Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(2): 1792-1799

Received: 18-01-2020
Accepted: 20-02-2020

J Kousika
Post-Doctoral Fellow, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

S Kuttalam
Post-Doctoral Fellow, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Corresponding Author:
J Kousika
Post-Doctoral Fellow, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Effect of tetraniliprole 200 SC on arthropod diversity of tomato ecosystem

J Kousika and S Kuttalam

Abstract

Field experiments were conducted to access the arthropod diversity in tomato ecosystem in tetraniliprole 200 SC sprayed and unsprayed filed. Collections were made using four different methods *viz.*, active searching, net sweeping, pitfall trap and rubbish trap. The treated and untreated fields were divided into 100 quadrats (4 m x 4 m) and five such quadrats were chosen each at random and the entire site was covered during the sampling period. Species richness and diversity was studies by various indices. The result showed that totally 2760 individuals were found out of 1717 and 1043 were found in sprayed and unsprayed, respectively. Under Arachnida ten species and nine genera were recorded. Family Lycosidae (49) was dominant followed by Araneidae (43), Tetragnathidae (22), Oxyopidae (19), Salticidae (17) and two unidentified species. Under Insecta, exopterygotes were the largest group represented by seven orders *viz.,* Orthoptera, Dictyoptera, Odonata, Hemiptera, Isoptera, Dermaptera and Thysanoptera. While endopterygotes were represented by five orders *viz.*, Diptera, Hymenoptera, Lepidoptera, Coleoptera and Neuroptera. From the above indices, it is inferred that maximum number of arthropods was recorded in unsprayed tomato fields than the sprayed fields. Maximum diversity of arthropods was observed during the month of November and minimum during the month of December in most of the diversity indices.

Keywords: Tomato, arthropod, diversity, tetraniliprole, sprayed, unsprayed

Introduction

Brinjal (*Solanum melongena* L.) also known as aubergine or eggplant, is an important solanaceous vegetable crop, which is grown all over the world. It is grown throughout the year in one or other parts of the country as a continuous source of income to vegetable farmers. It is grown extensively in India, Bangladesh, Pakistan, China and other parts of the world. India ranks second in the world and its contribution is 27.1 per cent. In India, it is mainly grown in Bihar, Orissa, West Bengal, U.P. and other parts. Brinjal is being cultivated round the year during *kharif*, *rabi* and summer season. The area under brinjal cultivation is estimated as 0.68 million ha with the total production of 12706 thousand MT [1]. The productivity of brinjal is still below the expected due to various constraints of which insect and non-insect pests that attack the crop at various physiological growth stages from the nursery stage to harvest considered to be major one. Brinjal fruit and shoot borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Pyralidae) is reported most destructive [2] as In the recent year, the demand for the foodstuffs free of contaminant has increased worldwide and has triggered the researchers to find the risk associated with the contaminant especially pesticides. The level of risk is directly proportional to the acceptable daily intake of the contaminated food which is usually in the higher side [1]. Tomato (*Lycopersicon esculentum* Mill.), belongs to the family Solanaceae is native to tropical America is grown across the world and grown in large area for fresh vegetable and other process *viz.*, making soup, salad, pickles, ketchup, puree, sauces, etc,. The productivity of tomato in India is very low (15.60 t/ha) when compared to the average global productivity (25.09 t/ha) [2] and the annual production is around 18 million tons [3]. Besides biotic factors, insect damage is the major reason which attacks the crop at all the stages and reduces the yield to greater extent. Among the insect pest, the fruit borer *Helicoverpa armigera* Hubner directly damages the produce and causes yield loss of 20-60% [4]. For the management of *H. armigera* farmers apply insecticide indiscriminately without knowing what and when should be applied. This again results in other consequents like insecticide resistant, resurgence of pest pesticide residues in fruits and soil and reduction in the population of natural enemies [5] and other non-target organism present in the tomato ecosystem. The reduction in the population of natural enemies will in turn affect the ecological balance subsequently the pest population will increase, and the management becomes tedious. The insecticide contaminated communities may experience changes in their behavior and damages in the food chain and nutrients [6]. Species diversity and abundance determines the biotic community. Diversity is about types of communities whereas abundance is number of individuals in a species.

Knowledge about diversity and the role of individuals in an ecosystem is essential to determine their richness because changes in the ecosystem will bring imbalance in the food chain. The diversity and species abundance data are very essential to determine the ecosystem health and it can be used to identify any occurrence of the attack of pest. The present study aims to examine the effect of tetraniliprole application on arthropod diversity in tomato ecosystem. Tetraniliprole belongs to anthranilic diamide group with unique chemical structure when compared to others existing insecticide groups. As it is newer, it is very well accepted for the pest control progamme. Being newer, its effect on arthropod diversity is not studies well and this study describes its effect on arthropod diversity in tomato ecosystem.

