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Evaluation on the effect of tetraniliprole 20 SC, a new chemistry of pyridine derivative to the rice arthropod biodiversity

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Abstract
A field experiment in rice was conducted to study the insecticide effect of tetraniliprole 20 SC, a new chemistry of pyridine derivative on arthropod biodiversity during 2014 in Boluvampatti, Coimbatore, India. A total of 5,095 individuals belonging to 90 species, 84 genera, 54 families and 11 orders were recorded in rice ecosystem from two classes *viz*., Insecta and Arachnida. Hemiptera and Hymenoptera were predominant in terms of individuals of exopterygota and endopterygota, respectively. Among exopterygota, maximum individuals were recorded in the order Hemiptera (781) followed by Orthoptera (127), Thysanoptera (85), Odonata (22), Dermaptera (18) and Dictyoptera (11). Under Arachnida, Araneae was the most dominant order with maximum individuals belong to Tetragnathidae. The biodiversity indices revealed that based on familial level, Species richness indices *viz.,* species number (51), Fishers alpha index (16.483), Q Statistic (16.11), Margelef D index (8.548), Shannon - Weiner index (3..2863) and Brillouin diversity index (3.063), the value was highest in unsprayed field and it was maximum in the month of October.

Keywords: Arthropod, biodiversity, tetraniliprole, pyridine derivative, rice

1. Introduction
Rice is the staple food crop in India consumed by the three fourth of the population for their livelihood. During 2013- 2014 the world production in rice has increased by 1% and trading by 8%. India has the production of 102MT, productivity 41.85 mha [1]. Rice crop is infested by more than 70 insect pests viz.., green leafhopper, stem borers, black bug, leaf folders and the leaf beetle are common pests in rice fields in which 20 of them are regular pests which caused Rs. 5, 51,200 lakh rupees, which comes out to 18.6 per cent of total loss [30]. Among the various insect pests attacking rice, leaf folder and stem borer are important. The leaf folder complex comprises of 8 species [6, 22, 33] among which, few has attained major pest status in the recent past and causes heavy yield loss when they damage the crops at tillering and boot leaf stages [26, 27]. Leaf folder, *Cnaphalocrocis medinalis* Guenee causes a loss of 60 to 70% leaf damage, [17] 76.1 per cent in grain yield and 14.6% in straw yield [29] and thus significant in causing yield losses [28, 38]. In rice ecosystem, natural enemies constitute the natural control of pests and the indiscriminate use of insecticides like organophosphates, organochlorines and synthetic pyrethroids causes the loss in beneficial organism which regulates the pest population in field [39].

Arthropod pest and predator populations in rice fields are intimately associated with each other [36]. A lot of ecological research has been done on this and many scientific publications brought out on the occurrence, abundance and diversity of arthropods, besides the variations due to topography, geographical conditions and weather conditions [14,18] relatively few of the large arrays of natural enemies, at least 188 species through its range [16] might be especially important in BPH control. The impetus for better understanding of the role of natural enemies stemmed from widespread and devasting outbreaks of *Nilaparvata lugens* Stal. associated with the early green revolution technology in tropical Asia. Spiders constitute a large part of predatory arthropod fauna in most of the ecosystems. It has a significant role to play in the ecology by being exclusively predatory and thereby regulate insect populations.

For sustainable agriculture, the beneficial organism in field should be protected from such insecticides and should avoid problems like residue and resurgence. Encouraging such beneficial organisms will decrease the usage of insecticides, cultivation cost and will avoid frequent pest outbreaks.

One such new group is phthalic acid diamide group, discovered as a novel class of insecticide having a unique chemical structure and showed excellent activity against a broad spectrum of lepidopterans. This compound has novel mode of action which binds and activates ryanodine receptors, resulting in depletion of intracellular calcium stores finally leading to muscle paralysis and death. In India, Bayer Crop Science, Mumbai has developed an insecticide, with a new chemistry of pyridine derivative, tetraniliprole 20 SC for use against lepidopteran pests.

The objective of the study is to evaluate the effect of tetraniliprole, a diamide group of insecticide on the arthropod diversity in rice ecosystem. This could help in better usage of tetraniliprole in Integrated Pest Management of rice.

2. Materials and Methods

Studies were conducted on arthropod biodiversity in rice ecosystem during 2013 at Boluvampatti, Coimbatore, Tamil Nadu. Two rounds of insecticide application were given at 15 days interval using hand operated knapsack sprayer, after 35 DAT. The various methodologies followed for survey, collection of arthropods, preservation and their identification and diversity analysis are described as follows.

2.1 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 quadrats (4 m x 4 m). Five such quadrats were chosen each at random and the entire site was covered during the sampling period.

