Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(5): 447-454

Received: 29-07-2017
Accepted: 30-08-2017

A Kuzhandhaivel Pillai
Department of Agricultural Entomology, Center for Plant Protection Studies (CPPS), Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

M Ganesh Kumar
Department of Agricultural Entomology, Center for Plant Protection Studies (CPPS), Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

S Kuttalam
Department of Agricultural Entomology, Center for Plant Protection Studies (CPPS), Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Correspondence
A Kuzhandhaivel Pillai
Department of Agricultural Entomology, Center for Plant Protection Studies (CPPS), Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Computation of arthropod biodiversity in grapes ecosystem

A Kuzhandhaivel Pillai, M Ganesh Kumar and S Kuttalam

Abstract
A field experiment was conducted to inventorize the arthropods diversity in grapes ecosystem during November 2013 to February 2014 in Coimbatore, Tamil Nadu (India). 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. The field was kept free from pesticide application. A total of 2983 individuals belonging to 12 orders and 44 families with 68 species were collected from grapes ecosystem. The class Insecta (2650 individuals) was the most dominant followed by Arachnida (333 individuals). In Insecta, exopterygota were represented by six orders and endopterygota were represented by five orders. In class, Arachnida, a total of 16 species recorded from seven families. Lycosidae was the dominant family followed by Salticidae. The biodiversity indices were worked out and at species level the alpha and Shanon-weiner indices were the highest during the second week of January (19.838 and 3.4245). The evenness index based on ordinal, generic and species level the value was the highest during the second week of January (0.83474, 0.80162 and 0.81158, respectively). This study stand as a base for further research in the biodiversity of arthropods in grapes ecosystem.

Keywords: Grapes, arthropod biodiversity, ecosystem

Introduction
Grapevine (*Vitis vinifera* L.) is the second most commercially important fruit crop of the world. It is grown in temperate to semi tropic and the tropics. In India, it occupies an area of about 1.180 lakh hectares with an annual production of 24.830 lakh tons. In Tamil Nadu, about 2,680 hectares are under grapes cultivation with an annual production of 43,380 tons [1]. Surveys conducted on pests of grapes in 1991-1992 revealed the infestation of 22 species of insect and mites. Among these, *Maconellicoccus hirsutus* (Green) and *Scirtothrips dorsalis* Hood were the major insect pests [2]. The productivity of the crop is low in the majority areas due to insect pests apart from diseases. In grapes, 94 species of insect pests have been reported from India [3]. The major insect pests in grapevine were found leafhopper, *Erythroneura* sp., grapevine thrips, *Rhipiphorothrips cruentatus* Hood, leaf-roller, *Sylepta lunalis* Guenee, grapevine beetle, *Sinoxylon anale* Lesne, grapevine-girdler, *Sthenias grisator* Fabricius and flea beetle, *Scelodonta strigicollis* Moltschulsky. Other minor insect pests include jassid, *Arboridia viniferata* Sohi and Sandhu, mealybugs, *Pseudococcus* sp., the hornworm, *Theretra alecto* L., the grapevine sphinx, *Hippotion celerio* (L.), wasps, *Polistes hebraeus* (Fabricius), *Vespa orientalis* L. and mite, *Oligonychus punicae* (Hirst) [4, 5].
Worldwide grapevine pests reviewed and reported a total of 459 insects (Dermaptera-2, Orthoptera-17, Isoptera-12, Hemiptera-116, Thysanoptera-34, Lepidoptera-106, Diptera-12, Hymenoptera-26 and Coleoptra-134) that were known to attack different parts of grapevine [6].
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 ecosystem such as pollination, soil structure and function, decomposition and nutrient recycling, natural enemies of pest species, prey for highly valued vertebrate, etc. [7]. They have short generation times and respond quickly to ecological changes. Further, various arthropod taxa have been used to detect anthropogenic impact on ecosystems including agriculture and climate change [8, 9]. Spiders (Arachnida: Araneae) are so diverse arthropods that they have attained seventh rank in diversity [10] and are predaceous arthropods which largely feed on insects, their larvae and eggs. There are evidences that species rich ecosystems are more stable than species poor ecosystems. It has recently been established that arthropod predators suppress the pest populations [11]

(Although several researches published reports on pests of grapes elsewhere. The information about the arthropod community and their importance in the grapes ecosystem is limited. Keeping this in view the present investigation was carried out to calculate the biodiversity of arthropods in grapes ecosystem.

Materials and Methods

A field experiment was conducted to inventorize the arthropod population in grapes during November-2013 to February-2014 at farmer field, Krishnapuram Pudhur, Coimbatore on the grape variety Panner.

