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Research Article

Spider fauna (Arachnida: Araneae) in temperate fruit orchards of Kashmir

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ABSTRACT: The spider fauna associated with temperate orchards of three fruit crops (apple, pear and cherry) of Kashmir comprising 14 families, 35 genera and 51 species during was recorded 2008–2009. Among the recorded species, 19 belong to web-building, 20 to visual hunter and 12 to tactile hunter group. The proportion of visual hunters was highest (44.97%), followed by web-builders (31.91%) and tactile hunter (23.12%). In web-spinning spider guild, *Araneus* sp. followed by *Neoscona mukerjei* Tikader of Araneidae; *Tetragnatha* sp. followed by *Leucauge celebesiana* (Walckenaer) of Tetragnathidae; *Theridula* sp. of Theridiidae and *Linyphia* sp. of Linyphiidae were found abundant. Among visual hunters, *Pardosa altitudus* Tikader and Malhotra of Lycosidae; *Ctenus himalayensis* Gravely of Ctenidae; *Myrmarachne.* sp. of Salticidae; *Oxyopes* sp. of Oxyopidae; *Setaphis* sp. of Gnaphosidae and *Pisaura*[1] sp. of Pisauridae and among tactile hunters, *Thomisus* sp. followed by *Xysticus* sp. of Thomisidae; *Clubiona* sp. of Clubionidae and *Cheiracanthium* sp. of Miturgidae were found abundant in the fruit orchards of Kashmir. The maximum population was recorded under family Lycosidae (12.22%), followed by Theridiidae (12.17%) and Thomisidae (9.51%). Margalef's richness index, Shannon-Wiener diversity index and Pielou's evenness index of visual hunters were greater followed by web-builders. The species richness was greater in pear orchard followed by cherry orchard while the species diversity was greater in apple orchard followed by cherry orchard and the variation in communities between species was recorded highest in pear orchard followed by apple orchard.

KEY WORDS: Araneae, relative abundance, species diversity, species richness, species evenness, spider, temperate fruit orchards

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INTRODUCTION

Spiders are so diverse animals that they have attained 7th rank in diversity (Nyffeler and Benz, 1985). Approximately, 1, 20,000 species of spiders occur worldwide and only one fourth of the total fauna has been named (Patrick and Alain, 1997). Until now, 109 families, 3802 genera and 41719 spiders have been described worldwide (Platnick, 2010). Over 1000 species of spiders belonging to 236 genera and 44 families are so far known from the Indian subcontinent (Saliwal *et al.*, 2005). Spiders have been considered important predators which help regulate the population densities of insect pests (Khan and Misra, 2009). Due to their diversity and abundance they significantly reduce plant damage caused by insects and can achieve equilibrium in pest control, after which their own numbers are suppressed by their territoriality and cannibalism (Riechert and Lockley, 1984; Khan and Misra, 2003). In particular, spider communities in area with a temperate climate achieve equilibrium in the control of orchard pests (Riechert, 1999; Sackett *et al.*, 2008). In spite of this, they have not usually been treated as mportant biocontrol agents because there is so little information on the ecological role of spiders in pest control (Turnbull, 1973; Khan, 2006). DeBach and Rosen (1991) attributed this in part to their generalist predatory habits.

Spiders often constitute a large part of the predatory arthropod fauna of orchards and prey on such pests as aphids and moths (Khan, 2009). With this in mind, a study was initiated to determine the species composition and habitat association of spiders in Kashmir fruit orchards. As information on biodiversity and abundance of the predatory community is a prerequisite for any detailed evaluation of the predator's role in pest control in temperate fruit orchards of Kashmir, the current study is supposed to be a valuable step in this concern.

MATERIALS AND METHODS

Study site and period of sampling

The study was carried out in the temperate apple fruit orchards of Kashmir located between 32.17 degree and 36.58-degree north latitude and 37.26 degree and 80.30-degree east longitude with altitude varying from 1500 to 2200 metres above mean sea level. The topography of Kashmir valley is characterized by mountain ranges encompassed by the mighty Himalayas. For the experiment, three districts, *viz.*, Srinagar, Baramulla and Pulwama (Sophian) of Kashmir, India were selected and from these districts three locations each were selected, namely, Shalimar, Harwan, and GulabBagh from Srinagar; Wagoora, Mamoosa, and Warpora from Baramulla and Khag, Shopian and Tral from Pulwama. Samples were collected from the three orchards (apple, pear and cherry) at fortnightly interval from 18th standard week to 38th standard week during 2008-2009 for two consecutive years. The age of selected trees was noted between 15-21 years grown with spacing of 6 × 6 meter. All the samples were collected during the day time.