Materials and method

Studies were conducted on arthropod biodiversity in tomato ecosystem during 2013-2014. The field experiment was conducted in Thennamanallur, Coimbatore, Tamil Nadu, India to identify the arthropod diversity in tomato. The various methodologies followed for survey, collection of arthropods, preservation and their identification and diversity analysis are described as follows.

Sampling methods

To develop package of methods for quantitative sampling of arthropod communities, arthropod collections were made with 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 quadrats (4 m x 4 m). Five such quadrats were chosen each at random and the entire site was covered during the sampling period.

Active searching of arthropods were made in the early morning and evening in selected quadrant for two hours while the wingless insects and spiders were collected by walking in the filed diagonally. Nets were used to collect flying and jumping insects above the vegetation. Flying and jumping arthropods at the ground level can be effectively collected by net sweeping. The nets used in systematic sweeping were made of thick cotton cloth with a diameter of 30 cm at the mouth and a bag length of 60 cm. For carrying out net sweeps, the treated and untreated area was divided into 100 quadrats, measuring 4 m x 4 m each. Five such quadrats representing the field were chosen at random. To collect the ground dwelling and nocturnal insect pitfall traps were set using plastic containers which was 15 cm height and 10 cm width was buried into the soil to a depth of 20 cm were placed. The traps were placed at the rate of 25 per plot. Similarly, rubbish traps were constructed using chicken wire mesh (45 cm length and 15 cm width), stuffed with leaf litter and made into cylindrical shape. Rubbish traps were constructed using chicken wire mesh (45 cm length and 15 cm width), stuffed with leaf litter and made into cylindrical shape. Five rubbish traps were placed in each of five randomly chosen 4 m x 4 m quadrats. The traps were placed in the field allowing a week for arthropods to take up the trap as their residence.

The arthropods collected from each quadrat were transferred to a bottle with a small amount of ethyl acetate to kill all the arthropods and were sorted on the same day. Soft bodied insects and spiders were later separated and preserved in vials containing 70 per cent alcohol.

Collection and identification of arthropods

Arthropod fauna was collected from March – May 2014 in tomato ecosystem at weekly intervals using above methods. The collected arthropods were sorted out according to their taxon. Soft bodied insects and spiders were preserved in 70 per cent ethyl alcohol in glass vials. Other arthropods were card mounted or pinned. The preserved specimens were photographed using image analyser and identified based on the taxonomic characters.

All arthropod species were identified to the lowest possible taxon [7-11] 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, Research Associate, Wildlife Information Liaison Development Society, Dehradun.

Diversity analysis of arthropods in tomato ecosystem

Alpha diversity indices

Measures of diversity are indicators of the well-being and measure of the species diversity in the ecosystem. The following indices were used to assess and compare the diversity and distribution of arthropods in tomato ecosystem. Species richness and diversity version ii (Pisces Conservation Ltd., *www.irchouse. demon.co.uk*) [12] programmes were used to assess and compare the diversity of arthropods in sprayed and unsprayed tomato ecosystem.

Species richness

Fisher's alpha [13]

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

$$\alpha x, \frac{\alpha x^2}{2}, \frac{\alpha x^3}{3}, \frac{\alpha x^n}{n}$$

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

Species number [14]

This represents the total number of species in each sample.

Shannon diversity index [15]

This is the representation of 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 ith species

H - This program calculates the index using the natural logarithm

n_i - is the number of individuals belonging to the i^{th} species and s is the species number.

Species Dominance indices

Simpson's index [16]

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 degree of the probability of the next encounter being from another species [17].

Evenness indices [18]

Evenness (E) represent the similarity in the abundances of different species or categories are in a community. The evenness index was maximum when all species in a community are equally abundant and decrease towards zero as the relative abundances of the species diverge away from evenness when it moves closer to zero. This means that most of the individuals belong to one or a few species or categories, when the evenness is close to one which in turn indicated that each species / category has same number of individuals.

$$E = \frac{H'}{\ln(S)}$$

where,

S – Total number of species in a community

H' - prime is the number derived from the Shannon diversity index

Beta diversity indices

Beta diversity represents the increase in species diversity along transects and is particularly indicates the environmental gradients. It measures two aspects; one is the number of distinct habitats within a region and second one is the replacement of species by another between disjoint parts of the same habitat. All the selected samples in the data will be used for the indices calculation by arranging the samples in the data grid in their order of occurrence along the transect. The five indices calculated and described below are based on [19]

Whittaker's measure, βw

This is the most straight forward measures of beta diversity which was introduced by [20]

$$\beta w = S / \alpha - 1$$

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).