1. Sampling methods

To develop a 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 collections, the field (1600 m^2 area) was divided into 100 quadrats (4 m x 4 m). Five such quadrates were chosen for each method at random and the entire field was covered during the sampling period.

a. Active searching

Active searching was done in the early morning. 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. Five 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 polyethylene 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 in to the soil to a depth of 20 cm. Five pitfall traps were placed in each of five randomly chosen 4 x 4 m quadrates (total of 25 pit fall traps). The traps were inspected and specimens were collected on every morning at 8 am. The water with two to three drops of teepol was kept in the traps as trapping fluid and fluid was changed every week. 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 per cent 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 [12-16] 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 grape and okra ecosystems. Species richness and diversity version ii (Pisces Conservation Ltd., *www.irchouse. demon.co.uk*) [17] programmes were used to assess and compare the diversity of arthropods in grape, sprayed and unsprayed okra ecosystems.

1. Species richness indices

i. Species number [18]

This represents the total number of species in each sample.

ii. Fishers 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. Q statistic [20]

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 R_1 falls

nR_2 - the number of individuals in the class where R_2 falls

iv. Margalef's D [21]

Margalef's D has been a favourite index for many years. This program uses the natural logarithm and is calculated by.

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

Where,

S - total number of species recorded

N - the total number of individuals summed overall S species

v. Shannon diversity index [22]

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 ith species

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

vi. Brillouin diversity index [18]

Brillouin index H was 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 ith species and s is the species number.

2. Species dominance indices

i. Simpson's index [23]

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 ith 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 (24).

ii. Berger Parker diversity index [25]

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 [22] to be one of the best. It is a simple measure of the numerical importance of the most abundant species.

iii. McIntosh index [26]

This index was calculated using the following formula proposed by McIntosh (1967) as

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

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 ith species and the summation is undertaken for over all the species.

3. Evenness indices [27]

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

i. 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)

Results

Arthropod diversity

Arthropods collected at weekly intervals from November to February (2013-14) in the grapes field were identified to the possible taxonomic level (Order, Family, Genus or Species) and various biodiversity indices worked out. The survey yielded a wide array of 68 species under 65 genera, 44 families and 12 orders (Tables 1 – 2).

Table 1 shows that totally 2,983 arthropods were collected of which maximum number of individuals belonged to Insecta (2650) followed by Arachnida (333).

1. Insecta

Under the class Insecta, the majority of individuals belonged to the division Endopterygota (1582) followed by Exopterygota (1068) (Table 1).

a. Exopterygota

The Exopterygotes (1068) were represented by six orders *viz*., Ephemeroptera, Odonata, Orthoptera, Dictyoptera, Hemiptera and Thysanoptera, among which hemipterans were the most abundant (Table 1). Totally seven families of Hemiptera were collected with the majority of individuals falling under the

family Pseudococcidae (361), followed by Aleurodidae (163), Cicadellidae (44), Aphididae (44), Scutelleridae (42), Miridae (5) and Derbidae (10) (Table 2).

Pseudococcidae was represented by two genera with the majority of individuals from the genus *Ferrisia* (182) (Table 2) followed by *Maconellicoccus* (179). Similarly, spiraling whiteflies (163) were dominant under the family Aleurodidae. *Scirtothrips dorsalis* Hood (213) was the most common species collected under the order Thysanoptera.

In Odonata, 70 individuals of Libellulidae and 13 individuals of Coenagrionidae were collected. Under Dictyoptera, Mantidae (68) was the dominant family followed by Blattellidae (4). *Mantis religiosa* (Linnaeus) (63) was the most common species collected under the family Mantidae. Blattellidae was represented by the genus *Blatta* with four individuals (Table 2). Order Orthoptera was represented by two species with 22 individuals. Ephemeroptera was represented by single species with nine individuals (Table 2).

b. Endopterygota

Endopterygota (1582) was represented by five orders *viz*., Diptera, Hymenoptera, Lepidoptera, Coleoptera, and Neuroptera in which Hymenoptera was the most dominant order (Table 1).

Hymenoptera was represented by five families. Maximum number of individuals were collected under the family Apidae (255), followed by Formicidae (218), Scelionidae (27) and Trichogrammatidae (14) with the majority of individuals under the family Apidae represented by *Apis cerana indica* Fabricius (152) (Table 2). *Camponotus compressus* (Fabricius) was dominant under the family Formicidae. Totally six families of Lepidoptera were collected. The greatest number of individuals were collected under the family Noctuidae (81), followed by Sphingidae (32), Pyralidae (14) and Pieridae (14). Only few individuals were found in the family Crambidae (9) and Erebidae (8) (Table 2).

