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Gurlaz Kaur
Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab, India

KS Sangha
Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab, India

Correspondence
Gurlaz Kaur
Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab, India

Diversity of arthropod fauna associated with chilli (*Capsicum annuum* L.) in Punjab

Gurlaz Kaur and KS Sangha

Abstract
India is the largest producer and exporter of chilli (*Capsicum annuum*) in the world and attack of insect pests is a major constraint in its production. Arthropod population was recorded weekly during *kharif* 2013 at Bharti Field Fresh Farm, Ladhowal, Ludhiana and during *rabi* 2014 at Department of Forestry and Natural Resources Research Farm, PAU, Ludhiana. Primary goal of this study was to record the arthropod fauna associated with the chilli agroecosystem and to identify the insect and mite pests among them. Forty one arthropod species were found to be associated with the chilli crop among which fourteen species were each of pests and natural enemies, twelve species of casual visitors and one species of pollinator. Order Coleoptera occupied the maximum share (26.83%) in arthropod fauna recorded on chilli ecosystem. The results of diversity indices represented a highly diverse arthropod fauna which was evenly distributed and without dominance of any species during both the seasons.

Keywords: Aphid, thrips, whitefly, mite, fruit borer, diversity indices

1. Introduction

Chilli (*Capsicum annuum* L.), also called hot pepper, chile pepper, chilli pepper, paprika and aji, is a member of nightshade family, Solanaceae. It is one of the important spice and vegetable crop. India is the largest producer and exporter of dry chillies and peppers in the world [1]. India's total production in 2013-14 was 1492 thousand MT from an area of 775 thousand ha and with a productivity of 1.9 MT/ha [2]. India is a world leader in chilli production but it ranks 45th in productivity of dry chillies and peppers as compared to developed countries like USA, China, South Korea, Taiwan etc. [1].

Among many other reasons responsible for the lower yield, damage done by insect pests holds a major share. A survey conducted in Benin for finding production constraints in chilli, ranked the attack of insect pests on leaves, flowers and fruits as first among all other constraints [3]. Another survey conducted by Asian Vegetable Research and Development Committee in Asia indicated that the key insect pests of chilli are aphids (*Myzus persicae* Sulzer, *Aphis gossypii* Glover), thrips (*Scirtothrips dorsalis* Hood) and mites (*Polyphagotarsonemus latus* Banks) which act as limiting factors in chilli production. Fifty one species of insects and two species of mites belonging to 27 families under 9 orders were recorded on chilli transplanted crop. Further, *Gonocephalum dorsogranosum* Frm. (vegetable beetle), *Melanotus sp*. (wire worms), *Odontotermes obesus* (termite), *Holotrichia serrata* (white grub), *Helicoverpa armigera*, thrips (*S. dorsalis* and *Thrips flavus* Schrank) and mites (*P. latus* and *Tetranychus neocaledonicus* Andre) were considered as important pests [4]. A similar study conducted in the nursery of chilli crop recorded 35 species of insects belonging to 6 orders and a species each of mite and snail and two species of millipedes and recognized ants, cutworms and crickets as important pests [5].

Major chilli producing states in India are Andhra Pradesh and Karnataka and most of the data on insect pests and other arthropod fauna of chilli is also available from that region. However, not much data is available in literature about arthropod diversity of chilli crop from Punjab. Insect and mite pests are a major constraint in the production of crops and for their proper management, monitoring is the key step to know the diversity of arthropod pests, their distribution and peak activities. Hence, there was a need to record the diversity of arthropods and mainly the insect and mite pests of chilli under Punjab conditions. Therefore, this study was conducted with an objective to record the arthropod fauna associated with the chilli crop for knowing the diversity of species and to identify the major insect and mite pests of chilli in Punjab.

2. Materials and Methods

2.1 Study sites

Arthropod diversity of chilli was recorded during *kharif* 2013 at Bharti Field Fresh Farm, Ladhowal, Ludhiana and during *rabi* 2014 at Department of Forestry and Natural Resources Research Farm, Punjab Agricultural University (PAU), Ludhiana. The chilli plants were transplanted after and also followed by chilli during *rabi* season but transplanted after poplar plantation during *kharif* season.

