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Research Article

Comparison of spider diversity in relation to pesticide use in apple orchards of Kashmir

AKHTAR ALI KHAN

Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology, Shalimar Campus, Srinagar 191121 Jammu and Kashmir, India

Corresponding author E-mail: akhtaralikhan47@rediffmail.com

ABSTRACT: Species diversity, abundance and habitat association of spiders were studied in 9 sprayed and unsprayed apple orchards in Kashmir. Fifty species of spiders were recorded from unsprayed orchards while 46 from sprayed orchards. Total number of species recorded from individual orchards varied from 31-38 in unsprayed orchards and from 20-28 in sprayed orchards. The proportion of web builders, visual hunters and tactile hunters was recorded as 22.32 %, 28.32% and 15.78% respectively in unsprayed orchards while, the corresponding figures for sprayed orchards were appreciably lower *viz.,* 8.84%, 16.96% and 7.78%, respectively. The web building spider families (Theridiidae and Tetragnathidae) were most affected by pesticide application followed by visual hunters (Lycosidae and Salticidae) whereas, the tactile hunters were the least affected with the exception of members of family Thomisidae. The spider species found to be altogether absent from the sprayed orchards, *viz., Araneus trifolium* Hentz, *Hyposigha* spp., *Zygoballus* spp., *Thomisus cherapunjeus* Tikader constituted very low percentage even in the spider communities that were not under the pesticide application pressure. The sprayed orchards exhibited poor spider diversity and less even distribution of spider taxa while species richness was little affected by pesticide application, the only exception being family Araneidae. The results indicated that pesticide application is posing a serious threat to diversity and richness of spiders in the apple orchards.

KEY WORDS: Araneae, pesticide application, relative abundance, species diversity, species richness, species evenness, spider,

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INTRODUCTION

Spiders form a prominent part of total predatory fauna of terrestrial community (Kaston, 1978). All spiders are predacious and insects comprise their primary prey (Turnball, 1973). But, due to their generalist predatory habits they have been neglected as potential biological control agents (Khan, 2006). Reichert and Lockley (1984). Khan and Misra (2009), however, emphasized the contribution of the spider community to insect control in many agro ecosystems and suggested conservation of spider diversity in agro ecosystems. The diverse prey capture strategies and microhabitat exploitation of different species would exert predation pressure on a variety of pests (Miliczky *et al*., 2000). Pickett *et al*. (1946) advocated an ecological approach for pest management that considered the role of natural enemies. Since then a number of studies have investigated the role of spiders on apples. Chant (1956) and Dondale (1956) were the first to study the spider fauna of apple orchards in England and Canada, respectively. Subsequently, orchard-inhabiting spiders have attracted the attention of workers in various parts of the World, including Australia (Dondale, 1966), Canada (Dondale *et al*., 1979), United States (McCaffrey and Horsburgh, 1980), Israel (Mansour, 1987), Italy (Angeli *et al.,* 1996) and India (Khan, 2009, 2011).

Several authors have observed that insecticides used in various crops are detrimental to the spider population (Riechert and Lockley, 1984; Mansour, 1987; Pekar, 1998). The detrimental impact of synthetic, broad spectrum insecticides on spider abundance and diversity has been clearly demonstrated. The orchards receiving heavy load of insecticides had lower spider population and fewer species as compared to those receiving little or no insecticides (Chant, 1956; Legner and Oatman, 1964; Mansour *et al*., 1980). Usually, the detrimental effect of the insecticides is mainly apparent during the first few weeks after application, although, it could also be detected during the rest of the season. The spider population then begins to proliferate again (Pekar, 1998).

The fact that beneficial species must be conserved in the field to promote a more stabilized pest-natural enemy balance, necessiates to establish the level of toxicity to spiders of compounds intended for pest control in many countries (Mansour *et al*., 1980). Apple grown in Kashmir holds the national and international pride for its delicacy, hence, the state of Jammu and Kashmir has been declared as agro–export zone for apple. One of the major constraints in apple production in Kashmir is the arthropod pest complex including insects such as San Jose scale, wooly aphid, green apple aphid, hairy caterpillar, apple stem borer, shot hole borer, leaf rollers and blossom thrips. Besides, the European red mite and two spotted spider mites have emerged as major pests of apple for the last few decades (Anonymous, 2007). To manage these pests, large quantities of various synthetic pesticides are being applied in the apple orchards. The current study was carried out to compare the species diversity, species abundance and few other ecological parameters of spiders in the apple orchards receiving high insecticide/acaricides application with unsprayed ones in Kashmir. Emphasis was laid on the overall impact of insecticide application on the population of spiders throughout the growing season.