Among endopterygotes, maximum individuals were from Hymenoptera. The reason that could be attributed to the dominance of Hymenoptera was due to the high abundance of *Apis* and *Camponotus* in the collection. Similar results were obtained by (28) who reported that Hymenoptera (78.33%) was the most dominant order with 2772 specimens followed by Araneae (14.80 %) with 524 individuals.

Coleopterans were represented by seven families with maximum number of individuals collected belonging to the family Eumolpidae and Cucujidae (123) followed by Curculionidae (65), Coccinellidae (60) and Scarabaeidae (23). The family Eumolpidae was represented by single species, *Scelodonta strigicollis* Motschulsky throughout the study period.

Dipterans were represented by four families *viz*., Muscidae (223), Drosophilidae (148), Tephritidae (75) and Dolichopodidae (12). Neuroptera was represented by single family Chrysopidae (25) by the genus *Chrysoperla*.

Under Coleoptera, the family Eumolpidae represented by a single species of *Scelodonta strigicolis* Mots was found throughout the study period. Diptera was the second most abundant order with maximum number of individuals belonged to Muscidae followed by Drosophilidae. Totally six families of Lepidoptera were collected. The greatest number of individuals were collected under the family Noctuidae followed by Sphingidae.

In class Insecta, endopterygotes were the largest group represented by five orders, while exopterygotes were represented by six orders. The results are also in agreement with Kennedy (29) and Thiruveni (30) who reported that endopterygotes were the largest group followed by exopterygotes and also found that the mango orchard had increased arthropod abundance in terms of total numbers, species richness, dominance and evenness indices. Similarly, Tandon and Verghese (3) reported 94 species of insect pests from grapes.

2. Arachnida

A total of 16 species of spiders from seven families were recorded. The major families represented under order Araneae belonged to Lycosidae (124) followed by Salticidae (94), Araneidae (61) and Oxyopidae (31). Minor families recorded we

re Thomisidae (10), Corrinidae (9) and Clubionidae (4) (Table 1).

The family Lycosidae (124) was represented by two genera *viz., Lycosa* (44) and *Pardosa* (80). Araneidae was represented by *Argiope, Eriovixia, Neoscona* and *Cyrtophora* with majority of individuals from *Neoscona* (21). *Plexippus paykulli* (Audouin) (64) was found abundant in the family Salticidae. Under Oxyopidae the maximum species recorded were *Oxyopes* (31), while *Thomisus* sp., *Clubiona* sp., and *Castianeira* sp. were found fewer in number (Table 2).

Spiders constitute the largest part of the predatory arthropod fauna of orchards. It has a significant role to play in the ecology by being exclusive predators and thereby maintain biotic balance of nature.

The present study revealed that Araneae was the most numerous with 333 individuals. The most dominant family was Lycosidae in which maximum population was recorded under the genus *Pardosa*. The second most dominant family was Salticidae with maximum abundance of *Plexippus paykulli* (Audouin). Under Oxyopidae, the species recorded were *Oxyopes* sp., *Thomisus* sp., *Clubiona* sp., and *Castianeira* sp., were found fewer in number. The present findings are in line with the findings of (31) who recorded Lycosidae, Salticidae, Theridiidae and Thomisidae comprising 85.56 per cent of the total collected spiders of fruit orchards of Oregon. Akthar (32) found that Lycosidae, Theridiidae, Thomisidae, Gnaphosidae, Salticidae and Tetragnathidae accounted for around 60 per cent of total spiders collected from fruit orchards. A survey from the vegetable fields revealed that spiders representing four families, nine genera and 12 species were prevalent, of which Araneidae was the most dominant family with five species. On the species level, *Cyclosa insulana* (Costa) was the dominant species (33).

Table 1: Diversity of arthropods at ordinal level in grapes ecosystem (unsprayed)

Class	Order	Total numbers recorded	Grand total
Arachnida	Araneae	333	333
	Exopterygota		
	Ephemeroptera	9	1068
	Odonata	83	
	Orthoptera	22	
	Dictyoptera	72	
Insecta	Hemiptera	669	
	Thysanoptera	213	
	Endopterygota		
	Neuroptera	25	1582
	Diptera	458	
	Coleoptera	418	
	Hymenoptera	523	
	Lepidoptera	158	
	Total insecta		2650
	Grand total		2983

Table 2: Diversity of arthropods in grapes ecosystem (unsprayed)