Sampling methods

Sampling was conducted using three different 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 and barks and spiders tapped loose with the cap. Smaller species were picked up with a moistened finger, or a small camel's hair brush. Five trees were selected randomly from each location for vial tapping for 15 minutes/trees. In quadrat method (wooden frame, 1.0 × 1.0 square meters), collection of spiders were made from five quadrats, 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 quadrat (1.0 × 1.0 square meters area), the spiders were collected from the understory vegetation under tree canopy carefully with least disturbance of arthropod fauna. For study of the ground dwelling spiders, pitfall trap was used at the experimental sites. The traps were plastic cups (diameter 9 centimetres and height 12 centimetre) buried in the soil at the surface level containing ethylene glycol as preservative filling the bottom up to 2 centimetre height. Five traps were placed in a row 10 meter apart 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 preservative.

Identification of spiders

All collected spiders were transported back 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 (70% alcohol – 85 parts, glycerine – 5 parts; glacial acetic acid – 5 parts) for identification. In the laboratory, specimens were identified on the basis of criteria given by workers (Tikader and Bal, 1980; Tikader, 1982, 1987; Barrian and Litsinger, 1981, 1995; Gajbe, 2004; Satpathi, 2004; Mukhtar, 2004; Platnick, 2010; Khan and Khan, 2011). Species were classified according to Platnick (2010). Additionally the recorded spiders were divided into three main guilds (Nyffler, 1982; Khan, 2009) – web builders (Araneidae, Tetragnathidae, Linyphiidae and Theridiidae), visual hunters (Lycosidae, Oxyopidae, Gnaphosidae, Pisuaridae and Sparassidae) and tactile hunters (Thomisidae, Clubionidae and Miturgidae).

Ecological indices for quantitative analysis

Quantitative estimation of individual species was made using the data derived from field survey. Species richness (Da) diversity and eveners of population were calculated using Margalef's richness index Shannon-Wiener diversity index and Pielou's evenness index, respectively.

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

Da = (S-1)/loge 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 one measure that is used to try to draw information from samples in the field. Though the results of the Shannon-Wiener index need 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:

$H' = -Ó\ pi\ \ln\ pi$; 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 is taken while 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).

RESULTS AND DISCUSSION

All collected spiders are listed in Table 1. There were 14 families, 35 genera and 51 species represented with 19 web-builders 20 visual hunters and 12 tactile hunters. A total of 39, 35 and 27 species were recorded from apple orchard, 25, 24 and 25 from pear orchard and 32, 34 and 30 from cherry orchard of Shalimar, Harwan and Gulabag of District Srinagar, while 30, 30 and 35 species were identified from apple orchards, 30, 27 and 25 species from pear orchards and 27,30 and 26 from cherry orchards of Waggora, Mamoosa and Warpora of district Baramulla and 36, 38 and 37 species from apple orchard, 29, 22 and 19 species from pear orchard and 31, 29 and 32 species from cherry orchard of Khag, Shophian and Tral of District Pulwama (Shopian), respectively. Similar reports have been documented based on numerous studies conducted elsewhere (Chant, 1956; Legner and Oatman, 1964; MaCaffrey and Horsburhg, 1980; Madsen and Madsen, 1982; Bogya *et al.,* 1997; Sackett *et al.,* 2008; Miliczky *et al.*, 2008). There was a total 51 species 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. Miliczky *et al.* (2008) reported occurrence of 43 species in 28 genera and 12 families in their study on overwintering spiders in apple and pear orchards in Washington, USA.