MATERIALS AND METHODS

Study site and period of sampling

The study was carried out in the temperate apple orchards of Kashmir (32.17 and 36.58 N and 37.26 and 80.30 E) with altitude varying from 1500 to 2200M above mean sea level. For the experiment, three locations – Shalimar, Harwan and Gulab Bagh from Srinagar district; Wagoora, Mamoosa and Warpora from Baramulla district and Khag, Shopian and Tral from Pulwama district were selected. Samples were collected from managed orchard where spray schedule (Table 1) as per the recommendation of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir were followed and compared with unsprayed orchard where spray schedule was not followed for at least 3 years. One sprayed and one unsprayed orchard with Red Delicious and Golden Delicious apple cultivars were selected for sampling from each location. The age of selected trees ranged between 15 and 21 years, grown with spacing of 6×6 meter. The samples were taken at fortnightly interval from March to October (growing season) during

Table 1. Insecticides/acaricides spray schedule for the pest management of apple orchard of Kashmir 2008-2009.

Spray	Tree Stage	Rate of application (Insecticides/Acaricides/HMO per 100 liter of water)
I	Green Tip (delay Dormancy) (15th March -15th April)	Horticultural Mineral oil (HMO)*** @ (2%) or diesel oil+ Fish oil soap (potash based) in the ratio of (Stock solution: water) plus ethion** 50 EC @ 100 ml/100 litre of water (in case of delay of D. oil spray, ratio should be & for HMO*** 1% conc. Should be used)
II	Pink Bud (16th April–30th April)	3-4 days after II fungicidal spray in case spray I is missed Chlorpyriphos 20 EC (100 ml)* or Endosulfan 35 EC (140 ml)* or summer oil spray (750 ml) or Fenzaquin 10 EC (40 ml)*** or herbal (200 ml)**
III	Petal Fall (80 to 100 %) (1st to 15th May)	3-4 days after III fungicidal spray Quinalphos 25 EC (100ml)* or methyl-o-demeton 25 EC(80ml)* or phosalone 35 EC (140 ml)* or summer spray Oil (750 ml)*** or fenazaquin 10 EC (40 ml)***
IV	Fruit let (Pea Size) (16th to 31st May)	3-4 days after IV fungicidal spray. Chlorpyriphos 20 EC (100 ml) * or methyl-o-demeton 25 EC (80 ml)* or phosalone 35 EC (140 ml)* or dicofol 18.5 EC (108 ml)** or summer Spray oil*** (750 ml) or fenazaquin 10 EC (40 ml)***
V	Fruit Development I (1st June to 15th July)	3-4 days after V fungicide spray Chlorpyriphos 20 EC (100 ml)* or methyl-o-demeton 25 EC (80 ml)* or dimethoate 30 EC (100ml)* or dicofol 18.5 EC (108 ml)** or summer Spray oil (750 ml) or fenazaquin 10 EC (40 ml)** or abamectin 1.8 EC (55.5 ml)**
VI	Fruit Development II (16th July to 15th August)	3-4 days after VI fungicide spray Chlorpyriphos 20 EC (100 ml)* or quinalphos 25 EC (100 ml)* or dicofol 18.5 EC (108 ml)**
VII	Fruit Development III (16th to 31st August)	3-4 days after VI fungicidal spray Chlorpyriphos 20 EC (100 ml)* or dimethoate 30 EC (100ml)* or endosulfan 35 EC (140 ml)* or methyl-o-demeton 25 EC (80ml)* or phosolone 35 EC (140ml)* or fenazaquin 10 EC (40 ml)*** or abamectin 1.8 EC (55.5 ml)**
VIII		Ethion 50 EC (100ml)** or Fenazaquin 10 EC (40 ml)** or HMO (750ml)***

- *Insecticide, **Acaricides, ***Both insecticide and acaricide
- Insecticides/Acaricides applied only need based

2008-2009 for two consecutive years. All the samples were collected during day time.

Sampling methods

Samples were collected using three techniques namely; vial–tapping or hand picking, quadrat method and pitfall trap for tree canopy, understory vegetation and ground surface, respectively. In vial tapping/ hand picking method, empty vials (5 cm height and 3cm diameter) were placed beneath the leaf blades or webs, folded leaves, branches, trunk, barks and spiders then tapped loose with the cap. Smaller species were picked up with a moisten finger or by small camel's hair brush. Five trees were selected randomly from each location for vial tapping for 25 minutes/trees. In quadrant method which is made of wooden frame (1.0 x 1.0 square meters), collection of spiders were made from five quadrants, four from the four corners of the orchard, leaving sufficient core area of about 10 meters from the borders and one from the middle of the orchard randomly. In each quadrant, the spiders were collected from the understory vegetation under tree canopy carefully with least disturbance of arthropod fauna. For the study of the ground dwelling spider, pitfall trap was used at the experimental sites. The traps were of plastic cups (diameter 9 cm and height 12 cm) buried in the soil at the surface level, containing ethylene glycol as preservative filling the bottom up to 2 cm height. Five traps were placed in a row 10 meter apart in the orchard leaving 5 meter from the edges to avoid the core effect. All the traps were emptied and samples were collected at fortnightly interval and again filled with the preservative.