Order	Family	Genus	Total	Grand total
Araneae	Araneidae	*Argiope* sp.	16	61
		Eriovixia laglaizei (Simon)	13	
		Neoscona sp.	21	
		Cyrtophora cicatrosa (Stoliczka)	11	
	Salticidae	*Brettus albolimbatus* Simon	13	94
		Myrmarachne maxillosa (Koch)	17	
		Plexippus paykulli (Audouin)	64	
	Oxyopidae	*Oxyopes* sp.	31	31
	Lycosidae	*Lycosa* sp.	44	124
		Pardosa birmanica Simon	56	
		Pardosa sp.	24	
	Corrinidae	*Castianeira* sp.	7	9
		Unidentified sp.	2	
	Clubionidae	*Clubiona* sp.	4	4
	Thomisidae	*Thomisus* sp.	4	10
		Parasteatoda mundula (Koch)	6	
Exopterygota				
Ephemeroptera	Unidentified	Unidentified sp.	9	9
Odonata	Libellulidae	*Orthetrum sabina* (Drury)	25	70
		Pantala flavescens (Fabricius)	35	
		Tholymis tillarga (Fabricius)	10	
	Coenagrionidae	*Ischnura aurora* Brauer	13	13
Orthoptera	Acrididae	Unidentified sp.1	11	22
		Unidentified sp.2	11	
Dictyoptera	Mantidae	*Eumantis* sp.	4	68
		Mantis religiosa (Linnaeus)	63	
Order	**Family**	**Genus**	**Total**	**Grand total**
		Unidentified sp.	1	
	Blattellidae	*Blatta germanica* (Linnaeus)	4	4
Hemiptera	Scutelleridae	*Chrysocoris stolli* Wolf	42	42
	Cicadellidae	*Amrasca biguttula biguttula* (Ishida)	44	44
	Aleurodidae	*Aleurodicus dispersus* Russell	163	163
	Aphididae	*Aphis gossypi* Glover	44	44
	Pseudococcidae	*Ferrisia virgata* (Cockerell)	182	361
		Maconellicoccus hirsutus (Green)	179	
	Miridae	*Cyrtorhinus lividipennis* Reuter	5	5
	Derbidae	*Proutista moesta* (Westwood)	10	10
Thysanoptera	Thripidae	*Scirtothrips dorsalis* Hood	213	213
Endopterygota				
Neuroptera	Chrysopidae	*Chrysoperla sp*	25	25
Diptera	Tephritidae	*Bactrocera* sp.1	68	75
		Bactrocera sp.2	7	
	Drosophilidae	*Drosophila* sp.	148	148
	Muscidae	*Musca domestica* Linnaeus	223	223
	Dolichopodidae	*Psilopus* sp.	12	12
Coleoptera	Eumolpidae	*Scelodonta strigicollis* Motschulsky	123	123
	Curculionidae	*Myllocerus viridanus* (Fabricius)	62	65
		Unidentified sp.	3	
	Coccinellidae	*Cryptolaemus montrouzieri* Mulsant	33	60
		Brumoides suturalis (Fabricius)	12	
		Scymnus sp.	15	
	Tenebrionidae	*Gonocephalum brachelytra*, Kaszab	12	12
	Cucujidae	Unidentified sp.	123	123
	Carabidae	Unidentified sp.	12	12
	Scarabaeidae	Unidentified sp.	23	23
Hymenoptera	Apidae	*Apis dorsata* Fabricius	103	255
		Apis cerana indica Fabricius	152	
Order	**Family**	**Genus**	**Total**	**Grand total**
	Formicidae	*Camponotus compressus* (Fabricius)	218	218
	Trichogrammatidae	*Trichogramma* sp.	14	14
	Scelionidae	Unidentified sp.	27	27
	unidentified	Unidentified sp.	9	9
Lepidoptera	Noctuidae	*Helicoverpa armigera* (Hubner)	17	81
		Spodoptera litura Fabricus	19	
		Othreis fullonica Linnaeus	16	
		Othreis materna Moore	29	
	Pyralidae	*Conogethes punctiferalis* (Guenée)	14	14
	Sphingidae	*Hippotion celerio* Linnaeus	24	32
		Agrius (Herse) convolvuli (Linnaeus)	8	
	Pieridae	*Eurema hecabe* Linnaeus	14	14
	Crambidae	*Diaphania indica* (Saunders)	9	9
	Erebidae	*Spirama retorta* (Clerk)	8	8

Biodiversity indices

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

1. Species richness indices

a. Species number

Based on ordinal level, the calculated species number was maximum (12) during the month of December and January and minimum (8) during the February. The familial level data revealed that the index value was the highest during second week of January and minimum was during the fourth week of April. The data based on species level showed that the species number was maximum of 54 during the fourth week of December and minimum of 37 during the fourth week of November (Fig.1).