Among the families, the life style of 4 families, *viz.,* Araneidae (orb-spinning spider), Tetragnathidae (four jawed spider), Theridiidae (comb foot spider) and Linyphiidae (dwarf spider) was web building; 5 families *viz.,* Lycosidae (wolf spider), Ctenidae (false wolf spider), Salticidae (Jumping spider), Oxyopidae (lynx spider), Gnaphosidae (ground spider) and Pisauridae (nursery web spiders) were visual hunters; 4 families *viz.,* Thomisidae (crab spider), Philodromidae (running crab spider), Clubionidae (sac spider or 2-clawed spider) and Miturgidae (prowling spiders or yellow sac spiders) were tactile hunters. Out of these recorded web builders, 10 species and 5 genera recorded under family Araneidae; 4 species and 3 genera under family Tetragnathidae; 3 species and 3 genera under family Theridiidae and 2 species and 2 genera under family Linyphiidae. Among visual hunters, 5 species and 4 genera recorded under family Lycosidae; 2 species and 1 genus under family Ctenidae; 7 species and 6 genera under family Salticidae; 3 species and 1 genus under family Oxyopidae; 2 species and 2 genera under family Gnaphosidae and 2 species and 1 genus under family Pisauridae. Out of 4 families of tactile hunters, 5 species and 3 genera under family Thomisidae; 2 species and 2 genera under family Philodromidae; 2 species and 2 genera under family Clubionidae and 2 species and 1 genus under family Miturgidae. Most of the web-building spiders were observed in vial tapping and quadrat method of sampling that indicate they are found on tree as well as understory vegetation. Visual hunters including families Lycosiae, Ganaphosidae, Pisauridae and Cetinidae and tactile hunters including family Philodromidae were observed in both quadrats and pitfall traps. It showed their presence in understory vegetation as well as ground surface. Salticidae and Miturgidae were recorded in all sampling methods (Table 1).

In the group of web-spinning spiders, *Araneus* sp. followed by *Neoscona mukerjei* of Araneidae; *Tetragnatha* sp. followed by *Leucauge celebesiana* of Tetragnathidae; *Theridula* sp. of Theridiidae and *Linyphia* sp. of Linyphiidae were found abundant. Among visual hunters, *Pardosa altitudis* of Lycosidae; *Ctenus himalayensis* of Ctenidae; *Myrmarachne* sp. of Salticidae; *Oxyopes* sp. of Oxyopidae; *Setaphis* sp. of Gnaphosidae and *Pisaura* of Pisauridae and among tactile hunters, *Thomisus* sp. followed by *Xysticus* sp. of Thomisidae; *Clubiona* sp. of Clubionidae and *Cheiracanthium* sp. of family Miturgidae were found abundant in fruit orchards of Kashmir.

The proportion of visual hunters was recorded highest (44.97%) followed by web-builders (31.91%) and tactile hunters (23.12%) (Table 3). Among all locations, the relative abundance of visual hunters was recorded highest in Wagoora (48.76%), while web-builder

Table 1. Summary of spider fauna captured in fruit orchards of Kashmir during 2008-2009