Identification of spiders

All collected spiders were transported to the laboratory for sorting, counting and identification. Labels containing all pertinent information *viz.* date of collection, location, crops etc. were placed inside the vials with the specimens. The collected samples were preserved in Oudeman's fluid (85 part – 70 % alcohol, 5 part- glycerine; 5 part- glacial acetic acid) (Barrion and Litsinger, 1995) for identification. In the laboratory, specimens were identified on the basis of key given by earlier workers (Tikader and Bal, 1980; Tikader, 1982; Tikader, 1987; Barrian and Litsinger, 1981, 1995; Gajbe, 2004; Mukhtar, 2004; Plantinck, 2010 and Khan and Khan, 2011). Species were classified according to Plantinck (2010). Additionally, the recorded spiders were divided into three main guilds (Nyffler, 1982, Khan, 2009); web builder (Aranidae, Tetragnathidae, Linyphiidae and Therididae), visual hunter (Lycosidae, Ctenidae, Salticidae Oxyopidae, Gnaphosidae and Pisuaridae) and tactile hunter (Thomisidae, Philodromidae Clubionidae and Miturgidae).

Ecological indices for quantitative analysis

Quantitative estimation of individual species under above three orchards was made using the data derived from field survey. Species richness (Da) was calculated using Margalef's richness index, species diversity was calculated by using Shannon-Wiener diversity index and for the evenness of the population, Pielou's evenness index was calculated by using the data.

Margalef's richness index: The simplest measure of species diversity is the number of species or species richness and was calculated after Margalef (1968).

$$Da = (S-1)/\log_e N$$

Where, Da=Margalef's richness index, S=Number of species, and N=total number of individuals.

Shannon-Wiener diversity index: The Shannon-Wiener diversity index (1948) is the measure used to draw information from samples in the field. Though the results of the Shannon-Wiener index needs to be used with caution, it still provides a good learning tool for comparing two distinct habitats. It combines two quantifiable measures: the species richness (the number of species within the community) and the species equitability (how even are the numbers of individual species?). It is computed by using following equation:

$$H' = -\Sigma\, pi \ln pi$$

Where, H'=Shannon-Wiener diversity index, and *pi*=the observed proportion of a particular species. The value of H' near zero would indicate that every species in the sample is the same. A value near 4.6 would indicate that the numbers of individuals are evenly distributed between all the species. Values in the middle are ambiguous which an obvious flaw of this index is and, thus, care was taken when using this index.

Pielou's evenness index: Species evenness is a diversity index, a measure of biodiversity which quantifies how equal the community is numerically. The evenness of a community can be represented by the Pielou's evenness index (Pielou, 1966):

$$E = H'/H_{max}$$

Where H' is the number derived from the Shannon diversity index and H_{max} is the maximum value of H', equal to:

$$H_{max} = -\Sigma\,[1/S.\ln S] = \ln S$$

Where, S is the total number of species. Thus:

$$E = H'/\ln S$$

E is embarrassed between 0 and 1. The higher value of E refers to the less variation in communities between the species.

All statistical analysis was performed using R software programme (R Development Core Team, 2008).

Table 2. Diversity of spider fauna in sprayed and unsprayed apple orchard in different districts of Kashmir during 2008-2009