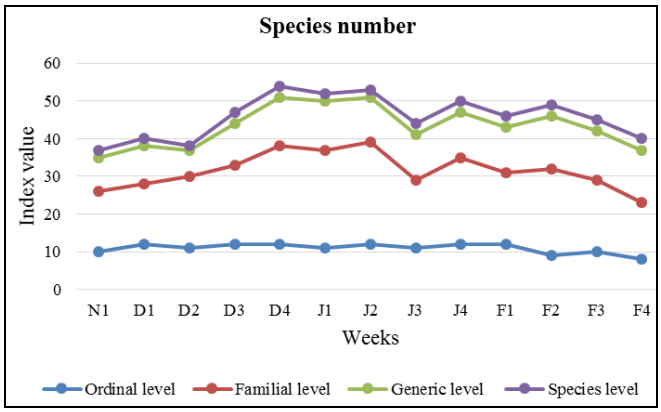

Fig 1: Arthropod diversity based on species number in grapes ecosystem

b. Fishers alpha index

Based on ordinal level, the Fishers alpha index value was the highest during the first week of December (3.1457) and the lowest during the fourth week of February (1.6929). At family level, Fishers alpha index varied between 6.8449 and 12.57. It attained a peak during the second week of January. At generic level, the value was maximum in the second week of January (18.705) and minimum in the fourth week of February (13.709). Based on species level, index value was the highest during the second week of January (19.838), while the lowest value was recorded during the second week of December (14.535) (Fig.2).

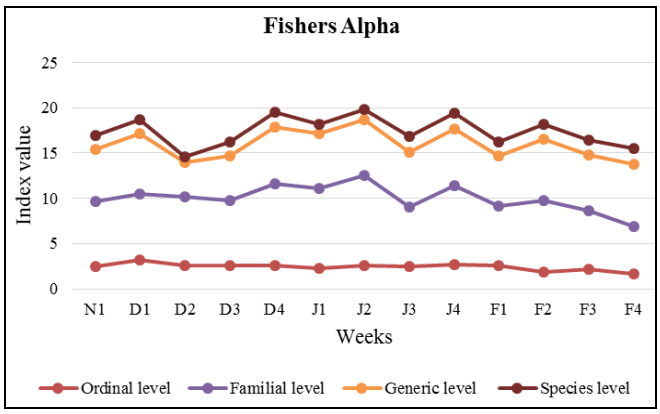

Fig 2: Arthropod diversity based on Fishers´ Alpha in grapes ecosystem

c. Q Statistic

The data revealed that based on ordinal level analysis, index value was minimum during the first week of February (2.164) and maximum in the fourth week of November (4.3209). At the family level, the value varied between 15.166 and 6.0364 and the lowest during the last week of February (6.0364). On the generic level, the value was maximum in the second week of January (18.329). Based on the species level, the value ranged between 11.162 and 19.115. The peak was observed during the first week of December (Fig.3).

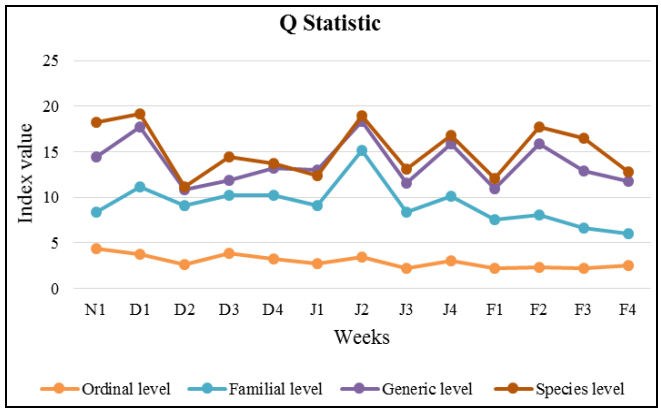

Fig 3: Arthropod diversity based on Q Statistic in grapes ecosystem

d. Margelef D index

From Fig.4, it could be seen that the Margalef D value based on ordinal level varied between a maximum (2.26) in the first week of December and minimum (1.3341) in the fourth week of February. Analysis of data based on a familial level revealed that the index was maximum during the second week of January (6.8012) and minimum during the last week of February (4.1929). At the generic level, value was maximum during the second week of January (8.9489) and minimum during the last week of February (6.861). Based on the species level, the index value was the highest in the second week of January (9.3069) and the lowest in the second week of December (7.095).