Cody Bc

Cody Bc was introduced to analyse the changes in the composition of communities along habitat gradients

$\beta c = g(H) + 1\ (H)/ 2$

Where, g(H) represents the number of species gained and 1(H) is the number lost moving along the transect.

Routledge's R, I and E [21]

The classification is based on how diversity measures can be portioned into alpha and beta components. According to him, 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 indicates the number of species pairs overlapping distributions.

Second equation is the simplified calculation for qualitative data and equal sample size

Assuming that sample sizes are equal,

$$\beta_I = \log(T)-[(1/ T)\ \Sigma e_i \log (e_i)] – [(1/ T)\ \Sigma\alpha_i \log(\alpha_i)]$$

Where,

e_i= is the number of samples along the transect in which species i is present and

α_i indicates the species richness of sample i and T is Σe_i.

α is the average sample diversity where each sample is with standard size

The third index β_E is the exponential form of β_I

The third Routledge' sindices is simply

$$\beta_E= \exp(\beta_I) - 1$$

Wilson and Schmida's T

The sixth measure of beta diversity and he considered this as the best. This index has the same elements of species loss (1) and gain (g)\ like 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: ability to detect change, additivity and independence of sample size.

Results and discussion

Arthropods collected at weekly intervals during November 2013 to January 2014 in sprayed and unsprayed tomato fields were documented, identified to the possible taxonomic level (Order, Family, Genus or Species) and various biodiversity indices were worked out are discussed. A total of 2760 individuals belonging to 14 orders and 48 families were collected from tomato ecosystem (Table 1).

Insecta

From the Table 1 the Class Insecta was the most common followed by Arachnida. Under Insecta, exopterygotes were the largest group represented by seven orders *viz.*, Orthoptera, Dictyoptera, Odonata, Hemiptera, Isoptera, Dermaptera and Thysanoptera. Whereas endopterygotes were represented by five orders *viz.*, Diptera, Hymenoptera, Lepidoptera, Coleoptera and Neuroptera.

Among exopterygotes, maximum individuals were recorded in the order Hemiptera (781) followed by Orthoptera (127), Thysanoptera (85), Odonata (22), Dermaptera (18) and Dictyoptera (11). Under Hemiptera, the most dominant family was Aphididae represented by single species *Aphis gossypii* Glover. The other taxonomically important families were; Cicadellidae, Aleyrodidae, Pentatomidae, Miridae, Anthocoridae, Membracidae, Coreidae, Meenoplidae, Lygaeidae and Delphacidae. In case of Aphididae, 136 individuals of *A. gossypii* were recorded in unsprayed tomato and 72 in sprayed field. Orthoptera was represented by five families *viz.*, Pyrgomorphidae (*Atractamorpha similis* Bolivar), Acrididae (*Trilophidia annulata* Thunberg and unidentified sp.), Gryllidae (*Gryllus* sp.), Tettigonidae (*Phaneroptera gracilis* Burmeister) and Tridactylidae (*Tridactylus* sp.) with majority of individuals from unsprayed tomato field (Table 1). In the early stage, Hemipterans were predominant indicated by the presence of large number of Aphididae and predatory mirids, *Macrolophus* sp. This was similar to the findings [21] who reported that *Macrolophus caliginosus* Wagner was colonized in tomato fields six to eight weeks after seedling transplantation. *Macrolophus* sp. were zoo phytophagous predators and were able to complete their development on tomato and other plants in the absence of prey [22]. Coleoptera was the third most dominant order with maximum number of coccinellids. Similar results were obtained [23] reported that pesticide treated plots did not cause any significant reduction in coccinellids. The reduction may be due to smaller number of aphids caused by pesticides were not enough to sustain the coccinellid population. Natural enemy complex mostly composed of predators including coccinellids *viz.*, *Menochilus sexmaculatus* (F.), *Coccinella transversalis* (F.) and *Coccinella repanda* (Th.) [24] in tomato ecosystem. The insecticides did not reduce ladybird beetle populations significantly [25]. Even when affected by pesticides; ladybird beetles could survive the insecticides or ladybird beetles in neighboring plots could emigrate in a short time to the plots where pesticides are sprayed.

Among endopterygotes, maximum individuals were recorded in the Order Diptera (458) followed by Hymenoptera (435), Coleoptera (417), Lepidoptera (182) and Neuroptera (12). Among the four families of Hymenoptera collected, majority of the individuals were from Formicidae followed by Apidae, Vespidae and Megachilidae. Order Coleoptera was represented by six families with majority of individuals belonging to Coccinellidae (181) in both spayed and unsprayed field. *Cheilomenes sexmaculata* Fabricius (163) was the more dominant species under the family Coccinellidae. Next to Coccinellidae, Curculionidae was the most important with majority of species being *Myllocerus* sp. (122). Neuropterawas represented by single family Chrysopidaewith single species *Chrysoperla zastrowi sillemi* (Esben - Petersen) (12). Under order Lepidoptera maximum number of individuals belonged to family Noctuidae (131), followed by Nymphalidae (26) and Lycaenidae (12).

