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Spider (Order: Araneae) fauna of Agro-ecosystem in South Andaman

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Abstract

The spider fauna of the Agro-ecosystem in South Andaman has been carried from the eleven sites in two consecutive seasons and sampling was conducted using various scientific methods during (November, 2017-January, 2018) and (Mid July-Early September 2018). A total of 56 spider species are distributed across 17 families.

Keywords: Agro-Ecosystem, Andaman, Araneae Diversity, Spiders

Introduction

In most natural ecosystems, invertebrates constitute the highest recorded fauna; however, their crucial role in sustaining these systems is often overlooked (New, 1995). Evaluating the distribution of invertebrates is essential for assessing their conservation status and determining potential management requirements. In the assessment of biodiversity, especially concerning insects, invertebrates cannot be disregarded (Holloway & Stork, 1991). The global count of existing species varies significantly, with estimates for insects ranging from 3 to 50 million species (Wilson & Peters, 1988). Recent literature suggests that the more accurate estimate is around 10 million species (Dobson, 1996). Discrepancies in estimating the number of insect species worldwide stem from variations in the calculation methods used for these estimates (Hawksworth, 1991; Solbrig *et al*., 1996).

Arachnids, a significant yet understudied group of arthropods, play a crucial role in regulating insect and other invertebrate populations across various ecosystems (Wesołowska & Russell-Smith, 2000). In India, previous conservation efforts have predominantly concentrated on larger vertebrates, neglecting invertebrates, which were only incidentally preserved in existing parks and protected areas. Recognising the importance of conserving all species, not just the larger vertebrates has become imperative (Samways, 1990). Consequently, surveys of invertebrate fauna, particularly in areas with established conservation strategies, have gained increased importance. Spiders, comprising approximately 50,936 described species globally (World Spider Catalog, 2023) and estimated to range from 60,000 to 170,000 species (Coddington & Levi, 1991), contribute significantly to terrestrial arthropod diversity. As the most diverse and abundant invertebrate predators in terrestrial ecosystems (Wise, 1993), spiders employ a remarkable variety of predation strategies, occupy diverse spatial and temporal niches, and demonstrate high taxonomic diversity within habitats. They exhibit taxon and guild responses to environmental changes, displaying extreme sensitivity to alterations in habitat structure such as vegetation complexity, litter depth, and microclimate characteristics (Uetz, 1991). Due to their high relative abundance, ease of collection, and diversity in habitat preferences and foraging strategies, spiders serve as effective indicators for monitoring site differences (Yen, 1995). The ubiquity, diversity, and ecological role of spiders position them as a promising focal group for invertebrate conservation, offering valuable insights into the impacts of land management on local biodiversity (Clauseu, 1986; Churchill, 1997; Topping & Lövei, 1997; Marc *et al*., 1999; Riecken, 1999).

Spiders exhibit potential as a collective group for conducting higher taxonomic surveys. According to

Oliver and Beattie (1996), individuals without specialized knowledge can undergo quick training to enumerate spider morphospecies accurately. However, there is a substantial need for further research to elucidate the utility of spiders as indicators, their relevance to high taxon surrogacy, and the development of standardized sampling techniques (New, 1999). This study seeks to contribute to a more nuanced understanding of these issues. Understanding the patterns of diversity among terrestrial arthropods is essential for effective biodiversity protection. These organisms, which may constitute 80% or more of the Earth's surface, have often been overlooked by resource managers and conservation planners. To enhance our knowledge of how and where to safeguard biodiversity, this study aims to address the gaps in understanding related to spiders and their potential role in ecological assessments (Wilson, 1992; Colwell & Coddington, 1994; Longino, 1994).