2.2 Raising of crop

The chilli jalapeño variety PEP-1 was transplanted in zigzag manner on the beds on August 26, 2013 in the field at Bharti Field Fresh Ladhowal, Ludhiana and chilli hybrid variety CH-1 was transplanted on the beds on February 25, 2014 in the research field area of Forestry and Natural Resources Research Farm, PAU, Ludhiana. The crop was raised following all the recommended Package of Practices for chilli crop except management of insect pests [6].

2.3 Experimental layout

The experiment was laid out in a Complete Randomized Block Design (CRBD) with three replications. The fields were divided into plots measuring 6 X 3.5 m (21 m^2) during *kharif* 2013 at Bharti Field Fresh, Ladhowal, Ludhiana. Each replication had 7 plots. Crop for conducting the same experiment and replications was sown in plots measuring 5 X 5m (25 m^2) during *rabi* 2014 at Forestry and Natural Resources, Research Farm, PAU, Ludhiana.

2.4 Monitoring of insect and mite pests

For monitoring purpose the chilli crop experimental plots were examined on weekly intervals for counting the arthropod populations encountered and categorized into target and non-target insects and mite species. Specimens were collected for identification.

2.4.1 Target insect pests and mites

2.4.1.1 Aphids (*Myzus persicae* Sulzer and *Aphis gossypii* Glover): In order to study the population dynamics of aphids infesting the chilli crop, the population data for the number of aphid individuals (nymphs and adults) were counted from four leaves per plant (two from upper canopy and two from lower canopy) of 5 randomly selected plants from each plot out of a total of seven plots in each replication. A magnifying hand lens (10 X) was used to see the aphid adults and nymphs present on the leaves (both upper and lower surface).

2.4.1.2 Thrips (*Scirtothrips dorsalis* Hood): Five plants were selected randomly from each plot and observed for presence of thrips adults and nymphs using a 10X magnifying hand lens. During vegetative stage the numbers of thrips (adults and nymphs) were counted from leaves (2 leaves from each canopy) and during reproductive stage the flowers and fruits were also observed along with leaves for the presence of thrips.

2.4.1.3 Whitefly (*Bemisia tabaci* (Gennadius)): Adult population of whitefly was counted from leaves of five randomly selected plants (2 leaves each from upper and lower canopy) from each plot. The plants were approached slowly without disturbing and the selected leaves were observed for presence of whitefly adult firstly on upper surface and then slowly by turning it to examine the lower surface of the leaf and number of whitefly adults encountered per leaf were recorded.

2.4.1.4 Fruit borers (*Helicoverpa armigera* Hübner and *Spodoptera litura* (Fabricius)): The population of fruit borers was counted on whole plant basis from randomly selected 10 plants per plot. The plant was searched thoroughly for presence of larvae of *H. armigera* and *S. litura* and their number counted and noted down if present. For examining the damage done by borers, ten plants were selected randomly per plot and counted for total number of fruits and the number of damaged fruits per plant at weekly intervals after transplanting.

2.4.15 Mite (*Polyphagotarsonemus latus* Banks): Mite (adult and nymph) populations were counted from five randomly selected and tagged plants in each plot. The plants were untagged after recording the mite population from four leaves (2 from each upper and lower canopy) from each tagged plant in the plot. These six leaves were plucked and collected in polythene bags, which were marked with the plot number, and examined under stereo binocular microscope in laboratory for counting the total number of mites per leaf.

2.4.2 Non-Target insects

2.4.2.1 Coccinellids and other coleopterans: The adult coccinellids were counted on the whole plant basis when encountered during data recording for the insect pests of chilli. The coleopterans which are well recognized for being coccinellids like lady bird beetle (*Coccinella septempunctata* (Linnaeus) and *Menochilus sexmaculatus* (Fabricius) were counted and their numbers were recorded and grouped into coccinellids whereas the other beetles were counted and grouped into coleopterans for diversity studies.