Spider group, Family, Genus, species	Abundance of spider species in fruit orchards of different districts of Kashmir																											Spider species collected in sampling methods
	Srinagar									Baramulla									Pulwama									
	Shalimar			Harwan			Gulabbagh			Wagoora			Mamoosa			Warpora			Khag			Shopian			Tral			
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	
WEB BUILDERS																												
Family Araneidae																												
Neoscona theisi (Walckenaer)	2	3	–	2	–	1	1	–	–	-	-	2	2	1	-	1	4	-	1	-	-	1	-	2	1	4	-	V, Q
Neoscona mukerjei Tikader	5	–	–	–	–	3	5	–	–	7	-	3	5	3	2	3	-	1	2	3	2	3	-	-	3		3	V, Q
Neoscona shillongensis Tikader & Bal	–		2	3	–	1	1	–	–	1	-	1	1	-	-	1	-	-	-	2	1	-	-	3	1	-	1	V, Q
Neoscona sp.	1	3	2	1	3	2	–	4	1	2	2	-	-	1	1	1	-	-	1	-	-	-	-	-	1	-	-	V, Q
Araniella cucurbitina (Clerck)	3	–	–	2	–	2	1	–	2	3	4	-	-	2	1	-	-	1	1	-	1	1	-	1	-	-	-	V, Q
Araneus trifolium (Hentz)	1	–	–	–	–	–	–	–	–	5	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	V, Q
Araneus sp.	6	5	4	4	8	2	6	–	4	-	8	4	7	-	1	5	-	-	4	5	2	6	5	8	4	9	2	V, Q
Nephila sp.	–	–	–	1	–	1	–	5	2	1	-	-	1	-	-	-	4	1	1	-	-	-	-	-	2	-	-	V, Q
Cyclosa elongata Biswas & Raychaudhuri	1	–	2	1	–	–	2	–	1	1	-	-	1	1	-	2	-	1	1	-	-	2	2	-	-	-	1	V, Q
Hypsosinga sp.	–	2	1	–	2	–	–	–	–	-	2	-	-	2	1	1	3	-	-	-	-	1	-	4	1	-	1	V, Q
Subtotal	19	13	11	14	13	12	16	9	10	20	16	10	17	10	6	14	11	4	12	10	6	14	7	18	13	13	8	
Family Tetragnathidae																												
Tetragnatha sp.	9	18	–	12	–	10	13	–	5	11	7	-	9	8	8	-	-	9	3	5	4	10	-	9	9	-	4	V, Q
Eucta sp.	2	–	–	–	–	–	–	–	4	5	2	2	1	-	-	2	-	-	1	-	-	-	2	-	1	-	-	V, Q
Leucauge celebesiana (Walckenaer)	5	–	9	8	–	4	7	19	3	-	-	-	-	5	-	-	10	-	4	3	3	5	10	7	2	7	2	V, Q
Leucauge sp.	5	–	8	6	18	6	3	–	–	3	9	4	7	-	-	10	-	-	3	2	2	-	-	-	-	4	2	V, Q
Subtotal	21	18	17	26	18	20	23	19	12	19	18	6	17	13	8	12	10	9	10	10	9	15	12	16	12	11	8	
Family Theridiidae																												
Theridula sp.	13	–	16	13	18	12	10	15	11	14	19	18	14	13	18	14	10	19	-	18	18	12	16	18	18	20	19	V, Q
Achaearanea sp.	4	5	–	3	3	1	–	2	–	-	-	2	2	-	-	7	-	-	3	-	-	2	4	-	-	4	3	V, Q
Theridion sp.	11	15	7	11	–	7	12	4	7	10	-	-	-	-	-	-	8	-	16	3		8	-	-	8	-	-	V, Q
Subtotal	28	20	23	27	21	20	22	21	18	24	19	20	16	13	18	21	18	19	19	21	18	22	20	18	26	24	22	
Family Linyphiidae																												
Linyphia sp.	6	–	2	9	–	1	15	–	–	14	8	3	7	4	2	6	9	1	-	4	20	14	-	3	5	12	1	V, Q
Lepthyphantes bhudbari Tikader	2	17	1	–	5	–	–	–	–	-	4	-	-	2	1	1	3	-	-	-	-	4	-	1	2	-	1	V, Q
Subtotal	8	17	3	9	5	1	15	–	–	14	12	3	7	6	3		12	1	-	4	20	18	-	4	7	12	2	