In India, the majority of ecological studies focusing on spiders were conducted predominantly in agro-ecosystems, particularly within rice ecosystems and coffee plantations (Sebastian *et al*., 2005; Kapoor, 2008). Limited information is available regarding the arachnid community composition in forest or natural ecosystems, particularly in undisturbed conserved areas in India. Previous efforts to inventory arachnids in protected areas in India were primarily motivated by objectives other than biodiversity assessment. Moreover, earlier studies employed a limited set of sampling techniques, potentially resulting in a partial and incomplete representation of the arachnid communities.

Literature Review

International Studies

Studies on Taxonomy

In India, most ecological studies on spiders have primarily focused on agroecosystems, specifically within rice ecosystems and coffee plantations (Sebastian *et al*., 2005; Kapoor, 2008). There is a scarcity of information regarding the composition of arachnid communities in forest or natural ecosystems, particularly in undisturbed conserved areas in India. Previous initiatives to catalogue arachnids in protected areas in India were primarily driven by objectives unrelated to biodiversity assessment. Furthermore, earlier studies utilized a restricted range of sampling techniques, possibly leading to a partial and inadequate portrayal of the arachnid communities.

The documentation and illustration of spider distribution in South Asian rice fields by Barrion and Litsinger (1995) represent a notable contribution to our understanding of these arachnids. While the Nearctic fauna is well-explored, particularly in regions like New Zealand, Australia, and Latin America, there exists a significant gap in knowledge regarding spiders in less-studied areas such as Africa, the Pacific, and other parts of Asia. The spider fauna in China has been subject to a thorough investigation, with Yin *et al*., (1997) covering three subfamilies, 33 genera, and 292 species, and Song and Zhu (1997) delving into the Thomisidae and Philodromidae families, encompassing 32 genera and 145 species. Noteworthy compendiums, including Kaston (1978) and Roth's field guide (Ubick *et al*., 1993), provide comprehensive insights into spider fauna in North America. The World Spider Catalog's latest update (2023) documents 50,936 spider species globally, spanning 4,115 genera and 132 families. The historical fascination with the distribution and diversity of spiders, dating back to the eighteenth century, continues to engage naturalists worldwide.

Studies on Ecology

Witt and Reed's (1965) analysis of spider web building asserts that the measurement of web geometry serves as a crucial tool in identifying components within the intricate behaviour patterns of invertebrates, as presented in their publication on a spider's web. Building on this, Wise (1975) conducted an experimental food study to delve into the potential food limitations of the spider Linyphia marginata. Toft's extensive work from 1976 to 1990, particularly in Danish beech wood, explored the life histories of spiders, providing notable insights into linyphiid spiders. In 1982, Wise focused on the predatory activity of the commensal spider Argyrodes trigonum upon its host, presenting findings from an experimental study. Schoener and Toft (1983) reported on the exceptionally high densities of spider populations on islands lacking top predators. Wise and Barata (1983) delved into the experimental effects of prey on two syntopic spiders with distinct web structures. Nossek and Rovner (1984) reported on agonistic behaviour in female wolf spiders (Araneae, Lycosidae). Wirth and Barth's (1992) experiments centred around forces acting on spider orb webs. Wise's publication in 1993, "Spiders in Ecological Webs," further contributed to the understanding of spiders in ecological contexts. Hénaut *et al*. (2006) studied the variation in web construction in *Leucauge venusta*, and subsequently, in 2010, they investigated the effects of drugs on web-building and their consequences for the web architecture of *Leucauge venusta*. These studies collectively underscore the significance of experimental approaches and varied ecological contexts in advancing our understanding of spider behaviour and ecology.