The overall data revealed that the predatory arthropods *viz.*, Coccinellids and Green lace wing, *C. zastrowi sillemi* were higher in the unsprayed fields compared to sprayed fields. Similarly, *A. similis*, *Tridactylus* sp. (Orthoptera), *Oxycetonia versicolor* Fabricius, *Aulacophora foveicollis* Lucas and *Alphitobius* sp. (Coleoptera) were greater in numbers in unsprayed plots, but no differences were found in the abundance of insects in the plots treated with tetraniliprole 200 SC (Table 1).

Table 1: Diversity of arthropods in tomato ecosystem

Order	Family	Genus	Unsprayed	Sprayed	Total
Araneae	Araneidae	*Argiope* sp.	11	9	20
		Neoscona theisi (Walckenaer)	14	9	23
	Salticidae	*Plexippus paykulli* (Audouin)	7	4	11
		Harmochirus brachiatus (Thorell)	4	2	6
	Oxyopidae	*Peucetia viridana* (Hentz)	12	7	19
	Lycosidae	*Pardosa birmanica* Simon	7	2	9
		Pardosa sp.	26	14	40
	Tetragnathidae	*Tetragnatha* sp.	13	9	22
		Unidentified spider sp. 1	9	5	14
		Unidentified spider sp. 2	8	5	13
Acarina	Tetranychidae	*Tetranychus urticae* Koch	17	8	25
Orthoptera	Pyrgomorphidae	*Atractomorpha similis* Bolívar	13	8	21
	Acrididae	*Trilophidia annulata* Thunberg	13	8	21
		Unidentified grasshopper sp.	12	8	20
	Gryllidae	*Gryllus* sp.	13	8	21
	Tettigoniidae	*Phaneroptera gracilis* Burmeister	11	6	17
	Tridactylidae	*Tridactylus* sp.	16	11	27
Dictyoptera	Blattidae	*Blattella germanica* (Linnaeus)	7	4	11
Odonata	Libellulidae	*Pantala flavescens* (Fabricius)	12	10	22
Hemiptera	Cicadellidae	*Amrasca biguttula biguttula* (Ishida)	54	39	93
	Aphididae	*Aphis gossypii* Glover	136	72	208

Order	Family	Genus	Unsprayed	Sprayed	Total
	Aleyrodidae	*Bemisia tabaci* (Gennadius)	62	47	109
		Aleurodicus dispersus Russell	20	13	33
	Pentatomidae	*Nezara viridula* (Linneaus)	11	5	16
	Miridae	*Macrolophus* sp.	112	61	173
	Anthocoridae	*Orius insidiosus* (Say)	8	5	13
	Membracidae	*Oxyrachis* sp.	11	5	16
	Coreidae	*Cletus bipunctatus* Westd	10	5	15

	Meenoplidae	*Nisia atrovenosa* (Motschulsky)	19	10	29
	Lygaeidae	*Oxycarenus hyalinipennis* (Costa)	6	2	8
		Lygaeus hospes (Fabricius)	11	4	15
	Delphacidae	*Peregrinus maidis* (Ashmead)	32	21	53
Isoptera	Termitidae	*Odontotermes obesus* (Rambur)	7	3	10
Dermaptera	Labiduridae	*Labidura* sp.	9	9	18
Thysanoptera	Thripidae	*Thrips tabaci* (Lindeman)	45	40	85
Diptera	Muscidae	*Musca domestica* Linnaeus	61	55	116
	Agromyzidae	*Liriomyza trifolii* (Burgess)	207	78	285
	Sepsidae	*Sepsis* sp.	15	6	21
	Tipulidae	*Tipula* sp.	23	13	36
Hymenoptera	Formicidae	*Solenopsis geminata* (Fabricius)	105	73	178
		Camponotus compressus (Fabricius)	103	47	150
	Megachilidae	*Megachile* sp.	15	10	25