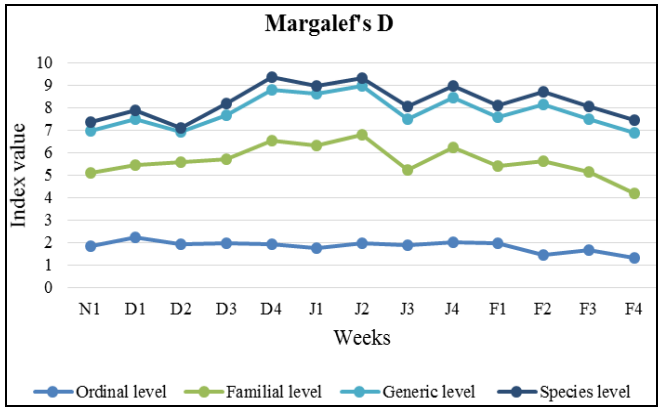

Fig 4: Arthropod diversity based on Margalef's D in grapes ecosystem

e. Shannon - Weiner index

Analysis of data using Shannon - Weiner index is presented in Fig.5.

At ordinal level, it could be seen that maximum value was observed during the first week of December (2.1396) and minimum during the last week of February (1.7717). At the familial level, the index value was maximum of 3.1588 during the second week of January and a minimum of 2.5425 during the last week of February. Analysis of values based on generic and species level revealed that maximum value was observed during the second week of January (3.3463 and 3.4245) and minimum during the last week of February (2.877 and 2.9363).

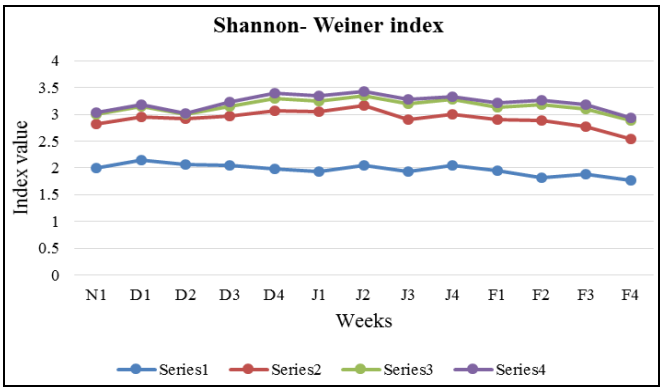

Fig 5: Arthropod diversity based on Shannon- Weiner index in grapes ecosystem

f. Brillouin diversity index

Based on ordinal level, Brillouin diversity index values fluctuated between 1.6933 in the last week of February and 1.9962 in the first week of December. Analysis of values based on family, generic and species level showed that the value attained a peak during the second week of January (2.932, 3.074 and 3.141 respectively) and it was minimum during the last week of February (2.3588, 2.619 and 2.6626 respectively) (Fig.6).

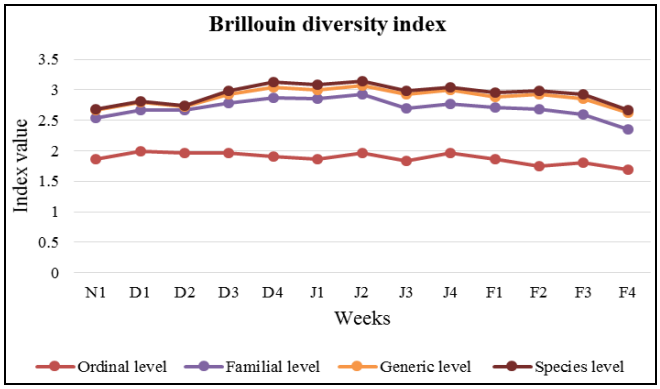

Fig 6: Arthropod diversity based on Brillouin diversity index in grapes ecosystem

2. Species dominance indices

a. Simpson's index

From Fig.7, it could be seen that Simpson's index values were the highest during the month of December (7.245 and 22.708) and the lowest during the month of February (5.072 and 12.426) at ordinal and specific level, respectively. At the family level, the maximum value was observed during the second week of January (17.872) and minimum during the last week of February (9.2266) (Fig.7).

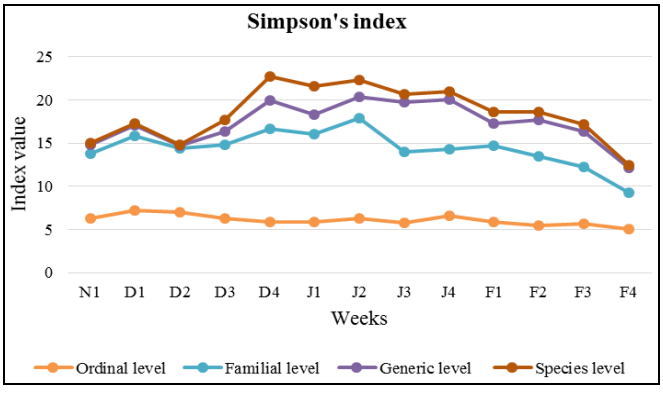

Fig 7: Arthropod diversity based on Simpson's index in grapes ecosystem

b. Berger Parker diversity index

Based on ordinal level analysis, the Berger Parker diversity index value was the highest during the last week of February (0.32632) and the lowest during the second week of December (0.22283) (Fig.8). At familial level, the value was maximum during the last week of February (0.21053) and minimum during the fourth week of December (0.11644). With reference to generic and species level, the index value observed was maximum during the last week of February (0.2) and minimum during the fourth week of January (1.0169) and December (0.099315), respectively.