2.1.1 Collecting devices

2.1.1.1 Active searching

Active searching was done in the early morning and evening hours. Each randomly selected quadrant was actively searched for arthropods for a period of two hours. Spiders and other wingless insects were collected by walking diagonally in the fields. Utmost care was taken while capturing them without injuring and kept in polythene bags for further studies.

2.1.1.2 Net sweeping

Flying and jumping arthropods at the ground level and under storey vegetation 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 and the entire ground level vegetation in the chosen quadrat was covered during the sweeping. Net sweeps were done between 10 a.m. to 12 noon in ground vegetation and above one feet height from the ground. The arthropods collected from each quadrat were transferred to a bucket 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.

2.1.1.3 Pitfall traps

This method was adopted to collect 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 in bunds. Five pitfall traps were placed in each of five randomly chosen spots. 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. Teepol (2-3 drops) mixed water was kept in the traps as trapping fluid and fluid was changed every week.

2.1.1.4 Rubbish traps

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 randomly. The traps were placed in the field allowing a week for arthropods to take up residence. Once in a week, these traps were removed and brought to the laboratory for arthropods collection.

2.1.2 Collection and identification of arthropods

Arthropod fauna were collected from October to December, 2014 in rice ecosystem at weekly intervals using above methods. The collected arthropods were sorted out based on 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. Insects were identified following [3, 8, 20, 32, 34] 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, Research Associate, Wildlife Information Liaison Development Society, Dehradun.

2.2 Diversity analysis of arthropods in rice ecosystem

2.2.1 Alpha diversity indices

Measures of diversity are frequently seen as indicators of the well-being of any ecosystem. They also serve as a measure of the species diversity in the ecosystem.

2.2.2 Species richness

2.2.2.1 Fisher's alpha [10]

This presents 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 gives the number of species predicted to have 1, 2, 3,…., n individuals in the sample.

2.2.2.2 Q Statistic [15]

This presents the interquartile diversity index for each sample. It measures the interquartile slope of the cumulative abundance curve and is estimated by,

$$Q = \frac{1}{2}nR_1 + \sum nr + \frac{\frac{1}{2}nR_2}{\ln\left(\frac{R_2}{R_1}\right)}$$

where,

nr - the total number of species with abundance R

$R_1 and R_2$ – 25 per cent and 75 per cent quartile of the cumulative species curve

nR_1 - the number of individuals in the class where R1 falls

nR_2 - the number of individuals in the class where R2 falls

2.2.2.3 Species [21]
This represents the total number of species in each sample.

2.2.2.4 Margalef's D [7]
Margalef's D has been a favourite index for many years.

$$D_{Mg} = \frac{(S-1)}{\ln N}$$

where,

S - total number of species recorded

N - the total number of individuals summed overall S species

2.2.2.5 Shannon diversity index [4]
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

2.2.2.6 Brillouin diversity index [21]
The Brillouin index H is calculated as follows:

$$H = \ln N! - \sum_{i=1}^{s} \frac{\ln n_i!}{N}$$

where,

N - is the total number of individuals in the sample

n_i - is the number of individuals belonging to the i[th] species and s is the species number.

2.2.3 Species Dominance indices

2.2.3.1 Simpson's index [37]
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

2.2.3.2 Berger Parker diversity index [5]
A simple dominance measure is the Berger Parker index. The index expresses the proportional importance of the most abundant species.

$$d = \frac{N_{max}}{N}$$

where,

N_{max} - is the number of individuals in the most abundant species

N - is the number of individuals in the sample

This simple index was considered by [4] to be one of the best. It is simple measure of the numerical importance of the most abundant species.

2.2.3.3 McIntosh index [24]
This index was calculated using the following formula proposed by McIntosh [24] as

$$D = \frac{N \quad U}{N - \sqrt{N}}$$

where,

N is the total number of individuals in the sample

U is given by the expression,

$$U = \sqrt{\sum n_i^2}$$

Where, n_i is the number of individuals belonging to the i[th] species and the summation is undertaken for over all species.

2.2.3.4 Evenness indices [31]
Evenness (E) is a measure of how similar the abundances of different species or categories are in a community. When all species in a community are equally abundant, the evenness index should be maximum and decrease towards zero as the relative abundances of the species diverge away from evenness closer to zero. It indicates that most of the individuals belong to one or a few species or categories, when the evenness is close to one; it indicates that each species / category consists of the 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

2.2.3.5 Equitability J [21]
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 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)

2.2.3.6 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 and described below are those considered by Wilson and Schmida (1984).

2.2.3.7 Whittaker's measure, βw
The first and one of the most straight forward measures of beta diversity was introduced by Whittaker (1972)

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

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).

2.2.3.7 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) is the number of species gained and 1(H) the number lost moving along the transect.

