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Impact of emamectin benzoate 5% SG on arthropod biodiversity in bhendi ecosystem

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Abstract
A field experiment was conducted to assess the impact of emamectin benzoate 5% SG on arthropod diversity in bhendi during March-May, 2014 in Coimbatore. Two rounds of a spray of emamectin benzoate 5% SG were given at fourteen days interval starting from 38 days after sowing (DAS). In other hand an unsprayed field was maintained. The sampling of arthropods were made using four different methods *viz*., active searching, net sweeping, pitfall trap and rubbish trap. The collected arthropods were sorted out, identified to the lowest possible taxon and the biodiversity indices were estimated. A total of 4093 individuals belonging to 63 species, 43 families and 11 orders in both sprayed and unsprayed okra field were collected. The unsprayed okra field recorded a total of 2388 individuals, whereas sprayed field recorded a total of 1705 individuals. The class Insecta (51 species) was the most dominant followed by Arachnida (12 species). In Insecta, exopterygota were represented by four orders and endopterygota were represented by five orders. Spiders belonging to eleven species, nine genera and six families were recorded. The family Lycosidae (104 individuals) was found to be dominant followed by Salticidae (85 individuals). Family Lycosidae was represented by two species *viz., Lycosa* sp. and *Pardosa birmanica* Simon. The biodiversity indices were worked out, and the alpha diversity indices *viz.,* Species richness indices (Species number, Fishers' alpha index and Shannon-Weiner index), species dominance index (Simpson's index) and evenness index revealed that maximum value were recorded in unsprayed fields than sprayed fields especially at the time of spraying and the population increased two weeks after the spray. The comparison of beta diversity in sprayed and unsprayed fields, indicated that, based on ordinal, familial, generic and species level, all the indices values were higher in sprayed field than the unsprayed field. Higher arthropod diversity recorded in unsprayed field than the sprayed field.

Keywords: Emamectin benzoate, impact, arthropod biodiversity, bhendi

Introduction
Okra [*Abelmoschus esculentus* (L.) Moench] has a special status in the field of nutrition among vegetables. In India, it is cultivated in an area of 530000 ha, with a production of 6.35 million tons and productivity of 12 tons ha^{-1}. Okra is cultivated in almost all states of India and the major producing states are Andhra Pradesh, West Bengal, Bihar, Gujarat, Odisha, Karnataka and Tamil Nadu [1]. Besides various reasons for low productivity, heavy damage to fruits inflicted by *Helicoverpa armigera* (Hubner) and *Earias* sp., which reduces vitality of the plant resulting in 54.04 per cent net yield loss [2]. Ewete [3] has reported 72 insect species that attack and damage okra. A total of 26 herbivores belonging to 24 genera, 20 families, and five orders and 23 predator insect species belonging to 21 genera, 11 families and seven orders were observed from the okra ecosystem [4]. Among the various methods of pest management, the use of agrochemicals forms the first line of defense against the insect pests.
Emamectin benzoate is a semi-synthetic derivative of avermectins, produced as fermentation metabolites of soil actinomycetes, *Streptomyces avermitilis* Burg. This was discovered in 1984 and has both stomach and contact action, being effective against lepidopteran pests. They are potent agonists at the GABA receptors and interact with glutamate-gated chloride channels in insect nervous system. The strong chloride ion influx into the nerve cells results in disruption of nerve impulses, paralysis and finally death of larvae [5].
Arthropods are frequently used as ecological indicators because they represent more than 80 per cent of the global species richness. They fulfill essential roles in the ecosystem such as pollination, soil structure and function, decomposition and nutrient recycling, natural enemies of pest species, prey for highly valued vertebrate, etc. [6]. They have short generation times and respond quickly to ecological changes.

Further, various arthropod taxa have been used to detect an anthropogenic impact on ecosystems including agriculture and climate change [7, 8]. Spiders (Arachnida: Araneae) are so diverse arthropods that they have attained the seventh rank in diversity [9] and are predaceous arthropods which largely feed on insects, larvae, and eggs. The indiscriminate use of insecticides in agro-ecosystems resulted in ecological imbalance and appearance of more resistant pest strains in crops. Favorable results can be achieved by using spiders and other arthropods (including insects) as biological control agents in combination with insecticides and restricting the number of their applications to only specific times so as to protect them [10, 11].

The ecofriendly method of insect pest management offers an adequate level of pest control with fewer hazards and safe to non-target organisms. In the present study, the impact of emamectin benzoate 5% SG on arthropod diversity in bhendi ecosystem were evaluated.