Spiders group, families, Genus, species	Srinagar						Baramulla						Pulwama						Spider captured in sampling methods
	Shalimar		Harwan		Gulab bagh		Wagoora		Mamoosa		Warpora		Khag		Shopian		Tral		
	US	S	US	S	US	S	US	S	US	S	US	S	US	S	US	S	US	S	
WEB BUILDERS																			
Family-Araneidae Dahl																			
Neoscona theisi (Walckenaer)	2	–	2	–	1	–	–	–	3	2	1	–	4	–	3	–	1	–	V, Q
Neoscona mukerjei Tikader	5	–	5	3	4	2	6	3	5	–	3	3	6	4	5	3	3	2	V, Q
Neoscona sillongensis Tikader & Bal	–	–	2	1	4	2	9	4	4	3	2	–	–	–	–	–	3	1	V, Q
Araneus trifolium Hentz	2	–	–	–	1	–	–	–	3	–	–	–	–	–	–	–	–	–	**V, Q**
Neoscona sp.	6	4	8	5	6	4	9	4	6	5	7	4	9	7	10	5	8	4	V, Q
Araneus cucurbitnus (Clerck)	2	–	1	–	2	–	3	–	–	–	–	–	3	2	3	–	–	–	V, Q
Araneus sp.	6	5	2	–	3	2	–	–	2	–	3	1	4	–	5	–	2	1	V, Q
Nephila sp.	–	–	2	1	–	–	1	–	1	1	–	–	1	1	–	–	2	–	V, Q
Cyclosa elongata & Biswas Raychudhuri	1	4	1	–	1	1	1	–	1	–	2	–	1	1	1	1	–	–	V, Q
Hyposigha sp.	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	V, Q
Sub total	24	13	23	10	22	11	29	11	25	11	20	8	28	15	27	9	20	8	
Family-Tetragnathidae Menge																			
Tetragnatha sp.	36	14	21	11	19	10	17	10	16	15	13	–	13	5	15	5	9	5	V, Q
Eucta sp.	8	4	–	–	–	–	3	–	1	–	–	–	2	–	–	–	1	–	V, Q
Leucauge celebesiana (Walckenaer)	15	–	10	3	6	–	–	–	5	4	–	–	6	4	6	2	7	4	V, Q
Leucauge sp.	–	–	7	–	2	1	6	–	6	5	9	–	7	–	–	–	–	–	V, Q
Sub Total	59	16	38	14	27	11	26	10	28	24	22	–	28	9	21	7	17	9	
Family- Theridiidae Sundevall																			
Theridula sp.	26	10	21	10	28	13	32	11	29	12	21	8	28	7	31	11	20	10	V, Q
Achaearanea sp.	3	–	3	–	–	–	–	–	–	–	2	–	2	–	1	–	–	–	V, Q
Theridion sp.	24	9	15	7	12	-	23	7	20	7	3	1	17	9	16	9	13	–	V, Q
Sub Total	53	19	39	17	40	13	55	18	49	19	26	9	47	16	48	20	33	10	
Family- Linyphlidae Blackwall																			
Linyphia sp.	11	10	5	–	8	–	12	10	8	–	25	6	–	–	14	11	17	9	V, Q
Lepthyphantes bhudbari Tikader	**7**	**5**	–	–	–	–	–	–	–	–	+	–	–	–	**5**	**4**	**4**	–	V, Q
Sub Total	18	15	5	–	8	–	12	10	8	–	25	6	–	–	19	15	21	9	
VISUAL HUNTERS																			
Family-Lycosidae Sundevall																			
Lycosa sp.	29	18	22	13	26	14	19	11	20	12	23	15	19	14	16	10	18	11	Q, P
Pardosa altitudes Tikader & Malhotra	4	2	6	5	8	5	12	8	9	5	10	7	12	11	9	6	9	7	Q, P
Pardosa ladakhensis Tikader	–	–	–	–	–	–	–	–	7	1	6	4	–	–	–	–	–	–	Q, P
Evippa sp.	2	1	1	–	–	–	8	5	–	–	1	1	4	–	1	–	–	–	Q, P
Arctosa sp.	14	8	12	6	–	–	–	–	–	–	–	–	–	–	6	3	5	4	Q, P

(Table 2 . Contd. ...)