Spider group, Family, Genus, species	Abundance of spider species in fruit orchards of different districts of Kashmir																											Spider species collected in sampling methods
	Srinagar									Baramulla									Pulwama									
	Shalimar			Harwan			Gulabbagh			Wagoora			Mamoosa			Warpora			Khag			Shopian			Tral			
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	
VISUAL HUNTERS																												
Family Lycosidae																												
Lycosa sp.	8	6	5	4	9	5	5	7	3	9	6	3	7	4	2	5	3	5	4	3	6	4	3	5	7	3	2	Q, P
Pardosa altitudis Tikader & Malhotra	10	16	14	16	16	10	18	10	9	15	15	16	13	12	10	14	10	9	18	16	10	11	11	10	14	9	10	Q, P
Pardosa ladakhensis Tikader	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	4	5	-	-	-	-	-	-	-	3	-	Q, P
Evippa sp.	2	-	1	1	-	1	-	-	2	4	-	-	-	2	-	4	2	-	1	3	2	1	2	1	-	3	-	Q, P
Arctosa sp.	3	-	-	4	2	2	-	-	2	-	3	-	-	-	6	-	1	-	-	-	3	4	-	2	2	-	6	Q, P
Subtotal	23	22	20	25	25	18	23	17	16	28	24	19	21	18	18	25	20	19	23	22	21	20	16	18	23	18	18	
Family Ctenidae																												
Ctenus indicus Gravely	15	-	-	10	-	6	-	10	-	-	12	10	-	8	1	10	13	-	-	5	4	9	4	3	7	4	1	Q, P
Ctenus himalayensis Gravely	-	2	-	2	-	-	11	-	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	1	Q, P
Subtotal	15	2	-	12	-	6	11	10	-	-	12	10	-	8	1	10	13	-	12	5	4	9	4	3	7	4	2	
Family Salticidae																												
Phidippus sp.	3	-	-	2	3	-	9	-	1	2	2	-	-	-	-	-	1	1	3	1	-	-	2	1	2	-	1	V,Q, P
Marpissa sp.	-	9	2	3	2	2	-	10	2	3	2	-	3	12	1	2	-	2	1	-	1	2	-	1	4	-	-	V,Q, P
Myrmarachne sp.	12	-	8	15	9	10	-	9	11	12	10	14	13	-	5	9	8	5	9	7	3	9	7	-	-	-	5	V,Q, P
Myrmarachne himalayensis Narayan	5	-	3	-	-	-	10	-	-	-	-	-	-	-	1	-	-	-	3	2	5	3	-	6	7	-	-	V,Q, P
Zygoballus sp.	-	-	-	-	1	5	-	1	-	-	1	4	-	-	1	2	2	1	-	-	-	-	-	-	-	-	-	V,Q, P
Plexippus sp.	1	9	2	-	2	-	-	-	-	5	3	-	3	-	-	2	-	-	1	-	1	1	-	-	4	11	2	V,Q, P
Subtotal	21	18	15	20	17	17	19	20	14	22	18	18	19	12	8	15	11	9	17	10	10	15	9	8	17	11	8	
Family Oxyopidae																												
Oxyopes ratnae Tikader	6	-	5	3	-	-	9	-	1	-	-	1	-	-	2	-	-	-	1	2	-	1	3	-	-	-	-	V,Q
Oxyopes javanus (Thorell)	-	4	-	-	-	-	4	2	-	-	-	1	-	-	2	18	-	-	-	-	-	3	-	-	-	-	7	V,Q
Oxyopes sp.	8	11	-	7	8	7	-	6	2	10	12	1	11	9	-	-	-	10	8	5	2	6	5	3	10	-	-	V,Q, P
Subtotal	14	15	5	10	8	7	13	8	3	10	12	3	11	9	4	18	-	10	9	7	2	10	8	3	10	-	7	
Family Gnaphosidae																												
Setaphis sp.	9	8	5	11	12	4	25	10	7	-	23	3	23	12	6	15	12	6	14	9	7	18	19	7	12	-	9	Q, P
Zelotes sp.	7	3	3	6	-	3	-	8	3	26	-	4	-	6	2	5	-	2	7	3	3	5	-	-	6	14	2	Q, P
Subtotal	16	11	8	17	12	7	25	18	10	26	23	7	23	18	8	20	12	8	21	12	10	23	19	7	18	14	11	
Family Pisauridae																												Q, P
Pisaura sp.[1]	9	7	6	12	11	8	7	5	3	16	9	8	12	-	6	12	10	8	10	10	7	11	7	6	12	-	8	Q, P
Pisaura sp.[2]	6	-	3	6	4	3	4	2	2	4	4	3	5	12	2	7	-	1	5	2	2	3	3	3	7	11	-	Q, P
Subtotal	15	7	9	18	15	11	11	7	5	20	13	11	17	12	8	19	10	9	15	12	9	14	10	9	19	11	8	

Spider group, Family, Genus, species	Abundance of spider species in fruit orchards of different districts of Kashmir																												Spider species collected in sampling methods
	Srinagar									Baramulla									Pulwama										
	Shalimar			Harwan			Gulabbagh			Wagoora			Mamoosa			Warpora			Khag			Shopian			Tral			
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	
TACTILE HUNTERS																													
Family Thomisidae																													
Thomisus sp.	7	3	1	20	7	1	4	2	1	6	3	1	6	-	2	3	2	2	3	1	2	4	4	1	3	4	2	V,Q
Thomisus whitakeri Gajbe	1	-	-	-	-	2	-	1	-	-	-	-	2	-	1	-	-	-	-	-	1	2	-	1	1	-	-	V,Q
Thomisus cherapunjeus Tikader	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	V,Q
Xysticus sp.	15	11	4	-	16	6	20	12	7	12	11	10	22	18	4	14	14	6	13	10	5	10	12	5	17	15	9	V,Q,P
Runcinia sp.	-	2	1	8	-	1	-	1	1	-	1	1	-	-	-	1	-	-	-	1	1	4	-	-	3	1	11	V,Q
Subtotal	23	16	7	28	23	10	24	16	10	18	15	12	30	18	7	18	16	8	16	12	9	20	16	7	24	20	13	
Family Philodromidae																													
Philodromus sp.	3	-	-	8	4	-	-	14	-	10	2	3	11	4	5	18	6	3	9	9	-	-	2	12	9	-	8	Q, P
Thanatus sp.	2	3	-	-	-	-	-	-	3	4	1	-	3	1	-	-	-	1	-	7	7	8	-	6	3	-	-	Q, P
Subtotal	5	3	-	8	4	-	-	14	3	14	3	3	14	5	5	18	6	4	9	16	7	8	2	18	12	-	8	
Family Clubionidae																													
Clubiona sp.	11	12	4	10	10	6	13	8	8	9	10	6	9	10	8	6	8	7	8	8	1	10	13	5	9	5	6	V,Q
Clubiona japonicola Boesenberg & Strand	-	-	3	-	-	-	-	-	-	-	3	-	-	-	-	3	-	-	2	-	1	-	-	-	-	-	-	V,Q
Subtotal	11	12	7	10	10	6	13	8	8	9	13	6	9	10	8	9	8	7	10	8	2	10	13	5	9	5	6	
Family Corinnidae																													
Castianeira sp.	5	-	1	3	-	1	2	-	-	-	-	1	3	-	1	1	-	1	1	-	-	5	-	-	2	-	1	V,Q
Subtotal	5	-	1	3	-	1	2	-	-	-	-	1	3	-	1	1	-	1	1	-	-	5	-	-	2	-	1	V,Q
Family Miturgidae																													
Cheiracanthium sp.	13	10	1	15	9	3	6	9	6	9	6	-	10	6	4	6	5	3	4	6	2	8	9	6	12	-	4	V,Q, P
Cheiracanthium himalayense Gravely	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	V,Q, P
Subtotal	14	10	1	15	9	3	6	9	6	9	6	-	10	6	4	6	5	3	4	6	2	10	9	6	12	-	4	
Total number of spiders collected	238	184	127	242	180	139	223	176	115	233	204	129	214	158	107	213	152	111	178	155	129	213	145	140	211	143	126	
Total species collected	39	25	32	35	24	34	27	25	30	30	31	27	30	25	30	35	24	26	36	29	31	38	22	29	37	19	32	