Studies on Indian Spiders

Spiders are highly abundant across the entire country, yet our understanding of Indian spiders remains quite incomplete. European researchers and later Indian Arachnologists have conducted studies on Indian spiders, with early contributions from Stoliczka (1869) and Karsch (1873). Simon (1887-1906) documented numerous species from the Himalayas and the Andaman and Nicobar Islands. Pioneering work on Indian spiders was carried out by Blackwell (1867), Karsch (1873), Simon (1887), Thorell (1895), and Pocock (1900). In his comprehensive work 'Fauna of British' India, Pocock, 1900a; (1895-1901) recorded two hundred spider species from India, Burma, and Ceylon. This publication, based on specimens at the British Museum, London, marked the first compilation, including enumerations and new descriptions of spiders in British India. Pocock also contributed valuable information on Oriental Mygalomorphs (1895a,b, 1899a, and 1900b), new species of Indian Arachnids (1899b and 1901), and spiders of Lakshadweep (Pocock, 1904), offering some of the earliest insights from these regions.

Throughout the twentieth century, significant contributions to the understanding of Indian spiders were made by various researchers. Narayan (1915), Gravely (1921), Reimoser (1934), and Dayal (1935) conducted notable studies on Indian spiders, while Sheriff (1919-1929) focused on describing numerous intriguing species in southern India. Gravely's work covered areas such as mimicry in spiders (Gravely's 1912) and mygalomorph spiders (1915 and 1935a-b), contributing valuable information to the field. Tikader (1987) provided the first comprehensive list of Indian spiders, encompassing 1067 species from 249 genera in 43 families. In his earlier works (1980, 1982), Tikader described numerous species from various families across India and compiled a dedicated book on Thomisid spiders (1980). Collaborating with Biswas (1981), Tikader studied 15 families, 47 genera, and 99 species in Calcutta and surrounding areas, offering detailed illustrations and descriptions.

The spider fauna of Gujarat has been extensively studied by Patel (1973, 1975), Patel and Vyas (2001), Patel and Reddy (1988-1993), and Reddy and Patel (1991-1993). Gajbe (1985-99) compiled a checklist of 186 spider species in 69 genera under 24 families, describing numerous new species from Madhya Pradesh and Chattisgarh. Vijayalakshmi and Ahimaz (1993) provided a brief account of spiders in their introductory book titled 'Spiders: An Introduction.' Despite these efforts, spiders in protected areas in India have received limited attention. Patel and Vyas (2001) conducted biodiversity studies in Hingolgarh Nature Education Sanctuary, Gujarat, describing 56 spider species in 34 genera across 18 families. Patel (2003) added to the knowledge by describing 91 species from Parambikulum Wildlife Sanctuary, Kerala. Uniyal (2006) recorded 19 spider species from Ladakh belonging to 10 families, while De (2001) listed 19 species in the Dudhwa Tiger Reserve as part of the reserve's management plan.

Research on spiders extends into agroecosystems, particularly in rice fields and coffee plantations (Sebastian *et al*., 2005; Kapoor, 2008). Hore and Uniyal (2008a, 2008b) conducted studies on spider assemblages, their diversity, and composition across various vegetation types in the Terai Conservation Area (TCA). Additionally, Hore and Uniyal (2008c) explored the potential of spiders as indicator species for monitoring habitat conditions in TCA. Biswas and Biswas (2004) made a significant contribution to spider diversity by presenting comprehensive lists of newly recorded spider species from Manipur and West Bengal. Siliwal *et al*., (2005) compiled an updated checklist of Indian spiders, providing a taxonomic re-evaluation of described species and referencing 1442 species from 361 genera within 59 families in the Indian Region. Reporting on Uttarakhand, Biswas and Biswas (2010) identified 127 spider species across 49 genera and 17 families. Sebastian and Peter (2009), in their book 'Spiders of India,' documented 1520 species, representing 361 genera and 61 families. These diverse studies contribute significantly to our understanding of spider ecology and diversity in various ecosystems across India.