Family- Oxyopidae Thorell																			
Oxyopes ratane Tikader	7	3	9	-	3	-	-	-	-	-	-	-	5	11	3	2	-	-	V,Q
Oxyopes javanus (Thorell)	-	-	-	-	11	8	-	-	-	-	16	6	-	-	8	7	-	-	V,Q
Oxyopes sp.	12	15	5	3	-	-	26	16	14	15	-	-	10	--	8	-	3	-	V,Q, P
Sub total	19	18	14	3	14	8	26	16	14	15	16	6	15	11	19	9	3	-	
Family- Pisauridae																			
Pisaura sp.	10	9	14	12	26	16	-	-	16	11	13	11	21	19	12	8	20	13	Q, P
Pisaura sp.2	8	-	9	5	-	-	21	16	-	-	6	5	8	-	7	3	1	1	Q, P
Sub total	18	9	23	17	26	16	21	16	16	11	19	16	29	19	19	11	21	14	
Family-Ganphosidae Pocock																			
Setappgis sp.	3	-	7	6	9	6	10	10	9	-	8	4	13	9	14	-	2	-	Q, P
Zelotes sp.	9	12	14	12	18	16	20	19	20	17	11	8	21	9	16	12	18	16	Q, P
Sub Total	12	12	21	18	27	22	30	29	29	17	19	12	34	18	30	12	20	16	
TACTILE HUNTERS																			
Family-Thomisidae Sundevell																			
Thomisus sp.	12	10	9	7	11	-	6	-	17	5	9	5	11	-	14	9	7	7	V,Q
Thomisus whitakeri Gajbe	2	-	-	-	-	-	-	-	4	1	-	-	-	-	1	-	1	-	V,Q
Thomisis cherapunjeus Tikader	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	V,Q
Xysticus sp.	24	19	24	13	16	-	19	10	18	14	14	8	11	-	20	10	17	9	V,Q,P
Runcinia sp.	-	-	1	-	-	-	-	-	-	-	1	1	-	-	1	1	3	-	V,Q
Sub Total	38	29	36	20	27	-	25	10	39	20	24	14	22	-	36	20	28	16	
Family- Philodromidae																			
Philodromus sp.	14	13	5	-	-	-	16	7	16	6	-	-	-	-	-	-	27	15	Q, P
Thanatus sp.	4	-	-	-	-	-	1	2	2	2	-	-	-	-	16	10	10	-	Q, P
Sub Total	18	13	5	-	-	-	17	9	18	8	-	-	-	-	16	10	37	15	
Family-Clubionidae Wagner																			
Clubiona sp.	15	10	11	10	22	15	8	-	11	-	23	-	10	-	13	9	11	4	V,Q
Clubiona japonicola Boesenberg et	-	-	-	-	-	-	-	-	-	-	10	20	10	7	-	-	-	-	V,Q
Castianeria sp.	2	-	3	-	5	1	-	-	1	8	1	2	1	-	5	1	1	-	V,Q
Sub total	17	10	14	10	27	16	8	-	12	8	34	22	21	7	18	10	12	4	
Family-Miturgidae																			
Cheiracanthium himalayensis Gravely	18	-	19	15	12	16	19	13	14	-	13	7	19	-	17	10	20	13	V,Q, P
Sub Total	18	-	19	15	12	16	19	13	14	-	13	7	19	-	17	10	20	13	
Total	392	213	332	170	297	148	359	195	335	170	282	137	327	144	334	166	288	146	
Total species in unsprayed/ Sprayed orchard	38	26	38	23	31	20	31	23	34	25	34	24	34	20	37	28	33	25	
Total no of species	50																		

US = unsprayed apple orchard, S = Sprayed apple orchard, – = species absent, V = vial tapping/hand picking, Q = Quadrate, P = Pitfall trap

(Table 2 . Contd. ...)

Sub Total	49	29	41	24	34	19	39	24	36	18	40	27	35	25	32	19	32	22	
Family-Ctenidae Keyserling																			
Ctenus indicus Gravely	10	6	9	8	–	–	11	–	–	–	2	–	–	–	8	–	5	–	Q, P
Ctenus himalayensis Gravely	–	3	4	–	8	2	5	8	8	6	–	–	14	8	–	4	–	3	Q, P
Sub Total	10	9	13	8	8	2	16	8	8	6	2	–	14	8	8	4	5	3	
Family- Salticidae Blackwall																			
Phidippus sp.	17	9	21	10	20	12	13	9	–	–	–	–	13	8	–	–	11	4	V,Q, P
Marpissa sp.	–	–	12	4	–	–	10	6	15	9	12	8	9	6	10	6	4	1	V,Q, P
Myrmarachne sp.	16	11	3	–	–	–	8	3	9	3	5	2	5	–	8	3	–	–	V,Q, P
Myrmarachne himalayensis Narayan	3	–	–	–	5	2	–	–	–	–	–	–	4	2	5	1	3	1	V,Q, P
Zygoballus sp.	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	V,Q, P
Plexippus sp.	3	1	–	–	–	–	5	3	5	1	4	2	4	–	1	–	1	1	V,Q, P
Sub Total	39	21	41	14	25	14	36	21	29	13	22	12	35	16	24	10	19	7	

RESULTS AND DISCUSSION

All the spiders collected are listed in Table 2. In all, 14, families, 36 genera and 50 identifiable species were recorded. From the sprayed apple orchards, a total of 14 families, 33 genera and 46 species were recorded while as all the 14 families, 36 genera and 50 species of spiders were recorded from unsprayed orchards. Total number of species recorded from individual orchards varied from 31–38 in case of unsprayed orchards and 20–28 in sprayed orchards. It was obvious that there were more species and spider number in the unsprayed than in any of the sprayed orchards. Without exception, the spider diversity and abundance was lower where the insecticide use was high compared to orchards receiving little or none of the insecticides. Similar reports have been documented based on innumerable studies conducted elsewhere (Chant, 1956; Legner and Oatman, 1964; MaCaffrey and Horsburhg, 1980; Madsen and Madsen, 1982, Mansour *et al.,* 1984; Bogya *et al.,* 1997 and Sackett *et al.,* 2008). There was a total 50 species was reported in this study, while Hagley (1974), Dondale *et al.* (1979), MaCaffrey and Horsburhg (1980) and Bogya *et al.* (1997) reported 50, 41, 68 and 66 species respectively from their study regions.