Materials and Methods

A field experiment was conducted to assess the impact of emamectin benzoate 5% SG on arthropod population in bhendi during March – 2014 to May – 2014 at farmer field, Puthur, Coimbatore on the bhendi hybrid Venus. Two rounds of a spray of emamectin benzoate 5% SG were given at fourteen days interval starting from 38 days after sowing (DAS). Spraying was done with hand operated pneumatic knapsack sprayer using 500 liters of spray fluid per hectare. In other hand an unsprayed field was maintained.

1. Sampling methods

To develop package of methods for quantitative sampling of arthropod communities, collections were made using four different methods *viz*., active searching, net sweeping, pitfall trap and rubbish trap. For carrying out arthropod collection, the treated and untreated fields were divided into 100 quadrates (4 m x 4 m). Five such quadrates were chosen each at random and the entire site was covered during the sampling period.

a. Active searching

Active searching was done in the early morning. Each quadrate was selected at random were actively searched for arthropods. Each site was searched for a total of two hours. Spiders were collected by walking diagonally in the fields and captured without injuring them. They were transferred to polyethylene bags for further studies. Specimens from a single quadrate at each habitat type were pooled for analysis.

b. Net sweeping

Sweeping is very effective for the collection of flying and jumping arthropods at the ground level and under story vegetation. The sweep nets were made of thick cotton cloth with a diameter of 30 cm at the mouth and a cloth bag length of 60 cm.

For carrying out net sweeps, the plot was divided into 100 quadrates, measuring

4 x 4 m each. Five such quadrates representing the field were chosen at random and the entire ground level vegetation in the chosen quadrate was covered during the sweeping. Net sweeps were always done between 8 am and 11 am. The arthropods collected were transferred into polyethene bags containing cotton dipped in ethyl acetate. They were sorted and preserved on the same day.

c. Pitfall traps

Pitfall traps were used to collect the ground dwelling and nocturnal arthropods. Pitfall traps were set out using a plastic container (15 cm height and 10 cm width) buried into the soil to a depth of 20 cm. Five pitfall traps were placed in each of five randomly chosen 4 x 4 m quadrates. The traps were set up between 6 am and 5 pm and specimens were collected the next morning. In order to stop the receptacle from filling with water or leaf litter and to deter some larger predators like mice, the trap was covered with a flat stone supported by four smaller stones. The water with two to three drops of teepol was kept in the traps as trapping fluid and fluid was changed every week. The traps were placed at the rate of 25 per plot. Observations were pooled and presented as weekly data.

d. Rubbish traps

Rubbish traps were constructed using chicken wire mesh, stuffed with leaf litter

(45 cm length and 15 cm width). Five rubbish traps were placed in each of five randomly chosen quadrates. The traps were placed in the field allowing a week for arthropods to take up residence. Every seven days, these traps were removed and brought to the laboratory to collect the arthropods found inside were collected.

2. Collection and identification of arthropods

The collected arthropods were sorted out based on taxon. Soft bodied insects and spiders were preserved in 70 percent ethyl alcohol in glass vials. Other arthropods were card mounted or pinned. All arthropod species were identified to the lowest possible taxon. Insects were identified following Lefroy [12], Comstock [13], Richards and Davis [14], Ayyar [15], Poorani [16] and also by comparing with the specimens in the Biosystematics Laboratory, Department of Agricultural Entomology, TNAU, Coimbatore. Spiders were identified with the help of Dr. M. Ganesh Kumar, Professor of Entomology, TNAU, Coimbatore and Dr. Manju Siliwal, Independent Researcher, Wildlife Information Liaison Development Society, Dehradun.

3. Estimation of biodiversity indices

I. Alpha diversity indices

Measures of diversity are indicators of the well-being of any ecosystem. They also serve as a measure of the species diversity in the ecosystem. The following indices were used to assess and compare the diversity and distribution of arthropods in okra ecosystem. Species richness and diversity version ii (Pisces Conservation Ltd., *www.irchouse.demon.co.uk*) [17] programs were used to assess and compare the diversity of arthropods in sprayed and unsprayed okra ecosystem.

1. Species richness indices

i. Species number [18]

This represents the total number of species in each sample.

ii. Fisher's alpha [19]

This presents the alpha log series parameter for each sample. This is a parametric index of diversity that assumes the abundance of species following the log series distribution.

$$ax, \frac{ax^2}{2}, \frac{ax^3}{3}, \frac{ax^n}{n}$$

Where, each term gives the number of species predicted to have 1, 2, 3,…., n individuals in the sample.

iii. **Shannon diversity index** [20]
This represents the Shannon - Weiner (also called as Weaver) diversity index for each sample and is defined as:

$$H' = \sum P_i \ln P_i$$

Where,

P_i - The proportion of individuals in the i[th] species

H' - This program calculates the index using the natural logarithm

2. Species dominance indices-Simpson's index [21]
Simpson's index describes the probability that a second individual drawn from a population should be of the same species as the first.

$$D = \sum \frac{[N_i(N_i - 1)]}{[N_t(N_t - 1)]}$$

Where,

N_i - is the number of individuals in the i[th] species

N_t - is the total number of individuals in the sample
So, larger its value, greater the diversity. The statistic 1 - C gives a measure of the probability of the next encounter being from another species [22].