2.4.2.2 Spiders: Spiders were also counted on whole plant basis from the randomly selected plants for insect pest population studies and their number noted under the group spiders due to lack of identification of the species.

2.4.2.3 Other insects: All the other insects encountered were grouped under their respective orders and their numbers were counted from randomly selected plants (same plants which were selected for studying population of insect pests). Dipterans included syrphid flies, robber flies; Hemipterans were hoppers and jassids; and butterflies and moths were grouped under lepidopterans etc.

2.5 Identification of specimens

Various identification keys were utilized for identification of arthropods collected. Keys were used for Coleoptera [7, 8, 9, 10, 11], Dictyoptera [12, 13], Diptera [14, 15, 16], Hemiptera [17, 18, 19], Hymenoptera [20, 21, 22], Isoptera [23], Neuroptera [24, 25], Odonata [26, 27], Orthoptera [28, 29, 30], Thysanoptera [31, 32] along with the help and guidance of various experts at Department of Entomology, Punjab Agricultural University, Ludhiana.

2.6 Statistical analysis

The mean populations for each insect pest and other insects were calculated in Microsoft Excel® and using the computer programme CPCS 1. Percentage of number of species encountered was calculated order-wise to see which insect order occupies the maximum percentage among all the insect species. Diversity, evenness and dominance indices were calculated. The formulas used for diversity indices are as follows:

(i) Simpson's index of diversity [33]

$$\text{Simpson's index } (D_s) = \sum_{i=1}^{s} \frac{[n_i(n_i-1)]}{[N(N-1)]}$$

where, n_i = number of individuals in the ith species
N = total number of individuals in the sample
Reciprocal of Simpson's index of diversity ($1/D_s$) was used to express the diversity of species so that as the index goes up, so does the diversity.
(ii) Index of species diversity [34]
Shannon Weaver's index (H') = $- \Sigma\, p_i \log_e p_i$
where, p_i = the proportion of individuals of species i (n_i/N)
n_i = number of individuals in the ith species
N = total number of individuals of all the species
(iii) Evenness index [35]
Evenness index (J) = $H'/ \log_e S$
Where, H' = Shannon-Weaver's index
S = number of species
(iv) Index of Dominance [36]
Index of dominance (D) = 1-J
where, J = Evenness index

3. Results and Discussion

3.1 Arthropod fauna on chilli crop

During the present study, 41 species of arthropods were found to be associated with the chilli crop at Ladhowal and at PAU, Ludhiana (Table I). These arthropod species included 14 species of pests of chilli constituting major, minor and sporadic pests (herbivorous arthropods), 14 species of natural enemies or beneficial, 12 species of casual visitors and 1 species of pollinator. Among the total arthropod fauna, maximum number of species belonged to order Coleoptera (11 species) representing 6 families, followed by Lepidoptera (6 species) representing 4 families, Hemiptera (4 species) representing 4 families, Hymenoptera (4 species) representing 3 families, Orthoptera (4 species) representing 2 families, orders Diptera, Odonata, Isoptera, Mites (2 species each) and Dictyoptera, Thysanoptera, Neuroptera (1 species each). Among the beneficial insect species, order Coleoptera constituted the maximum (4 species), followed by Diptera, Hymenoptera and Odonata (2 species each). Amongst the chilli pest complex, order Orthoptera constituted the maximum (4 species), followed by Hemiptera (3 species), Lepidoptera and Isopteran (2 species each), Hymenoptera, Thysanoptera and mite (1 species each). Majority of the casual visitors on chilli crop were from order Coleoptera (7 species), followed by Lepidoptera (4 species) and Hemiptera (1 species). Mites belonged to mainly 2 families, Tarsonemidae and Phytoseiidae. The family Phytoseiidae includes predatory mites. Among the predatory insects, Coccinellids (*C. septempunctata, M. sexmaculatus* and *B. suturalis*), spiders and ants were the dominant species while beetles, butterflies and plant bugs were the prominent casual visitors on the chilli crop. Amongst various insect orders which were found associated with the chilli crop, order Coleoptera occupied 26.83 percent followed by Lepidoptera (14.63 percent), Hemiptera, Hymenoptera and Orthoptera (9.76 percent each). Diptera, Isoptera and Odonata occupied 4.88 percent each followed by Dictyoptera, Neuroptera and Thysanoptera (2.22 percent each). Other unidentified arthropod species and spiders represented 2.42 percent of total arthropod fauna associated with the chilli ecosystem (Figure I).