Of the total number of 4435 specimens collected, 66.42% (2946) were recorded from unsprayed orchards and 33.58% (1489) from the sprayed apple orchards (Table 3). Among the samples collected, the proportion of web builders, visual hunters and tactile hunters was recorded as 22.32%, 28.32% and 15–78% respectively in unsprayed orchards while the corresponding figures for sprayed orchards were appreciably lower; 8.84%, 16.96% and 7.78%, respectively (Table 4). Web building species seem to be affected most and the tactile hunters the least.

The dominant spider family found in unsprayed apple orchard was Theridiidae (8.79%) followed by Lycosidae (7.63%), Salticidae (6.32%) Thomisidae (6.20%), and Tetragnathidae (5.99%), which account for more than 50% of total spiders reported from the unsprayed orchards. In sprayed orchards, Lycosidae (4.67%) was most abundant followed by Gnaphosidae (3.52%), Theridiidae (3.18%), Thomisidae (2.91%), Pisauridae (2.90%) and Salticidae (2.89%). The perusal of data presented in Table 3 indicated that family Theridiidae was most drastically affected by insecticide application followed by Tetragnathidae, Salticidae, Thomisidae and Lycosidae. It could be partly attributed to the foraging behavior of the spiders besides, other ecological and biological factors. Four species of spiders *viz., Araneus trifolium* Hentz and *Hyposigha* sp. of web builder guild, *Zygoballus* sp. of visual hunter group and *Thomisis cherapunjeus* Tikader from the tactile hunter group were lacking in the sprayed orchard at all the locations. The pesticides spray included organochlorines like endosulfan, organophosphates like chlorpyriphos, methyl-o-demeton, phosalone, dimethoate etc, and synthetic pyrethroids like abamectin; acaricides like dicofol, fenazaquin and petroleum oils. All these products have been shown to affect the spiders drastically (Herne and Putnam, 1966; Culin and Yeargen, 1983; Mansour and Nentwig, 1988). Some of these, for example, endosulfan and acaricides are known to cause 100% mortality of spiders in laboratory at recommended concentration (Mansour and Nentwig, 1988).

The web building spider families (Theridiidae, Tetragnathidae) were most affected by pesticide application followed by visual hunters (Lycosidae, Salticidae) whereas, the tactile hunters were the least affected with the exception of members of family Thomisidae. Legnar

Table 3. Relative abundance of spider families in unsprayed and sprayed apple orchard of Kashmir during 2008-2009

Families	Relative abundance (%) of spider families in unsprayed and sprayed apple orchard							
	Srinagar (1552)*		Baramulla (1478)*		Pulwama/Sophian (1405)*		Total (4435)*	
	Unsprayed (1021)	Sprayed (531)	Unsprayed (976)	Sprayed (502)	Unsprayed (949)	Sprayed (456)	Unsprayed (2946)	Sprayed (1489)
Araneidae	4.45	2.19	5.01	2.02	5.34	2.27	4.92	2.16
Tetragnathidae	7.98	2.65	5.14	2.31	4.69	1.78	5.99	2.26
Theridiidae	8.51	3.16	8.79	3.11	9.12	3.27	8.79	3.18
Linyphidae	1.99	0.97	3.04	1.08	2.84	1.71	2.62	1.24
Lycosidae	7.99	4.63	7.78	4.66	7.05	4.69	7.63	4.67
Ctenidae	1.99	1.23	1.76	0.95	1.92	1.07	1.89	1.09
Salticidae	6.77	3.16	6.57	3.12	5.55	2.3 5	6.32	2.89
Oxyopidae	3.03	1.87	3.78	2.36	2.63	1.43	3.16	1.89
Gnaphosidae	3.87	3.35	5.28	3.93	5.98	3.27	5.00	3.52
Pisauridae	4.31	2.70	3.78	2.91	4.91	3.14	4.32	2.90
Thomisidae	6.50	3.16	5.97	2.98	6.12	2.57	6.20	2.91
Philodromidae	1.48	0.84	2.37	1.16	3.78	1.78	2.50	1.25
Clubionidae	3.73	2.32	3.65	2.03	3.63	1.49	3.68	1.96
Miturgidae	3.15	1.99	3.11	1.35	3.98	1.64	3.40	1.66