3. Evenness indices - Equitability J [18]
Equitability or evenness refers to the pattern of distribution of the individuals between the species. This measure of equitability (J) compares the observed Shannon- Weiner index against the distribution of individuals between the observed species which would maximize diversity. If H is the observed Shannon - Weiner index, the maximum value of this could take log S, where S is the total number of the species in the habitat.
Therefore the index is:
J = H / log (S)

II. Beta diversity indices
Beta diversity measures increase in species diversity along transects and is particularly applicable to the study of environmental gradients. It measures two attributes, the number of distinct habitats within a region and the replacement of species by another between disjoint parts of the same habitat. All the selected samples in the active data set will be used to calculate the indices. It is assumed that the samples are arranged in the data grid in their order of occurrence along the transect. The five indices calculated, which are described below are those considered by Wilson and Schmida [23]. All five required presence/ absence of data.

1. Whittaker's measure βw
The first and one of the most straight forward measures of beta diversity was introduced by Whittaker [24]
$\beta w = S / \alpha - 1$
Where,
S = the total number of species and the average species richness of the samples
α = the average sample diversity where each sample is standard size and diversity is measured as species richness.
All samples must have the same size (or sampling effort).

2. Cody Bc
Cody Bc was introduced to analyze the changes in the composition of communities along habitat gradients
$\beta c = g(H) + 1 (H)/ 2$
Where-, g(H) is the number of species gained and 1(H) the number lost moving along the transect.

3. Routledge's R, I and E
Routledge [25] was concerned with how diversity measures can be portioned into alpha and beta components. The following three indices were derived from the data collected. The first measure β_{R-}, takes overall species richness and the degree of species overlap into consideration.
$\beta_R = S^2/ 2r+S-1$
Where,
S is the total species number for the transect and r is the number of species pairs overlapping distributions. Second equation simplified for qualitative data and equal sample size
Assuming equal sample sizes,
$\beta_I = \log(T)-[(1/ T) \Sigma e_i \log (e_i)] – [(1/ T) \Sigma \alpha_i \log(\alpha_i)]$
Where,
e_i = is the number of samples along the transect in which species i is present and α_i the species richness of sample i and T is Σe_i.
α = the average sample diversity where each sample is standard size
The third index β_E is the simply exponential form of β_I
The third Routledge's indices is simply
$\beta_E = \exp(\beta_I) - 1$

4. Wilson and Schmida's T
Wilson and Schmida [23] proposed the sixth measure of beta diversity.
This index has the same elements of species loss (1) and gain (g) that are present in Cody's measure and the standardization by average sample richness α, which is a component of Whittaker's measure
$\beta_T = [g(H)+1(H)] / 2\alpha$
Where the parameters are defined as c and w based on an assessment of the essential properties of a useful index: the ability to detect change, additive and independence of sample size. They concluded this as the best.

5. Similarity index
The binary data obtained by scoring the presence or absence of individual species in each of sampling site ecosystems were subjected to cluster analysis. The similarity matrix was constructed using Jaccard's [26] similarity coefficient. The similarity values were used for cluster analysis. Sequential Agglomerative Hierarchical Non-overlapping (SAHN) clustering was done using Unweighted Pair Group Method with Arithmetic averages (UPGMA) method. Data analysis was done using NTSYSpc version 2.02 [27].

Results
Arthropods were collected at weekly intervals from March to May 2014 in sprayed and unsprayed okra fields. Collected arthropods were documented, identified to the possible taxonomic level (Order, Family, Genus or Species) and various biodiversity indices were worked out. A total of 4093 individuals belonging to 11 orders and 43 families were collected from okra ecosystem (Table 1).