A = Apple, B = Pear, C = Cherry, V = vial tapping/hand picking, Q = Quadrat, P = Pitfall trap, – = absent

Table 2. Relative abundance of spider families in fruit orchards of different districts of Kashmir during 2008 -2009

Spider families	Srinagar (1624)			Baramulla (1521)			Pulwama (1440)			
	Shalimar (549*)	Harwan (561*)	Gulab bagh (514*)	Wagoora (566*)	Mamoosa (479*)	Warpora (476*)	Khag (462*)	Sophian (498*)	Tral (480*)	Total (4585*)
	%	%	%	%	%	%	%	%	%	%
Araneidae	7.83	6.95	6.80	8.12	6.88	6.09	6.06	7.83	7.08	7.11
Tetragnathidae	10.20	11.40	10.51	7.59	7.93	6.52	6.27	8.64	6.46	8.49
Theridiidae	12.93	12.13	11.87	11.13	9.82	12.18	12.56	12.04	15.00	12.17
Linyphidae	5.10	2.68	2.92	5.13	3.34	4.20	5.19	4.42	4.38	4.14
Lycosidae	11.84	12.13	10.89	12.55	11.89	13.45	14.29	10.84	12.29	12.22
Ctenidae	3.09	3.20	4.08	3.88	1.88	4.83	4.55	3.22	2.71	3.48
Salticidae	9.84	9.63	10.32	10.25	8.15	7.35	8.01	6.43	7.5	8.68
Oxyopidae	6.19	4.45	4.66	4.42	5.01	5.88	3.89	4.22	3.55	4.71
Gnaphosidae	6.38	6.42	10.32	9.89	10.23	8.40	9.31	9.83	8.96	8.81
Pisauridae	5.65	7.84	4.47	7.77	7.72	7.98	7.79	6.62	7.91	7.07
Thomisidae	8.37	10.87	9.74	7.95	11.48	8.82	8.01	8.64	11.87	9.51
Philodromidae	1.46	2.14	3.32	3.53	5.01	5.88	6.93	5.62	4.16	4.12
Clubionidae	6.56	5.35	6.04	5.15	6.47	5.48	4.55	6.63	4.79	5.67
Miturgidae	4.56	4.81	4.06	2.65	2.95	2.94	2.59	5.02	3.34	3.82

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

Table 3. Relative abundance of spiders of various foraging behavior in Kashmir fruit orchards during 2008-2009

