 2014;12(2):267–272.
36. Rai AB, Loganathan M, Jaydeep Halder V, Venkataravanappa, Prakash SN. Eco-friendly Approaches for Sustainable Management of Vegetable Pests. IIVR Technical Bulletin No. 53, IIVR, Varanasi; c2014. p.104.
37. Ray A, Ray R, Sreevidya EA. How many wild edible plants do we eat—Their diversity, use, and implications for sustainable food system: An exploratory analysis in India. Frontiers in Sustainable Food Systems. 2020;4:56.
38. Sahito HA, Talpur MA, Soomro MA, Mastoi AH, Dhiloo KH. Feeding efficacy of spiders on sucking complex of okra, *Abelmoschus esculentus* L. Journal of Sustainable Agriculture. 2013;2:142-159.
39. Sanwal SK, Venkataravanappa V, Singh B. Resistance to Okra yellow vein mosaic disease: a review. Indian Journal of Agricultural Sciences. 2016;86(7):835-843.
40. Satti AA, Bilal NAA. The major predators and their seasonal abundance in okra fields at elgorair scheme, northern Sudan. The Experiment. 2012;4(4):271-276.
41. Shannon CE. A mathematical theory of communication. Bell System Technical Journal. 1948;27:379-423, 623-659.
42. Simpson EH. Measurement of diversity. Nature. 1949;163:688. https://doi.org/10.1038/163688a0.
43. Singh R, Joshi AK. Pests of okra (*Abelmoschus esculentus* Moench) in Paonta Valley, Himachal Pradesh. Insect Environment. 2004;9(4):173-174.
44. Singh Y, Jha A, Verma S, Mishra VK, Singh SS. Population dynamics of sucking insect pests and its natural enemies on okra agro-ecosystem in Chitrakoot region. African Journal of Agricultural Research. 2013;8(28):3814-3819.
45. Srinivas Rao N, Rajendra R. Joint action potential of neem with other plant extracts against the leaf hoppers, *Amrasca devastans* (Distant) on okra. Pest Management and Economic Zoology. 2002;10:131-132.
46. Suman S, Choudhary RK, Naveen SS, Yadav N. Efficacy of advanced insecticides against sucking pests of okra. Journal of Pharmaceutical Innovation. 2021;10(11):1925-1928.
47. Thukral AK. A review on measurement of *Alpha* diversity in biology. Agricultural Research Journal. 2017;54(1).
48. Whittaker RH, Rh W. Evolution of species diversity in land communities. Evolutionary Biology; c1977;10:1-67.