Insecta
The class Insecta was the most dominant followed by Arachnida. In Insecta, exopterygotes were represented by four

orders and endopterygotes were represented by five orders. Among exopterygotes, maximum individuals were recorded in the Order Hemiptera (885) followed by Orthoptera (158), Odonata (105) and Thysanoptera (62). In Hemiptera, the most dominant families were Cicadellidae and Pseudococcidae. The other taxonomically important families were Aphididae, Aleyrodidae, Scutelleridae, Pyrrhocoridae, and Lygaeidae. In the case of Cicadellidae 144 individuals were collected in unsprayed okra and 104 in sprayed field. Orthoptera was represented by three families *viz*., Pyrgomorphidae (*Neorthacris simulans* Bolivar and *Atractomorpha crenulata* Fabricius), Gryllidae (*Gryllus* sp.) and Tettigoniidae (*Phaneroptera gracilis* Burmeister) with the majority of individuals from unsprayed okra field (Table 1).

It is evident from the present study, arthropods were found to be higher in unsprayed fields when compared to sprayed fields, but no differences were found in the abundance of insects in the plots treated with emamectin benzoate. In the early stage, Hemipterans were predominant indicated by the presence of a large number of *Amrasca biguttula biguttula* (Ishida). This was similar to the findings of Mandal [28] and Nath [29] who reported that, the jassids, *A. biguttula biguttula* were relatively abundant in bhendi. Latif [30] reported that, the relative abundance of jassids, *A. biguttula biguttula* (58.37%) ranked first with respect to the frequency followed by white flies *Bemisia tabaci* (Gennadius)) and aphids *Aphis gossypii* (Glover) in brinjal.

Among endopterygotes, maximum individuals were recorded in the Order Hymenoptera (963) followed by Coleoptera (798), Lepidoptera (372), Diptera (139) and Neuroptera (48). Hymenoptera was predominant in terms of individuals of endopterygota. Among the eight families of Hymenoptera collected, the majority of the individuals were from Formicidae followed by Apidae. Order Lepidoptera was represented by five families. A maximum number of individuals belonged to family Noctuidae (156), followed by family Nolidae (118), family Pieridae (54) and family Nymphalidae (35). Under Coleoptera, six families were collected with the majority of individuals belonging to Curculionidae (421) followed by Coccinellidae (345) in both sprayed and unsprayed okra field. *Cheilomenes sexmaculata* (Fabricius) was the most dominant species under the family Coccinellidae. Neuroptera was represented by single family Chrysopidae with single species.

The overall data revealed that the predatory arthropods *viz.,* Coccinellids and Green lace wing were found to be higher in numbers in the unsprayed fields compared to sprayed fields, but not greatly affected by the application of emamectin benzoate. Similarly, *Oecanthus indicus* Saussure (Orthoptera), *Musca domestica (*Linnaeus) (Diptera) and *Camponotus compressus* (Fabricius) (Hymenoptera) were greater in unsprayed plots, but no differences were found in the abundance of insects in the plots treated with emamectin benzoate (Table 1). Coleoptera was the second most dominant order under endopterygotes with maximum number of predatory coccinellids. Similar results were obtained by Yardim [31] who reported that pesticide treated plots did not cause any significant reduction in coccinellids. The reduction might be due to a lesser number of aphids caused by pesticides which were not enough to sustain the coccinellid population. Coccinellids have great importance, since they have proved their value in checking pest populations *viz*., mealybugs, scales, aphids and coccids [32].

Arachnida

Spiders belonging to eleven species, nine genera, and six families were recorded. The family Lycosidae (104) was found to be dominant followed by Salticidae (85), Oxyopidae (78), Thomisidae (37), Araneidae (22) and Gnaphosidae (13). Family Lycosidae was represented by two species *viz., Lycosa* sp. and *Pardosa birmanica* Simon. Under the family Oxyopidae majority of the species collected was *Oxyopes* sp. (59). Family Tetranychidae was represented by *Tetranychus urticae* (224) in both sprayed and unsprayed okra fields. The overall data revealed that the number of spiders collected was higher in untreated plots (192) compared to the treated plots (147) (Table 1).

The present study revealed that under Arachnida, Lycosidae was the dominant family followed by Salticidae. Members of Oxyopidae, Araneidae, and Thomisidae were found to be lower in number, as they are being diurnal which made them more sensitive to foliar spray compared to lycosids. The number of spiders was significantly higher in untreated plots than treated, but not greatly affected by the application of emamectin benzoate. The present results are in agreement with Mansfield [33] who reported that lycosids were nocturnal and ground-burrowing and they might have been less exposed to diurnal foliage sprays. Amalin [34] also reported that lycosids did not show sensitivity to the chemical spray. Karthik [35] reported that unsprayed cotton showed little higher species richness, abundance, and distribution than emamectin benzoate sprayed field. Agrochemicals were found to have an impact on the population of spiders in okra [36]. The spiders and beetles were the main defenders in bhendi ecosystem [37-39].