*Numbers in parentheses are total spider numbers on which percentage are based

Table 4. Relative abundance of spiders of various foraging behavior in apple orchards of Kashmir during 2008-2009

Foraging behavior	Relative abundance (%) of spiders in Kashmir apple orchards							
	Srinagar (1552)*		Baramulla (1478)*		Pulwama/Sophian (1405)*		Total (4435)*	
	Unsprayed (1021)	Sprayed (531)	Unsprayed (976)	Sprayed (502)	Unsprayed (949)	Sprayed (456)	Unsprayed (2946)	Sprayed (1489)
Web builders[a]	22.93	8.96	21.98	8.52	21.99	9.03	22.32	8.84
Visual hunters[b]	27.96	16.94	28.95	17.93	28.04	15.95	28.32	16.96
Tactile hunters[c]	14.88	8.32	15.08	7.51	17.50	7.47	15.78	7.78
Total	65.78	34.22	66.03	33.96	67.54	32.45	66.42	33.58

*Numbers in parentheses are total spider numbers on which percentage are based
[a] Araneidae, Tetragnathidae, Theridiidae and Linyphiidae
[b] Lycosidae, Ctenidae, Salticidae, Oxyopidae, Gnaphosidae and Pisauridae
[c] Thomisidae, Philodromidae, Clubionidae and Miturgidae

and Oatman (1964); Bostanian *et al.* (1984) and many others reported that hunting spiders were more adversely affected by pesticides in sprayed apple orchards. In all three cases, hunting spiders were the major guilds in the spider community of the orchards hence they were the groups to suffer major loss.

Spider webs have been reported to be efficient collectors of insecticide sprays (Samu *et al*., 1992); because, some web makers periodically ingest their web e.g Theridiidae, thus, increasing the risk of pesticide exposure. The reduced proportion of web-building spiders may in part be attributed to the mechanical disruption of spider webs induced by the high speed spray droplets (McCaffery and Horsburgh, 1980). Lack of prey is likely to affect web-building spiders the most because of their sedentary foraging behaviour. The hunter species inhabiting the ground vegetations are likely to be least affected simply because of escape from pesticide application. Foliage inhabiting spiders are affected by pesticide application but the added advantage of their high mobility increased their chances of survival. Besides, the lush foliage resulting from fungicide application provides a better habitat for this kind of spider (Legner and Oatman, 1964), innate capacity of resistance may also be responsible for variation in response to the pesticide application (Mansour and Nentwig, 1988).

None of the spider families showed a variation of more than 6% between the sprayed and unsprayed orchards. This could probably be attributed to the immigration of spiders from adjoining uncultivated land, thus compensating the diversity loss during the growing season of apple, owing to pesticide use. The spider species found to be altogether absent from the sprayed orchards, *viz., A. trifolium, Hyposigha* spp., and *Zygoballus* spp. *T. cherapunjeus* constituted very low percentage even in the spider communities that were not under the pesticide application pressure. Thus, their absence from the sprayed orchards can be safely justified (Joanna and Ronald, 1997).

The data pertaining to species abundance of the spider families in apple orchards of Kashmir is presented in Table 5. Margalef's richness index (Da) indicated that web building spider (6.210 and 6.170) were at par with visual hunters (6.133 and 6.258) so far as species richness is concerned in both the unsprayed and sprayed orchards, respectively. Tactile hunters, differ appreciably from the other two groups of spiders in both unsprayed (3.514) and sprayed (3.547) orchards. But, no appreciable difference was noted for species richness (Da) between the sprayed and unsprayed orchards. Shannon Wiener diversity index (H') was found to be significantly different for web building spider between unsprayed (0.474) and sprayed (0.580) orchards, while, no appreciable difference between sprayed and unsprayed orchards was noted in case of visual hunter spiders and tactile hunters. In case of visual hunters, H' for unsprayed and sprayed orchards was found to be 0.370 and 0.396 and for tactile hunters the values were 0.625 and 0.636, respectively.