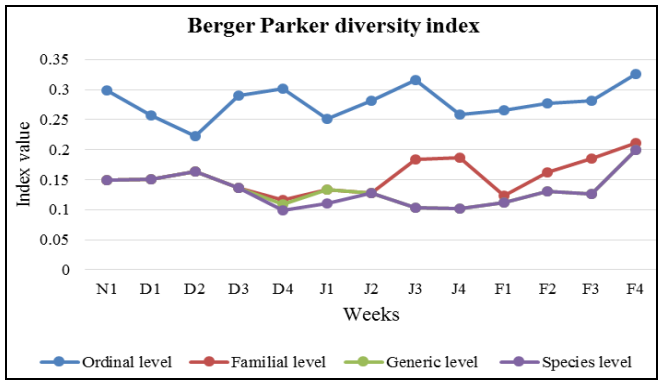

Fig 8: Arthropod diversity based on Berger Parker diversity index in grapes ecosystem

c. McIntosh index

McIntosh index calculated from the data collected revealed that based on ordinal, familial, generic and species level, the value was the lowest during the last week of February (0.59436, 0.71565, 0.75962 and 0.76328) and the highest during the month of December and January (0.67755, 0.80538, 0.82172 and 0.83112), respectively (Fig.9).

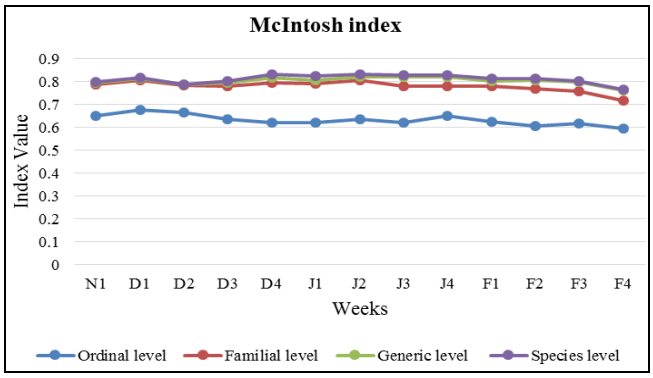

Fig 9: Arthropod diversity based on McIntosh index in grapes ecosystem

3. Evenness index-Equitability J

The Equitability J calculated based on ordinal level revealed a maximum of 0.86102 during the first week of December and minimum of 0.71297 during the last week of February. Based on familial, generic and species level, the value was the highest during the second week of January (0.83474, 0.80162 and 0.81158, respectively) (Fig.10).

It was concluded that the species richness of insects and spiders were found to be abundant during the study period. Considering the species diversity indices and species evenness indices, it was found that the maximum value observed during the month of January. The biodiversity indices in grapes was not reported earlier and henceforth the present findings stand as a base for further research in the biodiversity of arthropods in grapes ecosystem

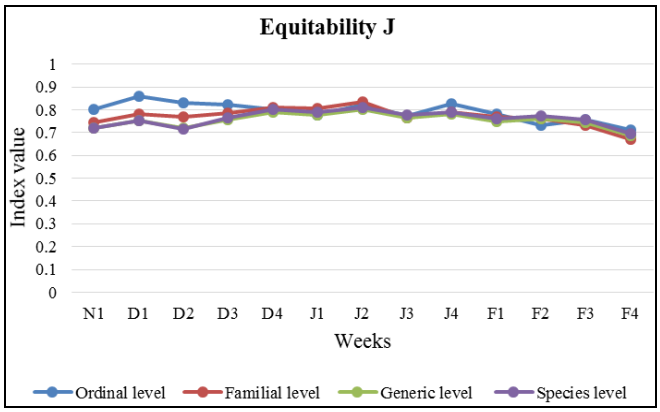

Fig 10: Arthropod diversity based on Evenness indices in grapes ecosystem

Acknowledgement
The first author thankful to Dr. Manju Siliwal, Independent Researcher, Wildlife Information Liaison Development Society, Dehradun for identifying spiders to this study.