Order	Family	Genus	Unsprayed	Sprayed	Total
	Apidae	*Apis cerana indica* Fabricius	13	12	25
		Apis dorsata Fabricius	19	12	31
	Vespidae	*Polistes* sp.	7	5	12
		Delta camponiforme (Fabricius)	8	6	14
Lepidoptera	Noctuidae	*Spodoptera litura* (Fabricius)	21	12	33
		Helicoverpa armigera Hubner	58	30	88
		Trichoplusia ni (Hubner)	7	3	10
	Nymphalidae	*Danaus chrysippus* (Linnaeus)	9	8	17
		Ergolis merione (Cramer)	5	4	9
	Lycaenidae	*Lampiedes boeticus* (Linnaeus)	7	5	12
		Unidentified moth sp.	8	5	13
Coleoptera	Curculionidae	*Myllocerus* sp.	65	57	122
	Scarabaeidae	*Oxycetonia versicolor* (Fabricius)	9	6	15
	Coccinellidae	*Cheilomenes sexmaculata* (Fabricius)	90	73	163
		Chilocorus nigritus (Fabricius)	3	1	4
		Micraspis discolor (Fabricius)	10	4	14
	Chrysomelidae	*Zygogramma bicolorata* Pallister	11	8	19
		Aulacophora foveicollis (Lucas)	15	7	22
		Epitrix cucumeris (Harris)	4	2	6
		Chiridopsis bipunctata (Linnaeus)	9	3	12
	Tenebrionidae	*Alphitobius* sp.	19	14	33
	Staphylinidae	*Paederus* sp.	5	2	7
Neuroptera	Chrysopidae	*Chrysoperla zastrowi sillemi* (Esben - Petersen)	8	4	12
Total			1717	1043	2760

Arachnida

Spiders belonging to ten species and nine genera were recorded. Family Lycosidae (49) was dominant followed by Araneidae (43), Tetragnathidae (22), Oxyopidae (19), Salticidae (17) and two unidentified species. Family Lycosidae was represented by two species *viz*., *Pardosa birmanica* Simon and *Pardosa* sp. Under Araneidae majority of the species collected were *Neoscona theisi* Walckenaer (23). *Peucetia viridana* Hentz (19) was the most species collected under family Oxyopidae. Family Tetranychidae was represented by *Tetranychus urticae* Koch species (25) in both sprayed and unsprayed tomato fields. The overall data revealed that the number of spiders collected was higher in untreated plots (111) compared to the treated plots (66) (Table 1). Lycosids were nocturnal and ground-burrowing and they might have been less exposed to diurnal foliage sprays [26]. Lycosid was not showing sensitivity to the chemical spray [27]. The most abundance spiders found in tomato habitat were Lycosidae (54 individuals), and Araneidae (51) [28]. Spiders from vegetable fields of which Araneidae was the most dominant family with five species [29].

Biodiversity indices

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

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

Species richness indices

Based on calculated familial level, species number was minimum (31) during the last week of December and maximum (37) during the second month of November in sprayed tomato. Similarly in the unsprayed tomato, value was maximum in November (44) and minimum (36) during the last week of December. Based on generic and species level, species number was maximum in the month of November and minimum in the month of December (Table 2).

Based on generic and species level, the Fisher’s alpha index values were the lowest in the first week of December and maximum in the second week of November in the sprayed field, whereas in unsprayed field it was minimum in the last week of December and maximum in the first week of November (Table 3).Minimum variation was observed with Shannon - Weinerindices based on ordinal, generic, familial and species level between the sprayed and unsprayed tomato fields (Tables 4).

Table 2: Arthropod diversity in tomato 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
November	1st week	11	34	41	43	10	37	49	51
	2nd week	11	37	48	50	12	43	53	55
	3rd week	11	35	43	43	12	44	56	58
	4th week	11	34	42	43	11	43	54	56
December	1st week	8	36	41	42	12	42	52	53
	2nd week	11	35	42	42	12	43	51	51
	3rd week	14	32	35	35	14	41	50	51
	4th week	10	31	35	36	10	36	43	44
January	1st week	12	36	42	43	11	38	45	47
	2nd week	10	32	38	39	10	38	44	46

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

Month	Sampling week	Species richness indices (Fishers alpha)							
		Sprayed field				Unsprayed field			
		Ordinal	Familial	Generic	Species	Ordinal	Familial	Generic	Species
November	1st week	3.1399	18.001	25.7	28.306	2.5213	17.169	28.41	30.691
	2nd week	3.1164	20.694	34.973	38.303	2.9283	18.271	25.956	27.701
	3rd week	3.1896	19.651	29.576	29.576	2.8057	17.438	25.83	27.419
	4th week	3.128	17.858	26.707	28.014	2.5567	17.483	25.451	27.083
December	1st week	1.768	14.35	17.684	18.399	2.7139	15.257	21.26	21.926
	2nd week	3.0826	18.243	25.706	25.706	2.7811	16.544	21.694	21.694
	3rd week	4.8524	19.301	23.102	23.102	3.585	16.864	23.389	24.195
	4th week	2.9421	17.57	22.256	23.568	2.4403	15.34	20.657	21.488
January	1st week	3.603	20.726	28.152	29.576	2.7615	16.689	22.234	24.01
	2nd week	2.6875	15.363	20.876	21.913	2.5341	18.167	23.549	25.564