The three groups (foraging behavior) of spiders showed similar trend for Shannon Wiener diversity index (H') in both unsprayed and spayed orchards i.e. 0.474, 0.370 and 0.625 H' values for web builders, visual hunters and tactile hunters, respectively in unsprayed orchards and 0.580 and 0.396 and 0.636 respectively for sprayed orchards. The Pielou's evenness index (E) varied significantly for web builders and tactile hunter between the unsprayed

Table 5. Parameters of abundance of spider fauna in unsprayed and sprayed apple orchard of Kashmir during 2008–2009

Spider group/family	Parameter of abundance of spider families in apple orchard of Kashmir									
	Unsprayed									
	N	S	E	H'	Da	N	S	E	H'	Da
WEB-BUILDER										
Araneidae	218	10	1.131	1.131	3.849	96	8	1.318	1.191	3.531
Tetragnathidae	266	4	1.735	1.045	1.237	100	4	2.440	1.469	1.500
Theridiidae	390	3	1.842	0.879	0.772	141	3	2.146	1.024	0.930
Linyphidae	116	2	4.667	1.405	0.484	55	2	4.756	1.432	0.574
Sub-total	990	19	0.371	0.474	6.210	392	17	0.471	0.580	6.170
VISUAL HUNTER										
Lycosidae	338	5	1.346	0.940	1.582	207	5	1.226	0.856	1.873
Ctenidae	84	2	5.132	1.545	0.519	48	2	4.956	1.492	0.594
Salticidae	280	6	1.313	1.022	2.043	128	5	1.527	1.066	1.898
Oxyopidae	140	3	2.773	1.323	0.932	84	3	2.615	1248	1.039
Ganaphosidae	222	2	3.730	1.123	0.426	156	2	3.262	0.982	0.456
Pisauridae	192	2	6.192	1.864	0.438	129	2	3.528	1.062	0.473
Sub-total	1256	20	0.284	0.370	6.133	752	19	0.231	0.296	6.258
TACTILE HUNTER										
Thomisidae	275	5	1.475	1.030	1.640	129	4	1.764	1.062	1.421
Philodromidae	111	2	4.730	1.424	0.488	55	2	4.757	1.432	0.574
Clubionidae	163	3	2.634	1.257	0.904	87	3	2.584	1.233	1.031
Miturgidae	151	1	0.000	1.290	0.000	74	1	0.000	1.304	0.000
Sub-total	700	11	0.533	0.625	3.514	345	10	0.636	0.636	3.547
Total	2946					1489				
Number of species		50					46			
Total spiders collected in apple orchards				4435						

N = Total number of individuals, S = Number of species, E = Pielou's evenness index, H' = Shannon-Wiener diversity index, Da = Margalef's richness index and sprayed orchards, while, no appreciable variation was noted in case of visual hunters. The E values noted in unsprayed and sprayed orchards were 0.371 and 0. 471 for web builders, 0.284 and 0.231 for visual hunters and 0.533 and 0.636 for tactile hunters, respectively. The maximum variation was observed in case of tactile hunters followed by web builders.

No appreciable difference was observed in case of individual families for Margalef's richness index between unsprayed and sprayed orchards, except family Araneidae and Saticidae. The variation in H' value for web builders was mainly because of the variation in family Tetragnathidae and Theridiidae between unsprayed and sprayed orchards. Similarly, family Lycosidae and Gnaphosidae showed some variation for H' value between the unsprayed and sprayed orchards, but, the overall value were at par for visual hunters and tactile hunters. Higher values of E were noted for all the web building and tactile hunter families in sprayed orchards or compared to unsprayed ones, while, as reverse was true for visual hunter, however, the average E values were at par between the two treatments for the later. Appreciable difference was noted in case of family Pisuridae (E=6.192, 3.528), respectively, for unsprayed and sprayed orchards. The difference was not observed among the selected locations for sprayed in relation to unsprayed orchards, although, the absolute values of species abundance and species diversity differ owing to differences in altitude, temperature humidity and the effect of local factors.

The species richness in a community and their evenness in abundance or equitability i.e. species evenness are the two parameters that define species diversity. As species are lost, diversity decreases and as species become less evenly distributed in abundance, diversity also decreases. In a diverse situation, species cannot be very dominant and in a low diversity community one or two species will be much more abundant than others (Pielou, 1969; Pielou, 1975; Poole, 1974). Among all the three spider guilds, the species richness of all of them was not affected by pesticide application; however, the diversity of web-builders and one family of tactile hunter (Thomisidae) was appreciably affected by pesticide application. This fact may be related to their great dispersal potential as Araneidae and Thomisidae (Bishop and Riechert 1990; Valverde and Lobo, 2007). The sprayed orchards exhibited poor spider diversity and less even distribution of spider taxa. The pesticide application affected the spider fauna almost to the same extent at all the locations. Keeping in view the importance of spiders in biological pest suppression, pesticides to safety of spiders should be an important part of pest management strategy.

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