Table I: Arthropod fauna encountered in chilli ecosystem during *kharif* 2013 and *rabi* 2014

S. No.	Common/Scientific name	Family	Plant part harboured
	Order: Coleoptera		
	Beneficial arthropods/natural enemies		
1.	Lady bird beetle, *Coccinella septempunctata* (Linnaeus)	Coccinellidae	Aphids*
2.	*Menochilus sexmaculatus* (Fabricius)	Coccinellidae	Aphids*
3.	*Brumoides suturalis* (Fabricius)	Coccinellidae	Aphids*
4.	Rove beetle, *Paederus fuscipes* (Curtis)	Staphilinidae	Small insects*
	Casual visitors		
5	*Rodolia cardinalis* (Mulsant)	Coccinellidae	Leaves
6.	*Zygogramma bicolorata* (Pallister)	Chrysomelidae	Leaves
7.	*Alticia cyanea* (Weber)	Chrysomelidae	Leaves
8.	Red pumpkin beetle, *Aulacophora foveicollis* (Lucas)	Chrysomelidae	Leaves
9.	*Myllocerus* spp.	Curculionidae	Leaves
10.	*Oxycetonia versicolor* (Fabricius)	Cetonidae	Flowers
11.	*Monolepta signata* (Olivier)	Galeuricidae	Leaves
	Order: Dictyoptera		
	Beneficial arthropods/natural enemies		
12.	European mantid, *Mantis religiosa* (Linnaeus)	Mantidae	Caterpillars, other insects*
	Order: Diptera		
	Beneficial arthropods/natural enemies		
13.	Syrphid fly, *Eristalis quinquestriatus* (Fabricius)	Syrphidae	Aphids*
14.	Robber fly, *Philodicus femoralis* (Ricardo)	Asilidae	Other insects*
	Order: Hemiptera		
	Pests		
15.	Whitefly, *Bemisia tabaci* (Gennadius)	Aleyrodidae	Leaves
16.	Aphid, *Myzus persicae* (Sulzer)	Aphididae	Leaves
17.	Jassid, *Amrasca biguttula biguttula* (Ishida)	Cicadellidae	Leaves
	Casual visitors		
18.	Horn bug, *Oxyrhachis* spp. (Walker)	Membricidae	Leaves
	Order: Hymenoptera		
	Pests		
19.	Leaf ant, *Solenopsis geminate* (Fabricius)	Formicidae	Leaves, Flowers
	Beneficial arthropods/natural enemies		
20.	*Eretomocerus* spp.	Aphelinidae	Whitefly*