2.2.3.8 Routledge's R, I and E
Routledge (1977) was concerned with how diversity measures can be portioned into alpha and beta components. The following three indices were derived from his work. 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
$\beta_E = \exp(\beta_I) - 1$

2.2.3.9 Wilson and Schmida's T [41]
Wilson and Schmida [41] 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: ability to detect change, additivity and independence of sample size. Wilson and Schmida concluded this as the best.

2.3 Statistical Analysis
The above given indices were used to assess and compare the diversity and distribution of arthropods in tomato and rice ecosystem. Species richness and diversity version ii (Pisces Conservation Ltd., *www.irchouse. demon.co.uk*) [11] programmes were used to assess and compare the diversity of arthropods in sprayed and unsprayed tomato ecosystem and rice ecosystem.

3. Result and Discussion
Arthropods collected at weekly intervals from October to December (2014) for four weeks in rice field were documented, identified to the possible taxonomic level (Order, Family, Genus or Species) and various biodiversity indices were worked out. The survey yielded a wide array of 89 species under 83 genera belonged to 54 families and 11 orders.
Table 1, shows that totally 5,095 arthropods were collected of which maximum number of individuals belonged to Class Insecta (4593) and Arachnida (442).

3.1 Insecta
Under Insecta, majority of individuals belonged to the division Exopterygota followed by Endopterygota (Table 1).

3.1.1 Exopterygota
The Exopterygota (2856) were represented by Orthoptera, Mantodea, Odonata, Hemiptera and Dermaptera, among which hemipterans were the most abundant (Table 1). Totally 10 families of Hemiptera were collected with the majority of individuals fall under the family Cicadellidae (791) followed by Delphacidae (514), Pentatomidae (303), Alydidae (274), Gerridae (133), Miridae (110), Meenoplidae (82), Reduvidae (65), Lophopidae (12) and Coreidae (11).
Cicadellidae was represented by five genera with majority of individuals from the genus *Nephotettix virescens* Distant (247) followed by *Recilia dorsalis* (Motschulsky) (192). Under the family Delphacidae, *Nilaparvata lugens* Stal (322) was dominant. Similarly, *Pygomenida varipennis* Westwood (146) was dominant insects under the family Pentatomidae. Under the order Orthoptera, Acrididae (44) was the dominant family followed by Gryllidae (24). Acrididae was represented by the genus *Oxya* sp. Most of the orthopterans collected belonged to Acrididae and Gryllidae [2].
Under Odonata, Coenagrionidae (216) was the dominant family followed by Libellulidae (193). *Agriocnemis rubricauda* Tillyard (156) was the most common species collected under the family Coenagrionidae. *Orthetrum sabina* (Drury) (72) was dominant under the family Libellulidae. Under the order Mantodea, 6 individuals of *Mantidae* sp. was collected. The order Dermaptera was represented by single individual species of ear wig (32). Maximum number of leaf and plant hoppers during vegetative stage [9]. The least diverse were Mantodea, Orthoptera and Dermatpera.

3.1.2 Endopterygota
Endopterygota was represented by five orders *viz*., Diptera, Hymenoptera, Lepidoptera, Coleoptera and Neuroptera of which Hymenoptera was the most dominant order.
Hymenoptera was represented by six families. Maximum number of individuals were collected under the family

Formicidae (551), followed by Apidae (104), Vespidae (41), Ichneumonidae (37), Crabronidae (10) and Braconidae (6). The majority of individuals from Formicidae were represented by the genus *Solenopsis geminate* Fabricius (322). Genus *Apis* was dominant under the family Apidae. The reason that could be attributed to the dominance of Hymenoptera was due to high abundance of ants *Solenopsis geminata* Fabricus and *Camponotus* sp. in the collection. The natural enemies from the family Formicidae were more tolerant to the insecticides compared to the other families [13].

Totally six families of Lepidoptera were collected. The greatest number of individuals were collected under the family Crambidae (272) followed by Hesperidae (122) and Pyralidae (94). Only one individual was found in Noctuidae (Table 1). Among the lepidopterans, except *Otheris* sp. all the species were found throughout the study period.

Coleoptera was represented by eight families with maximum number of individuals collected belonging to the family Chrysomelidae (141) followed by Coccinellidae (103), Staphylinidae (61) and Carabidae (50). Family Curculionidae and Melyridae were represented by *Myllocerus* sp. (15) and *Apalochrus* sp. (6), respectively. Individuals of families Elateridae and Lampyridae were less in number. The insecticides did not reduce ladybird beetle populations significantly. 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 [25].

Dipterans were represented by six families *viz*., Stratiomyidae (74) and Tipulidae (27). *Hedriodiscus* sp (74) was dominant in the family Stratiomyidae. Order Neuroptera was represented by a single family Myrmeleontidae (4) represented by the genus *Myrmeleon* sp.