Table 4: Arthropod diversity in tomato 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
November	1st week	2.0252	0.0055138	3.214	0.0071089	3.4067	0.0075236	3.4622	0.0077021	1.9846	0.003913	3.2037	0.0072266	3.4664	0.0085868	3.5127	0.0087696
	2nd week	1.9918	0.0063533	3.3006	0.0078066	3.5415	0.0092441	3.5843	0.0094829	2.0773	0.0033099	3.3688	0.0053147	3.5703	0.0060095	3.6006	0.0062265
	3rd week	2.0164	0.006204	3.1503	0.010062	3.3752	0.010281	3.3752	0.010281	1.9381	0.0033419	3.2989	0.0050255	3.5206	0.005779	3.5522	0.0059639
	4th week	1.9081	0.0078344	3.1412	0.0081524	3.3446	0.0091035	3.3633	0.0093624	1.9426	0.0028998	3.2218	0.0056511	3.4475	0.0060977	3.4697	0.0063555
December	1st week	1.8366	0.0028321	2.962	0.0073618	3.1239	0.0075896	3.1325	0.007779	1.9423	0.0034434	3.1214	0.0048325	3.3331	0.0053016	3.3393	0.0054071
	2nd week	1.917	0.0072036	3.1303	0.0094891	3.2652	0.011388	3.2652	0.011388	1.9296	0.003386	3.1249	0.0059707	3.3362	0.0057566	3.3362	0.0057566
	3rd week	2.0214	0.013003	3.0755	0.011744	3.1799	0.011979	3.1799	0.011979	2.0034	0.0043639	3.0959	0.0072251	3.3076	0.0074126	3.3185	0.007573
	4th week	1.8995	0.0068552	3.0268	0.01166	3.1962	0.010559	3.2125	0.01097	1.8681	0.0036134	2.9497	0.0088803	3.1565	0.0090631	3.166	0.0092806
January	1st week	2.0184	0.0071084	3.1512	0.011496	3.3933	0.0093885	3.413	0.0096345	1.9704	0.0039587	3.0772	0.0088074	3.291	0.0086474	3.3195	0.0090337
	2nd week	2.0089	0.0042446	3.0661	0.0076426	3.2501	0.0080965	3.263	0.0083959	1.9112	0.0047249	3.129	0.0089515	3.3443	0.0078015	3.3724	0.0082155

Species dominance indices

Analysis of data based on Simpson's index, at familial level the value was maximum (25.134 and 22.77) during second week of November in sprayed and unsprayed tomato fields (Table 5). Equitability J index showed that at generic level, the value was maximum (0.85478 and 0.86174) during the second week of November in both sprayed and unsprayed field, respectively. (Table 6).

From the above indices, it is inferred that maximum number of arthropods was recorded in unsprayed tomato fields than the sprayed fields. Maximum diversity of arthropods was observed during the month of November and minimum during the month of December with most of the diversity indices.

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

Month	Sampling week	Species dominance indices (Simpson's index)							
		Sprayed field				Unsprayed field			
		Ordinal	Familial	Generic	Species	Ordinal	Familial	Generic	Species
November	1st week	6.6013	24.396	31.173	33.007	6.2063	19.895	24.329	25.118
	2nd week	6.0799	25.134	31.836	33.038	6.7222	22.77	26.313	26.686
	3rd week	6.4937	19.897	26.606	26.606	5.6938	20.494	24.15	24.507

	4th week	5.2723	21.552	26.828	27.111	6.0073	19.069	23.758	23.922
December	1st week	5.3711	13.873	15.846	15.865	5.4688	17.154	20.455	20.472
	2nd week	5.4828	18.612	19.875	19.875	5.6944	16.045	20.885	20.885
	3rd week	5.6769	19.197	21.565	21.565	6.1022	15.599	19.494	19.544
	4th week	5.8717	17.33	23.032	23.182	5.622	13.471	16.493	16.519
January	1st week	6.3607	17.703	28.048	28.39	6.1684	14.48	18.156	18.313
	2nd week	6.7579	19.455	23.68	23.778	5.5784	16.645	23.793	24.07