21.	Black ant, *Polyrhachis simplex* (Mayr)	Formicidae	Small insects*
Pollinator			
22.	Carpenter bee, *Pithitis smaragdula* (Fabricius)	Anthophoridae	Flowers
Order: Isoptera			
Pests			
23.	*Microtermes obesi* (Holmgren)	Termitidae	Stem base, roots
24.	*Odontotermes obesus* (Rambur)	Termitidae	Stem, roots
Order: Lepidoptera			
Pests			
25.	*Helicoverpa armigera* (Hubner)	Noctuidae	Leaves, Fruits
26.	*Spodoptera litura* (Fabricius)	Noctuidae	Leaves, Fruits
Casual visitors			
27.	*Earias insulana* (Boisduval)	Noctuidae	Leaves
28.	Bihar hairy caterpillar, *Spilosoma obliqua* (Walker)	Arctiidae	Leaves
29.	Rice skipper, *Pelopidas mathias* (Fabricius)	Hesperidae	Leaves
30.	Cabbage butterfly, *Pieris brassicae* (Linnaeus)	Pieridae	Flowers
Order: Neuroptera			
Beneficial arthropods/natural enemies			
31.	Green lace wing, *Chrysoperla carnea* (Stephens)	Chrysopidae	Aphid, whitefly. Mite, small insects*
Order: Odonata			
Beneficial arthropods/natural enemies			
32.	*Pantala flavescens* (Fabricius)	Libellulidae	Small insects*
33.	*Coenagrion puella* (Linnaeus)	Coenagriidae	Small insects*
Order: Orthoptera			
Pests			
34.	Surface grasshopper, *Chrotogonus trachepaterus* (Blanchard)	Acrididae	Leaves
35.	*Acrida exaltata* (Walker)	Acrididae	Leaves
36.	*Oxya hyla hyla* (Serville)	Acrididae	Leaves
37.	Field cricket, *Gymnogryllus* spp.	Gryllidae	Leaves
Order: Thysanoptera			
Pests			
38.	*Scirtothrips dorsalis* (Hood)	Thripidae	Leaves, flower buds, fruits
Order: Araneae			
Beneficial arthropods/natural enemies			
39.	Spiders	-	Other insects*
Mites			
Pests			
40.	Yellow mite, *Polyphagotarsonemus latus* (Banks)	Tarsonemidae	Leaves, buds, fruits
Beneficial arthropods/natural enemies			
41.	Predatory mites, *Amblyseius* spp.	Phytoseiidae	Mites, thrips*

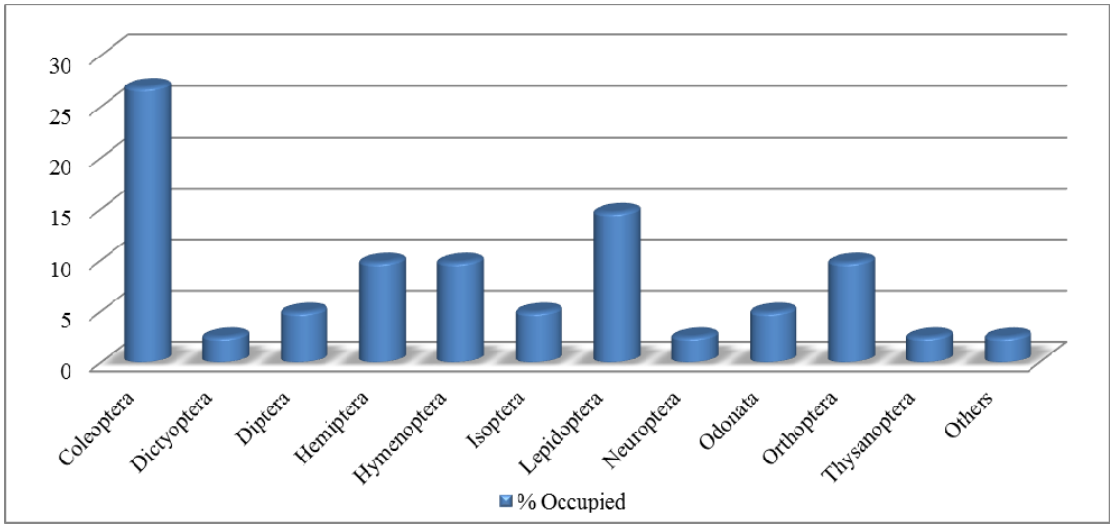

Fig. I: Percentage occupied by different insect orders in total arthropod fauna found in chilli ecosystem

3.2 Diversity indices of arthropod fauna associated with chilli agroecosystem

3.2.1 Arthropod diversity

The results determining the overall index values of arthropods belonging to different insect orders and mites encountered during monitoring studies of insect pests of chilli are presented in tables II-IV and figure II.