3.2 Arachnida

A total of 18 species of spiders from nine families were recorded. The majority of families represented under order Araneae belonged to Tetragnathidae (125) followed by Lycosidae (100), Oxyopidae (65), Araneidae (58), Clubionidae (28), Salticidae (21) and unidentified sp. (21). Minor families recorded were Thomisidae (19) and Philodromidae (5) (Table 1).

Family Tetragnathidae was represented by three species *viz*., *Tetragnatha javana*, *Tetragnatha* sp. and *Tylorida striata* Thorell. Majority of the genus collected were *Tetragnatha* (97). *T. javanas,* is one of the common spider found in rice ecosystem and they effectively reduce the population of green leafhoppers and brown planthoppers [23]. Lycosidae was represented by *Lycosa* sp, *Pardosa* sp., *Pardosa birmanica* Simon, *Hippasa* sp. and unidentified sp. with majority of individuals from *Hippasa* (26). *Oxyopes javanus* Thorell (30) was found abundant in the family Oxyopidae. Under Araneidae, majority of the species recorded was *Argiope* sp. (32) and *Neoscona* sp. (26).

3.3 Biodiversity indices

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

3.3.1.1 Species richness indices. Based on the calculated ordinal and familial level (Table 2), numbers in sprayed filed was maximum in the first week of December (10 and 43, respectively) and minimum in the month of November (9 and 36, respectively). The ordinal, familial, generic and species level numbers in unsprayed field was minimum in the third week of November (9, 39, 64 and 69, respectively) and maximum in the first week of October (11, 51, 80 and 87, respectively).

Based on generic and species level analysis, the Fishers alpha index value was the highest during the first week of October (30.615 and 35.03, respectively) and the value was minimum in the second week of November (23.342 and 26.191, respectively) in sprayed field. In unsprayed field, it was minimum in last week of November (19.898 and 21.4448, respectively) and maximum in first week of October (32.576 and 37.302, respectively) (Table 3).

From Table 4 it could be seen that the Q statistic value based on familial level varied between a minimum of 10.82 during the third week of November and maximum of 15.533 in the first week of October in sprayed rice. In unsprayed rice field, the index value was the highest during the first week of October (16.11) and the lowest during the last week of November (10.563).

Analysis of data using Margalef's D is presented in Table 5. The index value based on ordinal and familial recorded no significant variance in both sprayed and unsprayed rice field. On the generic level, the value was maximum in the first week of October (11.605) and minimum in the second week of November (9.9867) in sprayed rice. In unsprayed rice, the value was the highest in the first week of October (13.506) and the lowest in the last week of November (9.7447). The Shannon –Weiner index calculated based on the four taxonomic levels are presented in Table 6. The index value based on ordinal, generic, familial and species in sprayed rice was equal to unsprayed filed.

Brillouin diversity index (Table 7) showed minimum variation in the index value on analysis based on ordinal, generic, familial and species level between the sprayed and unsprayed rice.

The Simpson's index calculated based on ordinal level revealed maximum during the third week of October (4.3999) and minimum during December (3.0378) in sprayed rice. In unsprayed rice, the minimum was during the last week of November (3.1392) and maximum during December (4.3897) (Table 8).

Berger Parker diversity index was calculated based on the four taxonomic levels. The index value was higher in unsprayed rice than sprayed field (Table 9). McIntosh index also showed no clear variation in index values on the four taxonomic levels in both sprayed and unsprayed rice (Table 10).

Evenness indices (Equitability) also observed clear variation in the values of familial level: the maximum (0.79232) in sprayed and (0.82385) unsprayed was noticed on first week of October (Table 11). Spiders in rice fields are major components that act as predators in decreasing the planthopper and leafhopper [14]. Spider populations were not affected by insecticide applications even though there was a drop in numbers of many arthropods including insect pests [19]. The reasons for this were that the insecticides in the market had some level of selectivity and that rice field spiders may have developed resistance. Hence, the decreasing spider populations in previous studies were attributed to their prey rather than the insecticides.

In Beta diversity indices, according to Whittaker's Bw the value was higher in sprayed field (0.3333) and lower in unsprayed field (0.2430) at familial level. Based on ordinal, generic level and species level all the indices value were higher in the sprayed field than the unsprayed field (Table 12). The maximum number of arthropods was observed in unsprayed rice than sprayed field. The maximum diversity of arthropods occurred in the month of October with most of the diversity indices.