References

1. Anonymous. *Annual Report*, Indian Institute of Horticultural Research, Hessaraghatta, Bangalore, 1993, 204.
2. Anonymous. Indian Horticulture Database, National Horticultural Board, Ministry of Agriculture, Government of India, New Delhi, 2013-2014, 289.
3. Tandon PL, Verghese A. Present status of insect and mite pests of grapes in India. Drakshavritta, 1994, 49-157.
4. Anonymous. Package of Practices for Managing Major Diseases and Insect Pests on Grapes. Technical bulletin No.8 National Research Centre for Grapes, Pune, India, 2007, 27.
5. Atwal AS, Dhaliwal GS. Agricultural Pests of South Asia and Their Management. Kalyani Publishers, New Delhi, 2008, 369-373.
6. Mani M, Shivaraju C, Rao MS. Pests of grapevine: A worldwide list. Pest Manag. Hort. Ecosyst. 2014; 20(2):170-216.
7. Pettersson RB, Ball JB, Renhorn KE, Esseen PA, Sjoberg K. Invertebrate communities in boreal forest canopies as influenced by forestry and lichens with implications for passerine birds. Biol. Conserv. 1995; 74:57-63.
8. Parmesan C. Climate and species' ranges. Science. 1996; 382:765-766.
9. Buddle CM, Spence JR, Langor DW. Succession of boreal forest spider assemblages following wildfire and harvesting. Ecography. 2000; 23:424-436.
10. Nyffeler M, Benz G. Spiders in natural pest control: A review. J. App. Entomol. 1985; 103:131-144.
11. Chang GC, Kareiva P. The case for indegenious generalists in biological control. In: Theoretical approaches to biological control, (Eds.) Hawkins, B.A. and H.V. Cornell. Cambridge University Press, Cambridge, UK. 1999, 103-115.
12. Lefroy H. Indian Insect Life. Jagmander Book Agency, New Delhi, 1984, 786.
13. Comstock JH. An Introduction to Entomology. Sathish Book Enterprises, Agra, India, 1984, 1064.
14. Richards OW, Davis RJ. General Text Book of Entomology. BI Publications Private Ltd. New Delhi, 1983, 784.
15. Ayyar TVR. Hand book of Economic Entomology for South India. Narendra Publishing House, Delhi, 1984, 180-192.
16. Poorani J. An annotated checklist of the Coccinellidae (Coleoptera) of the Indian subregion, Orient. Insects, 2002; 36:307-383.
17. Henderson PA. Practical Methods in Ecology. Blackwell Publishers, UK, 2003, 151.
18. Magurran AE. The diversity of Macrolepidoptera in two contrasting woodland habitats at Banagher, Northern Ireland. Proc. R. Ir. Acad. 1987; 85:121-132.
19. 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. J. Anim. Ecol. 1943; 12:42-58.
20. Kempton RA, Taylor LR. Models and statistics for species diversity. Nature. 1976; 262:818-820.
21. Clifford HT, Stephenson W. An Introduction to Numerical Classification. Academic Press, London, 1975, 229.
22. Batten LA. Bird communities of some killarney woodlands. Proc. Roy. Irish Acad. 1976; 76:285-313.
23. Simpson EH. Measurement of diversity. Nature. 1949; 163:688-696.
24. Hulbert SH. The non-concept of species diversity: A critique and alternative parameters. Ecol. 1971; 52:577-586.
25. Berger WH, Parker FL. Diversity of planktonic Foraminifera in deep-sea sediments. Sci. 1970; 168: 1345-1347.
26. McIntosh RP. An index of diversity and the relation of certain concepts to diversity. Ecol. 1967; 48:392-404.
27. Pielou EC. The measurement of diversity in different types of biological collections. J. Theoretical Biol. 1966; 13:131-144.
28. Magnus EKS. Studies on epigeal and arboreal predatory arthropods in mango orchards in the central province of Papua New Guinea. Ph. D. Thesis, Fachbereich Agrarwissenschaft, Ökotrophologie und Umweltmanagement der Justus-Liebig-Universität Gießen, 2004, 132.
29. Kennedy N. Arthropod diversity in horticultural ecosystems with special reference to spiders. M.Sc. Thesis, Tamil Nadu Agric. Univ., Coimbatore, India, 2008, 121.
30. Thiruveni T. Studies on bioefficacy, phytotoxicity and residues of thiamethoxam 25 WG on tomato and mango. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore-3, India, 2014, 213.
31. Bajwa WI, Aliniazee T. Spider fauna in apple ecosystem of western Oregon and its field susceptibility to chemical and microbial insecticides. J. Econ. Entomol. 2001; 94: 68-75.
32. Akthar AK. Spider fauna (Arachnida: Araneae) in temperate fruit orchards of Kashmir. J. Biol. Control. 2011; 25(2):103-113.
33. Sharma S. A study on spiders as predators in the agro ecosystems. Mun. Ent. Zool. 2014; 9(1):80-83.