Balzan [40] recorded the high abundance of predatory Miridae, Nabidae (Heteroptera), Parasitica (Hymenoptera), Coccinellidae (Coleoptera) and Thomisidae (Araneae) in organic okra fields by sweep netting. Sharma [41] reported spiders from vegetable fields of which Araneidae was the most dominant family with five species.

Biodiversity indices in okra ecosystem

Biodiversity is a function of species present (species richness), the evenness with which individuals are distributed among these species (species evenness) and the interaction component of richness and evenness as documented by Ludwig [42]. Measures of diversity are frequently seen as indicators of the well-being of any ecosystem. As complete counts of organisms are impractical, indirect solutions that are practical, rapid and inexpensive are necessary and hence, diversity indices have gained importance. In the present study, the data on arthropods collected were subjected to alpha or within habitat diversity and beta or between habitat diversity of sprayed and unsprayed okra fields.

Table 1: Diversity of arthropods in sprayed and unsprayed okra ecosystem

Order	Family	Genus	Unsprayed	Sprayed	Total
Araneae	Araneidae	*Argiope* sp.	12	10	22
	Salticidae	*Plexippus paykulli* (Audouin)	41	31	72
		Carrhotus decoratus (Tikader)	8	5	13
	Oxyopidae	*Oxyopes* sp. 1.	32	27	59

		xyopes sp. 2	1	0	1
		Peucetia sp.	10	8	18
	Thomisidae	*Thomisus* sp. 1	7	4	11
		Thomisus sp. 2	15	11	26
	Lycosidae	*Lycosa* sp.	17	14	31
		Pardosa birmanica Simon	41	32	73
	Gnaphosidae	*Drassyllus* sp.	8	5	13
Acarina	Tetranychidae	*Tetranychus urticae*	130	94	224
Odonata	Libellulidae	*Crocothemis servilia* (Drury)	13	11	24
		Orthetrum sabina (Drury)	16	12	28
		Pantala flavescens (Fabricius)	19	14	33
	Coenagrionidae	*Ceriagrion coromandelianum* (Fabricius)	11	9	20
Orthoptera	Pyrgomorphidae	*Neorthacris simulans* (Bolivar)	17	14	31
		Atractomorpha crenulata Fabricius	21	17	38
	Tettigoniidae	*Phaneroptera gracilis* Burmeister	14	11	25
	Gryllidae	*Oecanthus indicus* Saussure	15	13	28
		Unidentified sp.	20	16	36
Hemiptera	Cicadellidae	*Amrasca biguttula biguttula* (Ishida)	144	104	248
	Aphididae	*Aphis gossypii* (Glover)	48	26	74
	Aleurodidae	*Bemisia tabaci* (Gennadius)	11	7	18
		Aleurodicus dispersus (Russell)	114	83	197
	Pentatomidae	*Nezara viridula* (Linnaeus)	37	21	58
	Pyrrhocoridae	*Dysdercus olivaceus* (Fabricius)	11	9	20
	Lygaeidae	*Oxycarenus hyalinipennis* (Costa)	12	10	22
	Pseudococcidae	*Phenacoccus solenopsis* (Tinsley)	137	111	248
Thysanoptera	Thripidae	*Thrips tabaci* (Lindeman)	35	27	62
Neuroptera	Chrysopidae	*Chrysoperla* sp.	32	16	48
Diptera	Muscidae	*Musca domestica* (Linnaeus)	64	55	119
	Bibionidae	Unidentified sp.	9	7	16
	Unidentified	Unidentified sp.	4	0	4
Coleoptera	Curculionidae	*Myllocerus* sp.	38	25	63
		Unidentified sp.	222	136	358
	Meloidae	*Hycleus balteatus*	19	10	29
	Coccinellidae	*Cheilomenes sexmaculata* (Fabricius)	108	81	189
		Brumoides suturalis (Fabricius)	25	22	47
		Micraspis discolor Fabricius	10	8	18
		Adalia bipunctata (Linnaeus)	21	18	39
	Chrysomelidae	*Cryptocephalus schestidti* Fabricius	10	5	15
	Scarabaeidae	*Gymnopleurus* sp.	11	7	18
	Melolonthidae	unidentified sp.	12	10	22
Hymenoptera	Apidae	*Apis dorsata* Fabricius	80	69	149
		Apis cerana indica Fabricius	69	54	123
	Tephritidae	Unidentified 1	6	3	9
	Vespidae	Unidentified 1	8	6	14
		Ropalidia marginata Lepeletier	5	2	7
	Trichogrammatidae	*Trichogramma* sp.	9	7	16
	Formicidae	*Camponotus* compressus (Fabricius)	267	225	492
	Braconidae	*Bracon* sp.	38	22	60
		Chelonus sp.	45	26	71
	Pompilidae	*Pompilus* sp.	10	6	16
		Unidentified sp.	4	2	6
Lepidoptera	Noctuidae	*Helicoverpa armigera* (Hubner)	91	39	130
		Spodoptera litura Fabricius	19	7	26
	Nymphalidae	*Melanitis* sp.	6	3	9
		Euthalia evelina (Stoll)	14	12	26
	Nolidae	*Earias vittella* (Fabricius)	78	40	118
	Pieridae	*Eurema hecabe* Linnaeus	13	10	23
		Pieris brassicae Linnaeus	19	12	31
	Erebidae	*Grammodes geometrica* (Fabricius)	5	4	9
		Total	2388	1705	4093