Foraging behavior	Srinagar (1624)			Baramulla (1521)			Pulwama (1440)			
	Shalimar (549*)	Harwan (561*)	Gulab bagh (514*)	Wagoora (566*)	Mamoosa (479*)	Warpora (476*)	Khag (462*)	Sophian (498*)	Tral (480*)	Total (4585*)
Web builders[a]	36.06	33.16	32.10	31.97	27.97	28.99	30.08	32.93	32.92	31.91
Visual hunters[b]	42.99	43.67	44.75	48.76	44.88	47.89	47.84	41.16	42.92	44.97
Tactile hunters[c]	20.95	23.17	23.15	19.27	27.15	23.12	22.08	25.91	24.16	23.12

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

Table 4. Parameters of abundance of spider fauna in fruit orchards of Kashmir during 2008 – 009

Spider group/family	Parameters of abundance of spider fauna in fruit orchards of Kashmir															Family recorded in sampling methods
	Apple					Pear					Cherry					
	N	S	E	H'	Da	N	S	E	H'	Da	N	S	E	H'	Da	
Web-builders																
Araneidae	139	10	1.153	1.153	4.199	102	9	1.223	1.167	3.984	85	9	1.175	1.121	4.147	V, Q
Tetragnathidae	155	4	1.832	1.103	1.369	129	4	1.116	1.065	1.422	105	4	1.709	1.029	1.484	V, Q
Theridiidae	205	3	2.056	0.981	1.298	177	3	1.943	0.927	0.890	176	3	1.687	0.805	0.890	V, Q
Linyphidae	85	2	4.531	1.364	0.508	68	2	1.649	1.342	0.545	37	2	2.326	1.482	0.637	V, Q
Subtotal	584	19	0.412	0.527	6.507	476	18	0.396	0.498	6.350	403	18	0.286	0.359	6.525	
Visual Hunters																
Lycosidae	211	5	1.391	0.971	1.791	182	5	1.311	0.915	1.769	167	4	1.377	0.829	1.350	Q, P
Ctenidae	76	2	4.694	1.413	0.532	58	2	4.691	1.412	0.567	26	2	5.435	1.636	0.707	Q, P
Salticidae	165	6	1.383	1.076	2.255	126	6	1.383	1.076	2.380	107	6	1.312	1.021	2.464	V,Q, P
Oxyopidae	105	3	2.667	1.272	0.989	67	3	2.827	1.349	1.098	44	3	0.856	1.408	2.951	V,Q
Ganaphosidae	189	2	3.378	1.017	0.439	139	2	3.428	1.032	0.467	76	2	3.887	1.170	0.531	Q, P
Pisauridae	148	2	3.730	1.123	0.461	97	2	3.950	1.189	0.503	79	2	3.827	1.152	0.527	Q, P
Subtotal	894	20	0.262	0.342	6.438	669	20	0.344	0.447	6.725	499	19	0.276	0.353	6.671	
Tactile hunters																
Thomisidae	201	5	1.460	0.990	1.737	152	5	1.425	0.994	1.834	83	5	1.618	1.131	2.919	V, Q
Philodromidae	88	2	4.481	1.349	0.514	53	2	4.820	1.451	0.580	48	2	4.416	1.369	0.594	Q, P
Clubionidae	112	3	2.607	1.244	0.976	87	3	2.588	1.235	1.031	61	3	2.651	1.265	1.120	V, Q
Miturgidae	86	2	3.445	1.359	1.236	60	1	0.000	1.397	0.000	29	1	0.000	1.588	0.000	V,Q, P
Subtotal	487	11	0.581	0.605	3.718	352	11	0.603	0.628	3.927	221	11	0.678	0.706	4.273	
Species numbers		51					49					48				
Individual numbers	1965					1497					1123					
All individual number	4585															

N = Total number of individuals; S = Number of species; E = Pielou's evenness index; H' = Shannon-Wiener diversity index; Da = Margalef's richness index.

population was recorded highest (36.06%) in Shalimar and tactile population was highest (27.13%) in Mamoosa orchard. Maximum population was recorded under Lycosidae (12.22%) followed by Theridiidae (12.17%) and Thomisidae (9.51%). In web-building spiders, maximum population of Theridiidae (15.00%) at Tral followed by 12.93% was recorded at Shalimar. Out of visual hunter families, maximum population of Lycosidae (14.29%) was recorded at Khag followed by 13.45% recorded at Warpora, while in tactile hunters, the proportion of Thomisidae (11.87%) was recorded highest in Tral followed by Mamoosa (11.48%) (Table 2).