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

Month	Sampling week	Evenness indices (Equitability J)							
		Sprayed field				Unsprayed field			
		Ordinal	Familial	Generic	Species	Ordinal	Familial	Generic	Species
November	1st week	0.76738	0.83022	0.82224	0.8294	0.75201	0.82757	0.83666	0.84149
	2nd week	0.75475	0.85261	0.85478	0.85864	0.78713	0.87022	0.86174	0.86255
	3rd week	0.76404	0.81377	0.81464	0.80854	0.73438	0.85215	0.84974	0.85095
	4th week	0.72301	0.81142	0.80725	0.80569	0.73611	0.83225	0.8321	0.83119
December	1st week	0.69594	0.76513	0.754	0.75041	0.73598	0.80632	0.80449	0.79995
	2nd week	0.72639	0.80861	0.7881	0.7822	0.73118	0.80721	0.80522	0.7992
	3rd week	0.76596	0.79447	0.76751	0.76176	0.75914	0.79973	0.79834	0.79497
	4th week	0.71976	0.78188	0.77145	0.76958	0.70788	0.76197	0.76186	0.75845
January	1st week	0.76483	0.814	0.81901	0.81759	0.74663	0.7949	0.79433	0.79521
	2nd week	0.76123	0.79204	0.78446	0.78166	0.72418	0.80827	0.80718	0.80789

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

From 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 tomato fields. According to Whittaker's Bw the value was higher in sprayed field (0.2844) and lower in unsprayed field (0.22807) at ordinal level. Based on familial, generic level and species level all the indices value were higher in the sprayed field than the unsprayed field (Table 7).

Arthropod diversity plays a major role in maintaining the agricultural ecosystem balance and thereby completing the food web which includes, herbivore, carnivores and detritivores. More number of individuals shows the richness of the diversity. The abundance of the predator and parasiotoids is indirectly proportional to the number of herbivores. From the above result more number of individuals is present in unsprayed than the sprayed field. This is because of the interference of the tetraniliprole 200 SC application.

Biodiersity is a measurement of ecological complexity, an index of biosafety and is expected to be higher in less disturbed ecosystems. It is highly threatened by modern agriculture. Agricultural intensification through use of pesticides is significantly correlated to reduction of various taxonomic levels. Arthropod diversity in agricultural landscapes was higher in less intensely cultivated habitats[30].

The use of insecticides is very effective in the pest management system which also increases the yield and quality of the produce. In the pest management programme, along with the pest it also kills the other non-target organism and natural enemies. The major factor which determines the dominance of the species in both sprayed and unsprayed field is the heterogeneity of the space. Diversity and abundance are indirectly proportional. For the balanced ecosystem no population will be higher than the other [31]. Higher the abundance lower will be the diversity, higher the diversity lower will be abundance [32]. The study infers that the use of insecticide will lower the population of natural enemies and make them more exposed to external factors like biotic and abiotic stresses, but no significant differences were found in the abundance of insects in the plots treated with tetraniliprole 200 SC.

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

Beta diversity indices	Beta diversity							
	Sprayed field				Unsprayed field			
	Ordinal	Familial	Generic	Species	Ordinal	Familial	Generic	Species
Whittaker's Bw	0.2844	0.40351	0.54791	0.5625	0.22807	0.18519	0.26761	0.26953
Cody Bc	3.5	15	23.5	24	4	10.5	16.5	16.5
Routledge's Br	0	0.00876	0.03819	0.04141	0	0	0.0020197	0.0023725
Routledge's Bi	0.17317	0.28455	0.34783	0.35375	0.1585	0.14338	0.19681	0.19886
Routledge's Be	1.1891	1.3292	1.416	1.4244	1.1717	1.1542	1.2175	1.22
Wilson and Schimida's	0.3211	0.4386	0.5774	0.57692	0.35088	0.25926	0.33199	0.32227

Conclusion

The study infers that the use of insecticide will lower the population of natural enemies and make them more exposed to external factors like biotic and abiotic stresses, but no significant differences were found in the abundance of insects in the plots treated with tetraniliprole 200 SC.

Acknowledgement

The authors are thankful to M/s. Bayer crop Science, Ltd., India, for funding the research and Dr. Manju Siliwal, Research Associate, Wildlife Information Liaison Development Society, Dehradun for helping in spider identification.