Table 1: Diversity of arthropods in rice ecosystem

Order	Family	Genus	Unsprayed	Sprayed	Total
Araneae	Araneidae	*Argiope* sp.	19	13	32
		Neoscona sp.	16	10	26
	Clubionidae	*Clubiona* sp.	18	10	28
	Lycosidae	*Lycosa* sp.	14	9	23
		Unidentified spider sp.1	11	7	18
		Pardosa sp.	14	9	23
		Pardosa birmanica Simon, 1884	7	3	10
		Hippasa sp.	16	10	26
	Oxyopidae	*Oxyopes javanus* Thorell	18	12	30
		Oxyopes sp.	13	9	22
		Peucetia viridana (Hentz)	10	3	13
	Philodromidae	*Philodromus rufus* Walckenaer	3	2	5
	Salticidae	*Plexippus paykulli* (Audouin)	12	9	21
	Tetragnathidae	*Tetragnatha javana* (Thorell)	44	34	78
		Tetragnatha sp.	13	6	19
		Tylorida striata (Thorell)	16	12	28
	Thomisidae	*Thomisus* sp.	11	8	19
		Unidentified spider sp.2	13	8	21
Orthoptera	Acrididae	*Oxya* sp.	15	10	25
		Acrida turricata (Linnaeus)	4	2	6
		Acrida exaltata (Walker)	8	5	13
	Tettigoniidae	*Conocephalus longipennis* (Haan)	6	5	11
	Gryllidae	*Anaxipha longipennis* (Serville)	6	4	10
		Gryllus sp.	7	7	14
	Pyrgomorphidae	*Neorthacris simulans* (Bolivar)	5	3	8
Mantodea	Mantidae	*Mantis* sp.	4	2	6
Odonata	Coenagrionidae	*Agriocnemis rubricauda* Tillyard	81	75	156
		Ceriagrion rubiae Laidlaw	15	9	24
		Ischnura aurora (Brauer)	13	8	21
		Enallagma sp.	9	6	15
	Libellulidae	*Crocothemis servilia* (Drury)	32	21	53
		Orthetrum sabina (Drury)	41	31	72
		Brachythemis contaminata (Fabricius)	26	18	44
		Diplacodes trivialis (Rambur)	14	10	24
Hemiptera	Reduviidae	*Polytoxus fuscovittatus* (Stal)	34	31	65
	Gerridae	*Limnogonus fossarum* (Fabricius)	68	65	133
	Miridae	*Cyrtorhinus lividipennis* Reuter	71	39	110
	Alydidae	*Leptocorisa oratorius* (Fabricius)	155	119	274
	Pentatomidae	*Pygomenida varipennis* (Westwood)	88	58	146
		Eysarcoris sp.	45	37	82
		Nezara viridula (Linnaeus)	26	18	44
		Scotinophara lurida (Burmeister)	7	4	11
		Unidentified stink bug sp.	11	9	20
	Delphacidae	*Nilaparvata lugens* (Stal)	211	111	322
		Sogatella furcifera (Horvath)	143	76	219
	Cicadellidae	*Nephotettix cincticeps* (Uhler)	92	63	155
		Nephotettix virescens (Distant)	141	106	247
		Recilia dorsalis (Motschulsky)	109	83	192
		Cofana spectra (Distant)	87	54	141
		Amrasca biguttula biguttula (Ishida)	36	20	56
	Meenoplidae	*Nisia atrovenosa* (Motschulsky).	50	32	82
	Coreidae	*Cletus bipunctatus* Westd	7	4	11
	Lophopidae	*Pyrilla perpusilla* Walker	6	6	12
Dermaptera		Unidentified ear wig sp.	19	13	32
Diptera	Muscidae	*Musca* sp.	13	6	19
	Tachinidae	*Argyrophylax nigrotibialis* (Baranov)	11	9	20
	Stratiomyidae	*Hedriodiscus* sp.	41	33	74
	Platystomatidae	*Rivellia* sp.	7	3	10
	Tipulidae	*Tipula* sp.	17	10	27
	Syrphidae	*Syrpha* sp.	7	5	12
Hymenoptera	Ichneumonidae	*Xanthopimpla flavolineata* Cameron	25	12	37
	Braconidae	*Microctonus hyperodae* Loan	5	1	6
	Apidae	*Apis* sp.	14	7	21
		Apis dorsata Fabricius	52	31	83
	Formicidae	*Camponotus* sp.	132	97	229
		Solenopsis geminata (Fabricius)	181	141	322
	Vespidae	*Ropalidia spatulata* Vecht	24	15	39
		Vespa cincta Drury	2	1	3
	Crabronidae	*Cerceris* sp.	7	3	10
Lepidoptera	Crambidae	*Scirpophaga incertulas* Walker	102	55	157
		Parapoynx stagnalis Zeller	72	43	115