Alpha diversity indices at ordinal, family, generic and species level

The arthropods were identified to order, family, genus and species level. Based on the data different indices were calculated as below

Species richness indices

Based on ordinal level calculated, species number varied between a minimum of 8 during the first two weeks of April and maximum of 11 during the fourth week of March and May in sprayed okra, similarly in the unsprayed okra. Based on the species level, species number was maximum in the month of March and minimum in the month of May in the unsprayed okra, while value was maximum of 48 and minimum of 25 during the month of April in the sprayed field (Table 2).

Based on generic and species level, the corresponding Fishers alpha index values were the lowest in the last week of May in the sprayed field (15.304 and 15.945) and the highest in the first week of April (26.207 and 28.691), whereas in unsprayed field generic and species level were minimum in the second week of April (18.33 and 20.04) (Table 3). Minimum variation was observed with Shannon - Weiner indices based on ordinal, generic, familial and species level between the sprayed and unsprayed okra fields (Tables 4).

The overall data revealed that the species richness indices *viz.,* species number, Fishers Alpha index and Shannon - Weiner index value were higher in unsprayed okra. This finding is in accordance with Chakraborty [4] who recorded a total of 26 herbivores belonged to 24 genera, 20 families and five orders and 23 predator insect species belonged to 21 genera, 11 families and seven orders were observed from the okra ecosystem. The Shannon and Wiener diversity index (H') values of herbivores (2.286 and 2.294) and predators (2.882 and 2.757) were more or less same during *Kharif*, 2012 and rabi, 2012-13.

Table 2: Arthropod diversity in okra ecosystem - Alpha diversity (Species number)

Month	Sampling week	Species richness indices (Species number)							
		Sprayed field				Unsprayed field			
		Ordinal level	Familial level	Generic level	Species level	Ordinal level	Familial level	Generic level	Species level
March 2014	2nd week	10	29	40	41	11	35	49	50
	3rd week	11	32	43	44	11	38	52	54
	4th week	9	22	29	30	11	38	54	56
April 2014	1st week	8	32	43	45	11	38	52	54
	2nd week	8	23	24	25	11	39	50	53
	3rd week	9	32	46	48	11	36	51	52
	4th week	10	35	47	48	11	40	53	54
May 2014	1st week	10	35	45	46	10	35	48	49
	2nd week	10	35	47	48	11	38	49	50
	3rd week	11	34	45	47	11	34	46	48
	4th week	9	28	38	39	10	32	42	44

Table 3: Arthropod diversity in okra ecosystem - Alpha diversity (Fishers alpha)

Month	Sampling week	Species richness indices (Fishers alpha)							
		Sprayed field				Unsprayed field			
		Ordinal level	Familial level	Generic level	Species level	Ordinal level	Familial level	Generic level	Species level
March 2014	2nd week	2.293	9.828	16.048	16.687	2.4619	11.91	19.928	20.589
	3rd week	2.5368	10.963	17.218	17.855	2.3708	12.609	20.24	21.474
	4th week	2.6836	10.588	17.562	18.78	2.3379	12.315	20.853	22.072
April 2014	1st week	1.9914	15.261	26.207	28.691	2.3788	12.682	20.381	21.628
	2nd week	2.6881	16.503	18.128	19.898	2.326	12.677	18.33	20.04
	3rd week	2.1781	13.311	24.751	26.78	2.3629	11.592	19.505	20.102
	4th week	2.2639	12.737	20.252	20.964	2.4333	14.239	22.043	22.712
May 2014	1st week	2.1936	12.046	17.664	18.285	2.1907	12.018	19.502	20.162
	2nd week	2.1793	11.91	18.659	19.289	2.5567	14.407	21.615	22.352
	3rd week	2.533	11.967	18.457	19.782	2.6174	12.659	20.488	22.001
	4th week	2.0355	9.5925	15.304	15.945	2.5088	13.371	21.138	22.969