References

1. D'Mello JPF. Food safety: Contaminants and toxins. Wallingford, CABI Publishing, 2003, 480p.
2. Sapkal SD, Sonkamble MM, Gaikwad BB. Bioefficacy of newer insecticides against tomato fruit borer, *Helicoverpa armigera* (Hubner) on tomato, *Lycopersicon esculentum* (mill) under protected cultivation. International Journal of Chemical Studies. 2018; 6(4):3326-3330.
3. Tiwari RK, Mistry NC, Singh B, Gandhi CP. Indian horticulture data base Haryana: National Horticulture Board, Ministry of Agriculture, Government of India, Gurgaon, 2013, 289p.
4. Hanafy HEM, El-Sayed W. Efficacy of Bio-And Chemical insecticides in the control of *Tuta absoluta* (Meyrick) and *Helicoverpa armigera* (Hubner) infesting tomato plants. Australian Journal of Basic and Applied Sciences. 2013; 7(2):943-948.
5. Armes NJ, Jadhav DR, Bond GS, King ABS. Insecticide resistance in *Helicoverpa armigera* in South India. Pesticide Science. 1992; 34:355-364.
6. Eisenhauer N, Sabais AC, Schonert F, Scheu S. Soil arthropods beneficially rather than detrimentally impact plant performance in experimental grassland systems of different diversity. Soil Biology and Biochemistry. 2010; 42:1418-1424.
7. Lefroy H. Indian Insect Life,Jagmander book agency, New Delhi, 1984, 786p.
8. Comstock JH. An Introduction to Entomology. Sathish book enterprises, Agra, India, 1984, 80p.
9. Richards OW, Davis RJ. General Text Book of Entomology. BI Publications private Ltd. New Delhi, 1983. 784p.
10. Ayyar TVR. Handbook of Economic Entomology for South India. Narendra Publishing House, Delhi, 1984, 180-192.
11. Poorani J. An annotated checklist of the Coccinellidae (Coleoptera) of the Indian subregion. Oriental Insects. 2002; 36:307-383.
12. Henderson PA. Practical Methods in Ecology. Blackwell Publishers, United Kingdom, 2003, 151p.
13. 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.
14. Magurran AE. The diversity of Macro Lepidoptera in two contrasting woodland habitats at Banagher, Northern Ireland. Proceeding of Royal Irish Academy. 1987; 85:121-132.
15. Batten LA. Bird communities of some Killarney woodlands. Proceeding of Royal Irish Academy. 1976; 76:285-313
16. Simpson EH. Measurement of diversity. Nature. 1949; 163:688-696.
17. Hulbert SH. The non-concept of species diversity: A critique and alternative parameters. Ecology. 1971; 52:577-586.
18. Pielou EC. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology. 1966; 13:131-144.
19. Wilson MV, Schmida A. Measuring Beta diversity with presence-absence data. Journal of Ecology. 1984; 72:1055-1064.
20. Whittaker RH. Evolution and measurement of species diversity. Taxon. 1972; 21:213-251.
21. Routledge RD. On Whittaker's components of diversity. Ecology. 1977; 58:1120-1127.
22. Alomar O, Goula M, Albajes R. Colonisation of tomato fields by predatory mirid bugs (Hemiptera: Heteroptera) in northern Spain. Agriculture Ecosystem and Environment. 2002; 89:105-115.
23. Portillo N, Alomar O, Wackers F. Nectarivory by the plant-tissue feeding predator *Macrolophus pygmaeus* Rambur (Heteroptera: Miridae): nutritional redundancy or nutritional benefit?. Journal of Insect Physiology. 2012; 58:397-401.
24. Yardim EN, Edwards CA. The influence of chemical management of pests, diseases and weeds on pests, disease and weeds on pest and predatory arthropods associated with tomatoes. Agriculture Ecosystem and Environment. 1998; 70:31-48.
25. Nalini T. Biodiversity of pests and natural enemies in tomato varieties and inter cropping ecosystems. M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, 2006, 130p.
26. Men Xingyuan, Feng Ge, Clive A, Erdal Yardim N. Influence of pesticide applications on pest and predatory arthropods associated with transgenic Bt cotton and non-transgenic cotton plants. Phytoparasitica. 2004; 32(3):246-254.
27. Mansfiel S, Dillon ML, Whitehouse MEA. Are arthropod communities in cotton really disrupted?. An assessment of insecticide regimes and evaluation of the beneficial disruption index. Agriculture Ecosystem and Environment. 2006; 113:326-335.
28. Amalin DM, Pena JE, Dungan R, Leavengood J, Koptur S. Effects of pesticides on the arthropod community in the agricultural areas near the Everglades National Park. Proceeding of the Florida State Horticulture Society. 2009; 122:429-437.
29. Memah VV, Tulung, Max Warouw, Maramis J, Redsway RTD. Diversity of spider species in some agricultural crops in north Sulawesi, Indonesia. International Journal of Science and Engineering Research. 2014; 5(6):70-75.
30. Sharma AK, Bisen UK. Taxonomic documentation of insect pest fauna of vegetable ecosystem collected in light trap. International Journal of Environmental Science and Development Monitoring. 2013; 4(3):4-11.
31. Amman K. Effects of biotechnology on biodiversity: Herbicide-tolerant and insect-resistant GM crops. Trends Biotechnology. 2005; 23:388-394.
32. Kirkpatrick L, Bailey S, Park KJ. Negative impacts of felling in exotic spruce plantations on moth diversity mitigated by remnants of deciduous tree cover. Forest Ecology Management. 2017; 404:306-315.
33. Untung K. Pengantar Pengelolaan Hama Terpadu. Gadjah Mada University Press, Yogyakarta, Indonesia, 2006, 188p.