	Lycaenidae	*Lampiedes boeticus* (Linnaeus)	5	1	6
	Noctuidae	*Otheris* sp.	1	0	1
	Hesperidae	*Pelopidas mathias* Fabricius	74	48	122
	Satyridae	*Melanitis leda* Linnaeus	2	0	2
	Pyralidae	*Cnaphalocrocis medinalis* Guenee	56	38	94
Coleoptera	Coccinellidae	*Adalia bipunctata* (Linnaeus)	29	20	49
		Cheilomenes sexmaculata (Fabricius)	16	11	27
		Micraspis discolor (Fabricius)	10	5	15
		Harmonia octomaculata (Fabricius)	7	5	12
	Chrysomelidae	*Leptispa pygmaea* Baly	70	53	123
		Menolepta sp.	3	2	5
		Aulacophora foveicollis (Lucas)	9	4	13
	Carabidae	*Ophionea nigrofasciata* (Schmidt-Goebel)	27	23	50
	Staphylinidae	*Paederus fuscipes* Curtis	35	26	61
	Melyridae	*Apalochrus* sp.	4	2	6
	Curculionidae	*Myllocerus* sp.	9	6	15
	Elateridae	Unidentified click beetle sp. 1	2	3	5
	Lampyridae	Unidentified sp. 2	2	1	3
Neuroptera	Myrmeleontidae	*Myrmeleon* sp.	3	1	4
		Total	3036	2059	5095

Table 2: Arthropod diversity in rice 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
October	1st week	9	42	63	68	11	51	80	87
	2nd week	9	38	57	61	9	45	72	78
	3rd week	9	39	59	63	10	42	64	70
	4th week	9	40	59	63	10	44	68	73
November	1st week	9	36	56	60	10	44	68	73
	2nd week	10	38	55	59	9	40	64	70
	3rd week	9	36	59	62	9	39	64	69
	4th week	10	39	61	63	10	39	58	61
December	1st week	10	43	68	73	10	47	73	79

Table 3: Arthropod diversity in rice 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
October	1st week	1.9159	15.824	30.615	35.03	2.1659	16.483	32.576	37.302
	2nd week	1.9234	13.689	26.077	29.273	1.6934	13.828	27.744	31.458
	3rd week	1.9577	14.738	28.972	32.538	1.9271	12.528	23.121	26.512
	4th week	1.9159	14.686	27.368	30.615	1.9462	13.612	25.935	28.972
November	1st week	1.931	12.713	25.567	28.755	1.9245	13.346	25.278	28.209
	2nd week	2.1522	13.159	23.342	26.191	1.7146	11.97	23.814	27.361
	3rd week	1.8901	12.226	26.428	28.726	1.6877	11.244	22.985	25.771
	4th week	2.0988	13.073	26.04	27.452	1.9245	11.269	19.898	21.448
December	1st week	1.9192	12.859	25.126	28.03	1.9934	15.639	30.71	34.962

Table 4: Arthropod diversity in rice ecosystem - Alpha diversity (Q Statistic)

Month	Sampling week	Species richness indices (Q Statistic)							
		Sprayed field				Unsprayed field			
		Ordinal level	Familial level	Generic level	Species level	Ordinal level	Familial level	Generic level	Species level
October	1st week	4.0782	15.533	24.886	27.051	2.4423	16.11	30.445	33.863
	2nd week	2.7873	12.557	21.64	23.444	4.2146	12.984	24.836	27.068
	3rd week	3.641	13.116	23.083	23.804	2.8825	14.427	21.552	21.766
	4th week	3.641	12.557	23.211	25.487	2.6935	13.297	21.07	25.785
November	1st week	2.4122	11.441	19.572	20.919	3.1067	12.743	20.042	22.603
	2nd week	3.7453	12.837	19.572	20.193	3.1357	11.15	18.274	20.042
	3rd week	3.2464	10.82	22.722	23.444	2.5251	13.706	21.487	25.164
	4th week	2.6712	10.923	20.193	21.125	2.6712	10.563	15.929	16.831
December	1st week	2.4653	12.022	20.299	22.883	2.5328	12.061	25.475	28.271

Table 5: Arthropod diversity in rice ecosystem - Alpha diversity (Margalef's D)

Month	Sampling week	Species richness indices (Margalef's D)							
		Sprayed field				Unsprayed field			
		Ordinal level	Familial level	Generic level	Species level	Ordinal level	Familial level	Generic level	Species level
October	1st week	1.4975	7.6745	11.605	12.541	1.7096	8.548	13.506	14.703
	2nd week	1.5015	6.9446	10.511	11.262	1.3697	7.5334	12.156	13.183
	3rd week	1.5201	7.2206	11.021	11.781	1.5402	7.0163	10.781	11.808
	4th week	1.4975	7.3002	10.857	11.605	1.5512	7.4111	11.548	12.409
November	1st week	1.5057	6.5874	10.352	11.104	1.5386	7.3513	11.454	12.309
	2nd week	1.6645	6.8428	9.9867	10.726	1.3824	6.7394	10.887	11.923
	3rd week	1.4832	6.4891	10.753	11.31	1.3663	6.4901	10.76	11.614
	4th week	1.636	6.9075	10.907	11.27	1.5386	6.4965	9.7447	10.258
December	1st week	1.5356	7.1663	11.432	12.285	1.5779	8.0648	12.623	13.675