3.2.1.1 Arthropod diversity in *kharif* 2013 transplanted chilli

The diversity indices of arthropod fauna recorded in chilli ecosystem during *kharif* 2013 is represented in Table II. The Simpson's index of diversity (1/Ds) ranged from 1.98 to 3.88 during the *kharif* season with highest diversity during October (3.88) and lowest diversity during November (1.98). Similarly, The Shannon Weaver's Diversity index (H') varied

from 0.99 to 1.52 in the recorded arthropod fauna with maximum diversity seen during October (1.52) and minimum during November (0.99). The diversity of arthropod fauna started increasing from September and reached its peak in October and declined again in November. The rise of diversity again in December is mainly due to appearance of some hairy caterpillars which were not present during November. Throughout the crop season in *kharif* the species were evenly distributed with low Dominance index and higher Evenness index except during November, where dominance index (0.55) is higher than the evenness index (0.45). Reason for high dominance is due to the higher number of thrips species present in November, when the other species number declined during this month. Overall diversity indices show that the arthropod community recorded in chilli ecosystem is a relatively diverse community with all the species distributed evenly during the *kharif* season. Overall Simpson's diversity index (3.17) and Shannon Weaver's index (1.41) clearly show that the arthropod fauna associated with the chilli ecosystem is quite diverse. Evenness index (0.64) demonstrates the even distribution of all the species in the chilli crop without dominance of any particular species; same is also proved by the Dominance index (0.36) that no species was found to be dominant in the chilli crop during *kharif* 2013.

Table II: Diversity indices of arthropods during *kharif* 2013

Month	Simpson's index (1/Ds)	Diversity index (H')	Evenness index (J)	Dominance Index (D)
September	3.27	1.49	0.68	0.32
October	3.88	1.52	0.66	0.34
November	1.98	0.99	0.45	0.55
December	2.27	1.05	0.65	0.35
Overall	3.17	1.41	0.64	0.36

3.2.1.2 Arthropod diversity in *rabi* 2014 transplanted chilli crop

The diversity indices worked out for *rabi* 2014 are shown in Table III. The maximum diversity can be seen during April (5.88) by Simpson's index but in May (1.76) by Shannon Weaver's index. Minimum diversity for both the diversity indices is same in March (2.33 and 0.88 in Simpson's and Shannon-Weaver's index, respectively). So, the maximum numbers of species were found in April and May and least numbers of species were found in March during *rabi* 2014. Overall diversity indices represent a relatively diverse community of arthropod fauna in chilli ecosystem with overall diversity index values of 4.92 and 1.76 in Simpson's index and Shannon Weaver's index, respectively (Fig. II). The higher values of diversity indices as compared to *kharif* season can be seen representing that the arthropod fauna was more diverse and more numbers of species were found during *rabi* season as compared to *kharif* season in chilli crop. Evenness index value (0.80) is also higher in *rabi* as compared to *kharif* (0.64) season demonstrating that the species recorded are more evenly distributed during *rabi* than the *kharif* season. Lower dominance (0.19) of species during *rabi* 2014 is comparatively lower than the dominance index (0.36) of kharif season proving that no species was dominant during both the seasons.

Table III: Diversity indices of arthropods during *rabi* 2014

Month	Simpson's index (1/Ds)	Diversity index (H')	Evenness index (J)	Dominance Index (D)
March	2.33	0.88	0.80	0.19
April	5.88	1.68	0.94	0.06
May	4.99	1.76	0.85	0.15
June	3.92	1.64	0.79	0.21
Overall	4.92	1.76	0.80	0.19

3.2.2 Diversity of major insect pests of chilli crop

Thrips (*S. dorsalis*), Mite (*P. latus*), Whitefly (*B. tabaci*), Aphid (*M. persicae*) and Fruit borer (*H. armigera*) were recorded as the major pests of chilli crop during this study (Table IV). Maximum diversity of insect pests was observed during October 2013 and April 2014 according to the Simpson's index and during October 2013 and May 2014 according to the Shannon-Weaver's Index. Species were evenly distributed during both the seasons except for September 2013 and March 2014 months which showed dominance of species rather than even distribution. During September 2013, there was dominance of thrips species as compared to other insect pest species and during March 2014 there was no other insect pest present except for aphids. Complete dominance is indicted by the maximum dominance index of 1 during March 2014.