Table 4: Arthropod diversity in okra ecosystem - Alpha diversity (Shannon - Weiner index)

Month	Sampling week	Species richness (Shannon - Weiner index)															
		Sprayed field								Unsprayed field							
		Ordinal level		Familial level		Generic level		Species level		Ordinal level		Familial level		Generic level		Species level	
		H	Variance H	H	Variance H	H	Variance H	H	Variance H	H	Variance H	H	Variance H	H	Variance H	H	Variance H
March 2014	2nd week	1.9949	0.003099	2.9113	0.004749	3.1322	0.006723	3.1536	0.006895	2.0118	0.002915	3.0648	0.004084	3.2989	0.005886	3.3417	0.005812
	3rd week	2.0298	0.002852	3.0104	0.004309	3.2769	0.005204	3.3194	0.005144	2.0663	0.002259	3.1597	0.003678	3.4293	0.004486	3.4585	0.004632
	4th week	1.9085	0.006492	2.807	0.009123	3.006	0.012414	3.0318	0.012916	1.9636	0.002148	3.129	0.003399	3.4012	0.00454	3.4469	0.004556
April 2014	1st week	1.8596	0.002928	3.1255	0.007202	3.4128	0.008238	3.4612	0.008508	1.9437	0.002482	3.0895	0.003827	3.3839	0.004413	3.4412	0.004387
	2nd week	1.8814	0.008609	2.9106	0.012992	2.9383	0.013903	2.9765	0.014498	1.878	0.002417	3.0552	0.00401	3.2491	0.004751	3.3099	0.00486
	3rd week	1.8988	0.003383	3.1191	0.005534	3.4832	0.006543	3.5226	0.006804	1.9827	0.002165	3.0821	0.003349	3.3541	0.004338	3.3985	0.004222
	4th week	1.8241	0.003494	3.0519	0.00502	3.2489	0.00659	3.3126	0.006204	1.9862	0.002599	3.2162	0.0038	3.441	0.004774	3.484	0.004652
May 2014	1st week	1.993	0.002557	3.0164	0.004313	3.2264	0.005274	3.2656	0.005273	1.9676	0.002768	3.0304	0.004333	3.2147	0.005932	3.2537	0.005937
	2nd week	1.8815	0.003074	3.0394	0.004426	3.2483	0.005795	3.3129	0.005464	2.1024	0.002662	3.2677	0.003784	3.4545	0.00489	3.4934	0.00476
	3rd week	2.0596	0.00278	3.0156	0.004661	3.191	0.006099	3.269	0.005865	2.0388	0.003282	3.0725	0.004777	3.296	0.006363	3.3361	0.006574
	4th week	1.854	0.003415	2.7576	0.005999	2.9118	0.008242	2.9862	0.007915	2.0097	0.003425	3.0264	0.006906	3.231	0.0089	3.2812	0.009136

Species dominance indices

Analysis of data based on Simpson's index at familial level, the value was maximum (21.491 and 23.188) during the second week of April in sprayed and second week of May in unsprayed okra fields respectively (Table 5). From the above indices, it was observed that a maximum number of arthropods were recorded in unsprayed okra fields than the sprayed fields especially at the time of spraying and increased two weeks after spray. Chakraborty [4] reported that the Simpson index (λ) values of herbivores (0.155 and 0.154) and predators (0.063 and 0.076) were more or less same during *Kharif*, 2012 and rabi, 2012-13.

Evenness indices

Based on generic and familial level, Equitability J index showed higher values in the unsprayed field than sprayed field and the Equitability J index values are presented in Table 6. The species diversity indices and species evenness indices of predators and herbivores were more or less equal and exhibited a similar diversification [4].

Beta diversity indices at ordinal, family, generic and species level

In the current study, Beta diversity indices *viz.,* Whittaker's Bw, Cody Bc, Routledge's Br, Routledge's Bi Routledge's Be and Wilson and Schmida's Bt indices were used to compare the species compositions of different communities in both sprayed and unsprayed okra fields. According to Whittaker's Bw the value was higher in sprayed field (0.15238) and lower in the unsprayed field (0.016807) at ordinal level. Based on familial, generic level and species level all the index values were higher in the sprayed field than the unsprayed field (Table 7).