Table 6: Arthropod diversity in rice 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
October	1st week	1.7705	0.003673	3.1606	0.0055745	3.7461	0.0043779	3.8454	0.0041391	1.7946	0.0025094	3.2863	0.003603	3.9549	0.0026929	4.0524	0.0026416
	2nd week	1.6668	0.004112	3.0279	0.0057196	3.6427	0.0042788	3.7286	0.0041652	1.6884	0.0024155	3.1628	0.0034609	3.8209	0.0027434	3.9208	0.0026319
	3rd week	1.7599	0.00379	3.1528	0.0054997	3.6967	0.0046368	3.7908	0.0041789	1.7203	0.0026387	3.1288	0.0033851	3.721	0.0025502	3.8052	0.0025501
	4th week	1.675	0.004214	3.0534	0.0059284	3.6039	0.0047586	3.6752	0.0048572	1.7467	0.0024483	3.1713	0.0034327	3.7346	0.0029217	3.8181	0.0028857
November	1st week	1.6904	0.0037	3.0104	0.0054318	3.586	0.0046422	3.652	0.0047541	1.7085	0.002399	3.1027	0.003584	3.7009	0.0028642	3.7776	0.0028651
	2nd week	1.6842	0.004353	3.0214	0.0054519	3.5618	0.0042636	3.6331	0.0043237	1.6218	0.0026652	3.0799	0.003268	3.6673	0.0028669	3.7332	0.0030161
	3rd week	1.7446	0.003534	3.0839	0.0043656	3.6292	0.0045443	3.7083	0.0041888	1.5848	0.0029298	2.99	0.0035647	3.6097	0.0031088	3.7068	0.0029357
	4th week	1.7517	0.003533	3.1573	0.0037244	3.6967	0.0034445	3.7413	0.0033927	1.557	0.0033731	2.8981	0.0039654	3.4867	0.0029949	3.547	0.0029575
December	1st week	1.5186	0.003312	2.9609	0.0040124	3.5899	0.0034091	3.6797	0.0033084	1.784	0.0026454	3.2848	0.0031233	3.8823	0.0027737	3.9689	0.0028519

Table 7: Arthropod diversity in rice ecosystem - Alpha diversity (Brillouin diversity index)

Month	Sampling week	Species richness indices (Brillouin diversity index)							
		Sprayed field				Unsprayed field			
		Ordinal level	Familial level	Generic level	Species level	Ordinal level	Familial level	Generic level	Species level
October	1st week	1.6902	2.8796	3.3487	3.4241	1.7349	3.063	3.624	3.6997
	2nd week	1.5895	2.7679	3.2707	3.336	1.6362	2.9598	3.5159	3.5962
	3rd week	1.6759	2.8668	3.2945	3.3681	1.6641	2.934	3.4413	3.5077
	4th week	1.5972	2.788	3.235	3.2872	1.689	2.9645	3.4376	3.504
November	1st week	1.6128	2.7566	3.2196	3.2673	1.6539	2.9068	3.4174	3.4785
	2nd week	1.6064	2.7749	3.2227	3.2763	1.5692	2.8871	3.382	3.4308
	3rd week	1.6689	2.8393	3.2681	3.3323	1.5337	2.8108	3.34	3.421
	4th week	1.6778	2.9185	3.353	3.3881	1.5031	2.7228	3.2391	3.2893
December	1st week	1.4666	2.7766	3.3161	3.3902	1.7204	3.0527	3.541	3.6058

Table 8: Arthropod diversity in rice 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
October	1st week	4.3726	16.656	35.516	41.72	4.3191	17.656	40.782	46.392
	2nd week	3.8757	14.552	32.139	36.094	3.8988	15.928	35.433	40.715
	3rd week	4.3999	16.859	33.934	41.082	3.945	15.239	32.356	35.855
	4th week	3.8731	14.491	30.022	32.201	4.2262	16.366	32.393	35.907
November	1st week	4.1179	14.49	29.671	31.738	4.0658	14.717	30.88	33.612
	2nd week	3.7872	14.04	27.906	30.004	3.6307	15.454	30.871	32.863
	3rd week	4.2152	16.321	29.271	33.739	3.3469	13.051	26.681	30.904
	4th week	4.1537	18.248	34.317	36.274	3.1392	11.507	24.304	26.044
December	1st week	3.0378	12.151	25.626	28.974	4.3897	20.929	41.489	45.121

Table 9: Arthropod diversity in rice ecosystem - Alpha diversity (Berger Parker diversity index)