Table IV: Diversity indices of major insect and mite pests of chilli during different months of 2013 and 2014

Month-Year	Simpson's index (1/Ds)	Diversity index (H')	Evenness index (J)	Dominance index (D)
September-13	1.89	0.79	0.49	0.51
October-13	3.33	1.28	0.79	0.20
November-13	1.88	0.86	0.54	0.46
December-13	1.70	0.59	0.37	0.63
March-14	1	0	0	1
April-14	3.39	1.08	0.67	0.33
May-14	2.93	1.17	0.73	0.27
June-14	2.32	1.06	0.66	0.34

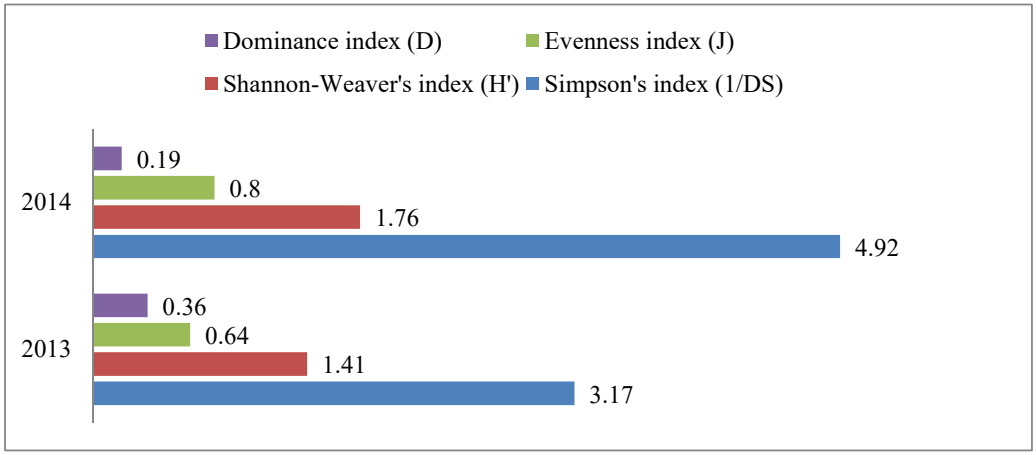

Fig. II: Overall diversity indices of arthropod fauna in chilli ecosystem during 2013 and 2014

In previous studies, 51 species of insects and 2 species of mites belonging to 27 families under 9 orders have been reported in transplanted chilli crop of variety Byadgi at Dharwad, Karnataka [4]. Thirty five species of insect pests and 1 species each of mite and snail infesting nursery of chilli crop have also been recorded at Dharwad, Karnataka [5]. A total of 293 insect and mite species infest pepper plants in the field and some attack pepper fruits in storage. Some species such as aphids, thrips and mites attack more than one plant part. *Myzus persicae* an aphid species which is an important virus vector is the most widespread insect infesting pepper in 37 countries including several tropical countries. Two other well-known virus vectors, an aphid (*A. gossypii*) and a whitefly (*Trialeurodes vaporariorum*) occur in 13 and 10 countries, respectively. *Aphis gossypii* occur in the tropics as well as temperate areas. Two mite species, (*Hemitarsonemus latus* and *T. urticae*) are also widespread and found in the tropics [37]. Extensive survey made on mites in Punjab, India revealed the occurrence of Tarsonemid mite, *P. latus* on chilli [38]. Although, many studies report the occurrence of various insects and mites in chilli agroecosystem and their management but, there is very few work reported on biodiversity analysis of arthropod fauna. In Punjab also, various insect pests have been reported affecting chilli but this study on arthropod fauna biodiversity of chilli agroecosystem is first of its kind from Punjab region. Further studies are needed to know the association of these species among each other and with their abiotic environment. It will be helpful in designing efficient IPM modules with utilization of beneficial arthropods to manage the insect pests.

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