Studies on Spiders of Andaman and Nicobar Islands

Limited research has been conducted on the spiders of the Andaman and Nicobar Islands. Walckenaer (1841) conducted foundational taxonomic work on spiders in the Andaman Islands. Frauenfeld (1867) initiated taxonomic investigations on the araeneo-fauna of spiders in the Andaman and Nicobar Islands, presenting a checklist in the Negotiations of the Imperial Royal Zoological and Botanical Society in Vienna. Simon (1888) commenced South Asian Arachnid Studies based on specimens collected in the Andaman Islands by Oldham. Thorell (1891) studied spiders in the Nicobar Islands and other regions of South Asia, providing valuable insights. Thorell (1892) contributed additional observations on spiders from the Andaman Islands. Thorell (1892) and Pocock (1900a) emerged as pioneers in the field, describing sixteen spider species from these islands. Hingston (1927) reported on protective devices in spiders' snares and described seven new species of orb-weaving spiders. Strand (1907) provided spider descriptions from the Andaman and Nicobar Islands in "Spiders of the Zoological Institute in Tübingen." In 1977a, Tikader described 65 species across 41 genera and 20 families, adding to the scientific understanding of spiders in this region.

Methods

Study Area

The Andaman and Nicobar Islands, strategically positioned in the Bay of Bengal between peninsular India and Burma, form an archipelago in a north-south direction. As an offshore outpost of the Indian Union, the islands are approximately 190 km northeast of Burma and about 1200 km from the mainland of India. To the north, the expansive mangrove belt of the Sunderbans lies in the distance. This island group is divided into two main segments: the Andaman group and the Nicobar group, separated by the notorious 10° channel. The Andaman Islands consist of key islands such as North Andaman Island, Middle Andaman Island, Baratang, South Andaman Island, Rutland, and Little Andaman Island. In the Nicobar group, three distinct assemblies of islands are present: the Car Nicobar group, the Nancowry group, and the Great Nicobar group. Overall, the Andaman and Nicobar Islands span over 1000 km in the sea.

Geologically, the Andaman Islands are believed to be a continuation of the Arakan-Yoma Mountain ranges of West Burma, tracing their origin to the ancient Gondwana landmass. The islands, considered submerged mountain summits, experienced alterations in their topography after a series of submergence events during alpine folding. Some islands in the region have coral formations, indicating sporadic occurrences of such formations.

The Andaman and Nicobar Islands shifted approximately 1.25m southeastward and twisted anticlockwise due to the impact of the seismic activity and the resulting tsunami. The islands feature a tropical climate, characterized by temperatures ranging from 18°C to 34°C throughout the year. The mean annual rainfall hovers around 3000–3500 mm, with showers occurring during the southwest and northwest monsoons. The island's proximity to the equator contributes to a consistently hot and humid climate, with relative humidity fluctuating between 70% and 95% (Sachithanandam *et al*., 2013; Velmurugan *et al*., 2018). The study was conducted in the South Andaman region, chosen for its extensive exploration area and accessibility to survey sites compared to other areas in the archipelago. South Andaman encompasses two major Marine National Parks, Mahatma Gandhi Marine National Park (MGMNP) and Rani Jhansi Marine National Park (RJMNP), known for their diverse species and strict conservation practices. The study focused on five selected sites within this region.

The eleven sites had a mixed ecosystem of agricultural land and Deciduous Forest (Figure 1). *Pterocarpus dalbergioides* is associated with *Terminalia procera*, *T. manii, Canarium euphyllum*, *Parishia insignis*, *Albizia lebbeck*, etc. The second stroey consists of small trees like *Lannea coromandelica*, *Sageraea elliptica*, *Sterculia villosa*, *Semecarpus kurzii*, etc. The third storey is represented by *Licuala spinosa*, *Grewia disperma*, *Cordia grandis*, etc. Among the shrubs *Actephila exelsa*, *Ixora grandifolia* and *Rinorea bengalensis* occur.

We have selected eleven cultivation lands in these five sites as listed below in Table 1 for the present study.