Despite spatial variation in absolute number, the proportion of web-builders was lower than visual hunters in most instances although the two were on par statistically at some of the locations depending upon sampling methods. The most important reason for higher proportion of visual hunters sampled is their foraging behaviour. The members of families like Araneidae are relatively easy to detect because of their size, colouration and their webs but the visual hunters keep on moving here and there frequently near the habitats and hence they are more prone to get trapped (Velbordo and Lobo, 2007). However, it partly depends on the method of sampling (Dobyns, 1997) besides other ecological factors. Members of families like Thomisidae ambush prey from flowers or leaves where their cryptic colouration allows them to go unnoticed. Some genera like *Xystius* live primarily among flowers, leaf litter and under story vegetation and showing minimal movements (Foelix, 1996; Bogya *et al.*, 1999). However, there must be some other rationale behind the species distribution.

Bajwa and Aliniazee (2001) recorded that Lycosidae, Salticidae, Theridiidae and Thomisidae comprised 85.56% of the total collected spiders of fruit orchards of Oregon. Earlier McCaffery and Horsburgh (1980) reported that Salticidae, Philodromidae, Thomisidae, Anyphanidae and Dictynidae comprised 75-92% of total spiders collected in study orchards of apple in Central Virginia. In the current study, it was found that Lycosidae, Theridiidae, Thomisidae, Gnaphosidae, Salticidae and Tetragnathidae accounted for around 60% of total spiders collected from the fruit orchards (Table 2), which is quite consistent with the earlier findings of species abundance in the fruit orchards.

Margalef's richness index indicated that the species richness of visual hunters was greater followed by web-builders in fruit orchards of Kashmir (Table 4). The species richness was higher (Da 6.725) in pear orchard followed by cherry orchard (6.671). In apple orchard, species richness was greater of web-builder spiders followed by visual hunters, while among families, richness was greater in Araneidae followed by Salticidae. In pear orchard, Da value (6.725) was highest for visual hunters followed by web-builders and among the families, the richness was greater in Araneidae fallowed by Thomisidae. In cherry orchard, the richness was observed similar to pear orchard.

Shannon-Wiener diversity index showed that the diversity of visual hunters was greater followed by web-building spiders in fruit orchards of Kashmir. Spider diversity was observed greater in apple orchard followed by cherry orchard. In apple orchard, the diversity of visual hunters was observed greater followed by web-building spiders and the diversity of Lycosidae was observed highest followed by Theridiidae. In pear and cherry orchard, the diversity was similar to apple orchard.

Pielou's evenness index indicated that evenness of the community of visual hunters was greater followed by web-building spiders (Table 4). The variation in communities between species was recorded highest in pear orchard followed by apple orchard. Among families, the variation was very less and the highest variation was recorded in Araneidae followed by Oxyopidae in apple orchard. In pear orchard, evenness of the community was greater in Tetragnathidae followed by Araneidae but among spider groups, the variation was higher in visual hunters. In cherry orchard, between communities the species variation was also greater among visual hunters and highest variation was observed in Oxyopidae followed by Araneidae.

The number of species, *i.e.*, 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 added, diversity increases, and as species become evenly distributed in abundance, diversity increases. 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, 1975; Poole, 1974). Margalef's richness index, Shannon-Weiner diversity index and Pielou's evenness index of visual hunters were greater followed by those of web-builders in fruit orchards of Kashmir. Spider diversity was observed greater in apple orchard, species richness was higher in pear orchard and variation in communities between species was recorded highest in pear orchard.

These factors probably account for the variation in species composition, species variation and species richness in the three types of orchards, different locations

studied and method of sampling. Thus we conclude that vegetation complexity is an important determinant of species richness for spiders. Additionally, other climatic and topographic factors have been highlighted as relevant for spiders, *e.g.*, humidity, temperature and altitude (Bonte *et al.*, 2002; Chataki *et al.*, 2005). A reasonable variation exists in the altitude of some of the selected locations above mean sea level; Srinagar (1730 metres), Tral (1970metres), Baramulla (1581 metres). Besides, some of the local factors may also modify the microclimate of the selected locations like the presence of a huge water body (Dak Lake) near Harwan and Shalimar, mountainous ranges on the North and North East of Tral and Shopian, although the average climatic condition of the selected locations is the same.

The selected fruit orchards show healthy condition of spider diversity as compared to reports from elsewhere, where the comparatively lower species diversity is mainly because of the heavy use of pesticides in the orchards, *e.g.* Central Virginia (McCaffery and Horsburgh, 1980) and Oregon (Bajwa and Aliniazee, 2001). Thus, the predaceous spider fauna can be an effective tool for biological pest suppression through proper conservation in Kashmir.

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