Biodiversity is a function of species present (species richness), the evenness which individuals are distributed among these species (species evenness) and the interaction component of richness and evenness. Measures of diversity are frequently seen as indicators of well-being of any ecosystem. As complete counts of organisms are impractical, indirect solutions that are practical, rapid and inexpensive are necessary and hence, diversity indices have gained importance. In the present study, the data on arthropods collected were subjected to alpha or within habitat diversity and beta or between habitat diversity of sprayed and unsprayed okra fields. The overall data revealed that the species richness indices *viz.,* species number, Fisher's Alpha index, Q Stastistic, Margalef's D index, Shannon - Weiner index, and Brillouin diversity index value were higher in unsprayed okra and the dominance indices expressed higher arthropod diversity in unsprayed okra field and lower in sprayed field. Hence, the present study imply that the arthropod diversity was abundant in unsprayed than the sprayed bhendi field.

Table 5: Arthropod diversity in okra ecosystem - Alpha diversity (Simpson's index)

Month	Sampling week	Species dominance indices (Simpson's index)							
		Sprayed field				Unsprayed field			
		Ordinal level	Familial level	Generic level	Species level	Ordinal level	Familial level	Generic level	Species level
March 2014	2nd week	6.1296	14.386	15.769	15.896	6.071	16.9	18.613	19.33
	3rd week	6.5556	16.639	20.487	21.321	6.6307	18.425	22.735	23.071
	4th week	6.2092	15.795	18.128	18.374	6.1145	18.075	21.599	22.439
April 2014	1st week	6.0806	20.297	27.634	28.712	5.9093	17.225	22.594	23.901
	2nd week	6.2183	21.491	21.875	22.685	5.5111	15.591	17.826	18.623
	3rd week	5.9725	19.935	28.47	29.216	6.2577	17.871	22.031	23.209
	4th week	5.1497	16.802	18.721	20.458	6.1605	20.632	24.192	25.394
May 2014	1st week	6.2076	16.522	19.187	19.805	5.9453	16.542	18.068	18.61
	2nd week	5.3187	16.07	17.82	19.33	7.0753	23.188	26.31	27.693
	3rd week	6.6624	16.44	18.058	19.837	6.5112	17.861	20.353	20.838
	4th week	5.2976	11.929	12.469	13.476	6.6399	16.752	18.716	19.377

Table 6: Arthropod diversity in okra ecosystem - Alpha diversity (Equitability J)

Month	Sampling week	Evenness indices (Equitability J)							
		Sprayed field				Unsprayed field			
		Ordinal level	Familial level	Generic level	Species level	Ordinal level	Familial level	Generic level	Species level
March 2014	2nd week	0.83194	0.77405	0.765	0.76117	0.83901	0.81484	0.80571	0.80657
	3rd week	0.8465	0.80039	0.80036	0.80118	0.8617	0.84008	0.83757	0.83474
	4th week	0.79589	0.7463	0.73418	0.73176	0.81889	0.83191	0.8307	0.83195
April 2014	1st week	0.77551	0.831	0.83355	0.83542	0.81058	0.82141	0.82648	0.83058
	2nd week	0.78462	0.77384	0.71765	0.71842	0.78317	0.81231	0.79356	0.79888
	3rd week	0.79187	0.82928	0.85074	0.85022	0.82686	0.81944	0.81921	0.82026
	4th week	0.76069	0.81141	0.79351	0.79954	0.8283	0.85511	0.84042	0.84092
May 2014	1st week	0.83116	0.80197	0.78801	0.78819	0.82054	0.8057	0.78516	0.78533
	2nd week	0.78463	0.80809	0.79335	0.79961	0.87676	0.86879	0.84373	0.84319
	3rd week	0.85893	0.80177	0.77937	0.78902	0.85025	0.8169	0.80502	0.80522
	4th week	0.77316	0.73318	0.71117	0.72076	0.83809	0.80464	0.78914	0.79197

Table 7: Beta diversity of arthropods in okra ecosystem (at ordinal, familial, generic and species level)

Beta diversity indices	Beta diversity							
	Sprayed field				Unsprayed field			
	Ordinal level	Familial level	Generic level	Species level	Ordinal level	Familial level	Generic level	Species level
Whittaker's Bw	0.15238	0.37092	0.4519	0.45553	0.016807	0.1737	0.20879	0.22872
Cody Bc	1.5	13.5	20.0	21.0	0.5	9.5	14.5	16.0
Routledge's Br	0.0	0.010309	0.01045	0.010318	0.0	0.001083	0.000556	0.005574
Routledge's Bi	0.11121	0.24573	0.29537	0.29466	0.014528	0.12154	0.1529	0.15877
Routledge's Be	1.1176	1.2786	1.3436	1.3427	1.0146	1.1292	1.1652	1.1721
Wilson and Schimida's	0.15714	0.44065	0.49217	0.50108	0.046218	0.25931	0.29212	0.31206

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