Study Period

We collected spider samples from the eleven sites in two consecutive seasons. Sampling was done during Ravi-rain

Table 1. Study location

Sl. No.	Location	
1	Wandoor	11°36.934′N 92°36.684′E
2	Manjery	11°32.386′N 92°39.231′E
3	Stewartganj	11°43.658′N 92°43.447′E
4	Shippighat	11°36.249′N 92°40.678′E
5	Garachrma	11°47.749′N 92°42.705′E

fed (November, 2017-January, 2018) and again Kharif-Rain Fed (Mid July-Early September 2018).

Sampling Methods

A sampling of the forest (no canopy) followed the concept of Coddington *et al*. (1991), with minor modification and included additional methods: pitfall trapping, sweep-netting, and hand searching for cryptic fauna. Sweep netting was used in the inventory of Silva (1996) but not as a repeated method.

1. Pitfall Trapping (Pitfall)

Pitfall traps, measuring 9 cm in diameter and 10 cm in depth, were utilised for eight days. Each trap was filled with 95% ethanol and a small quantity of soap detergent. A total of 50 pitfalls were strategically placed in two series adjacent to, but outside, the plot boundaries to minimise disturbance. To reduce variation in the abundance of adult spiders, groups of five pitfall samples were pooled.

2. Cryptic Searching (Cryptic)

Cryptic habitats, including litter, small tree holes, fallen logs, bark crevices, and under stones, were explored through hand collection. Sampling from the litter involved a direct search using a 1 cm mesh on sheets, treated as a distinct method following Coddington *et al*., (1991).

3. Sweep Netting (Sweeping)

Low herbaceous or shrubby vegetation was selectively swept, and areas lacking suitable vegetation were excluded. The net was emptied at regular intervals (after 3-5 sweeps) to prevent specimen loss and damage.

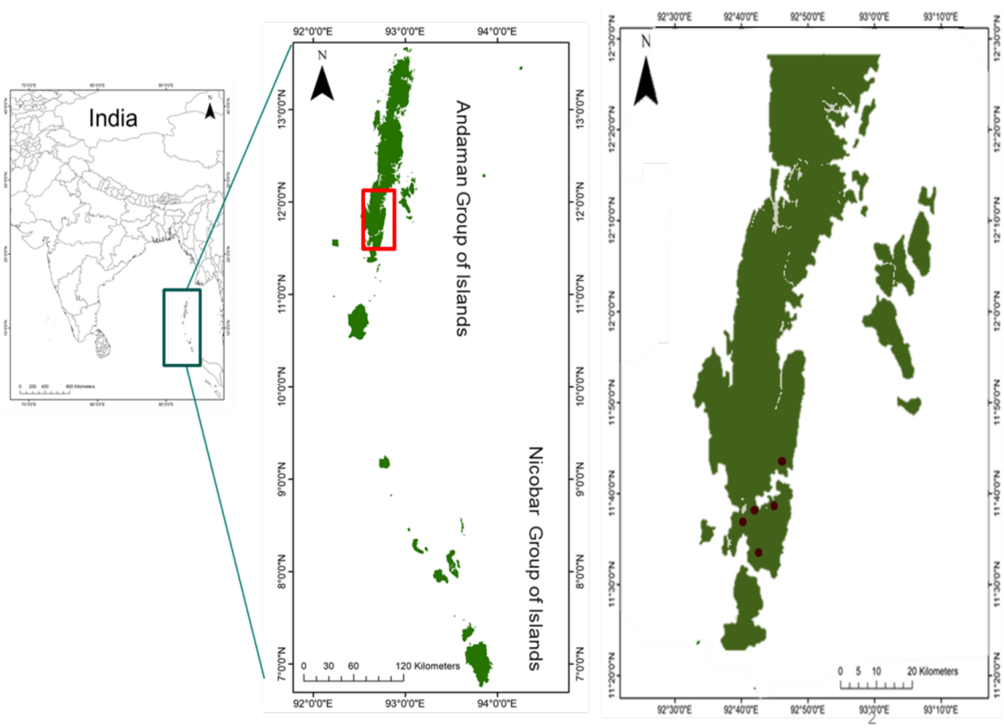


Figure 1. Showing a map of South Andaman and the study localities.