Month	Sampling week	Species dominance indices (Berger Parker diversity index)							
		Sprayed field				Unsprayed field			
		Ordinal level	Familial level	Generic level	Species level	Ordinal level	Familial level	Generic level	Species level
October	1st week	0.41627	0.15311	0.08612	0.07177	0.42363	0.14697	0.07493	0.05764
	2nd week	0.45146	0.15534	0.08738	0.08738	0.45349	0.15116	0.07849	0.06105
	3rd week	0.41451	0.1658	0.09845	0.057	0.45217	0.14783	0.08116	0.08116
	4th week	0.44976	0.16268	0.08612	0.08612	0.42296	0.15106	0.07855	0.07251
November	1st week	0.42857	0.16256	0.08867	0.08867	0.42939	0.15274	0.08357	0.08357
	2nd week	0.46188	0.14798	0.08969	0.08969	0.47546	0.15337	0.07976	0.07669
	3rd week	0.43182	0.15909	0.1	0.09091	0.5043	0.18338	0.10029	0.08596
	4th week	0.43673	0.11429	0.08163	0.08163	0.52738	0.18444	0.10951	0.10951
December	1st week	0.53846	0.19088	0.10256	0.08262	0.41667	0.1	0.06667	0.06667

Table 10: Arthropod diversity in rice ecosystem - (McIntosh, 1967)

Month	Sampling week	Species dominance indices (McIntosh, 1967)							
		Sprayed field				Unsprayed field			
		Ordinal level	Familial level	Generic level	Species level	Ordinal level	Familial level	Generic level	Species level
October	1st week	0.55642	0.80139	0.87973	0.8925	0.54583	0.79928	0.88203	0.89175
	2nd week	0.5251	0.784	0.87146	0.88134	0.51943	0.78646	0.87075	0.88204
	3rd week	0.55935	0.80456	0.87742	0.89281	0.52251	0.78063	0.86284	0.87169
	4th week	0.52469	0.78313	0.86507	0.87135	0.54093	0.7906	0.86363	0.8725
November	1st week	0.54144	0.78371	0.86456	0.87064	0.53034	0.77588	0.85855	0.86608
	2nd week	0.5176	0.7775	0.85699	0.86377	0.50081	0.78343	0.85956	0.86515
	3rd week	0.54621	0.79778	0.86175	0.87443	0.47709	0.75909	0.84462	0.85852
	4th week	0.54074	0.80952	0.87389	0.87854	0.45847	0.74053	0.8353	0.84232
December	1st week	0.44853	0.74856	0.84051	0.85246	0.55189	0.82171	0.88574	0.89206

Table 11: Arthropod diversity in rice 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
October	1st week	0.73837	0.79232	0.84775	0.85456	0.74839	0.82385	0.89501	0.90056
	2nd week	0.6951	0.75906	0.82436	0.8286	0.7041	0.79289	0.86468	0.87133
	3rd week	0.73393	0.79037	0.83657	0.84243	0.71742	0.78436	0.84207	0.84563
	4th week	0.69853	0.76545	0.81559	0.81675	0.72845	0.79501	0.84516	0.8485
November	1st week	0.70495	0.75467	0.81152	0.81158	0.71248	0.77782	0.83753	0.83951
	2nd week	0.70236	0.75744	0.80604	0.80739	0.67635	0.77209	0.82993	0.82964
	3rd week	0.72755	0.7731	0.82131	0.8241	0.66092	0.74957	0.81688	0.82377
	4th week	0.73051	0.7915	0.83657	0.83144	0.64933	0.72652	0.78906	0.78826
December	1st week	0.6333	0.74227	0.8124	0.81774	0.74399	0.82347	0.87858	0.88202

Table 12: Beta diversity of arthropods in rice 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	0.17857	0.33333	0.35754	0.38462	0.125	0.24297	0.22259	0.22727
Cody Bc	1.5	9.5	15.5	17.5	0.5	5	6.5	7
Routledge's Br	0.016807	0.03761	0.03764	0.0403	0	0.0132	0.0079	0.00746
Routledge's Bi	0.060708	0.17661	0.20698	0.22655	0.07225	0.14537	0.14014	0.14392
Routledge's Be	1.0626	1.1932	1.23	1.2543	1.0749	1.1565	1.1504	1.1548
Wilson and Schimida's	0.06071	0.24359	0.25978	0.27535	0.05114	0.11509	0.09575	0.09546

4. Conclusion
The present investigation clearly revealed that the natural enemies were initially decreased at the time of application and later on recolonization was noticed in all the treated plots of tomato and rice trials. Hence, agriculturists and farmers should have a clear understanding of the nature of the pesticides they apply and they should be cautious in applying the pesticides according to the formulation and in appropriate quantity so as to avoid distortion and destruction of the ecosystem. Hence new chemistry tetraniliprole can be a suitable candidate for inclusion in Integrated Pest Management to borers and defoliators as it is comparatively less toxic to natural enemies in the tomato and rice ecosystems.

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