4. Ground Hand Collecting (Ground)

Hand collection from ground level to knee height targeted spiders visible on leaf litter, low buttresses, logs, and the lowest vegetation, necessitating kneeling or crawling. This method was implemented as a separate approach to minimize variance.

5. Aerial Hand Collecting (Aerial)

Hand collection was conducted from knee height to as high as reachable, targeting web-building and free-living spiders on foliage, stems, tree trunks, and lianas. This method captured spiders inhabiting both living and dead shrubs.

6. Vegetation Beating (Beating)

Spiders residing in shrubs, high herb vegetation, bushes, small trees, and branches were accessed using a beating method. This involved tapping the vegetation with a heavy stick while collecting spiders in a tray underneath, as per Coddington *et al*., (1996).

The comprehensive use of these methods provides a nuanced understanding of spider diversity across various microhabitats within terrestrial ecosystems. Each method targets specific niches and behaviours, contributing to a holistic assessment of the spider community in the study area. The methods cited above are practicable both during night and day, but not sweep netting. Again, all the activities were comprised of 1 h active sampling. Dusting webs with cornstarch to enhance their visibility improved the efficiency of hand collecting. All spiders obtained via one method in 1 hr. were transferred to a single ethanol vial and labelled with the date, time of day, method, collector, and replicate number.

Preservation and identification

Collected specimens were preserved in 70% alcohol for subsequent examination. A stereoscopic microscope (CZM 6: LABOMED) was employed for detailed specimen analysis. Male palps were detached, scrutinized, and stored in a separate vial alongside the original specimen. Female genitalia were delicately excised using a fine surgical scalpel, and the epigyne was then immersed in a petri dish containing a 10% aqueous solution of KOH for clarification. Measurements were conducted using a USB digital microscope with micro-measure software, and leg measurements were presented as the total length of the femur, patella, tibia, metatarsus, and tarsus. Identification procedures followed taxonomic keys and catalogues by Tikader (1980), Tikader and Biswas (1974), Barrion and Litsinger (1995), Prószyński (1992; 2003), and other pertinent literature. The specimens examined during this investigation are archived in the museum of the Andaman and Nicobar Regional Centre, Zoological Survey of India. All adult specimens were identified to at least the family level, sorted into morphospecies, and assigned unique species codes. Previously documented species with ample descriptions were accompanied by brief descriptions, specimen examination data, and distributional information.

Statistical Analysis

We used the PAST package (Hammer *et al*., 2003) for statistical analyses. The diversity indices *viz*. Dominance, Simpson index, Shannon index (entropy) and Buzas and Gibson's evenness (e^H/S) were used to calculate species richness among the eleven sites.

Results and Discussion

Occurrence of Spider Species

In our study, a comprehensive survey yielded a total of 56 spider species distributed across 17 families, as detailed in Table 2 and illustrated in Figures 2-5. Among the collected specimens, 16.23% were identified as male, 66.75% as female, and the remaining 21.43% as immature. Species-level identification was challenging for immature specimens, and their identification was primarily determined by association with females or by direct observation of emergence from the egg sac within the female's web during field visits. Taxonomically, families such as Salticidae, Gnaphosidae, Lycosidae, and Uloboridae posed challenges in identification. Several immature specimens presented difficulty in reaching species-level identification. In our survey across 11 sites, employing sweep netting and bush-beating methods for families like Araneidae, Salticidae, Tetragnathidae, and Thomisidae resulted in an increased species count with each increment in sampling size. Notably, a decline in the number of species was observed in the most recent sample, suggesting that additional sampling efforts would likely contribute to an increased species count for both collection methods.

Argiope aemula (Walckenaer, 1841)

Nephilengys malabarensis (Walckenaer, 1841)

Cyrtophora moluccensis Doleschall, 1857

Poltys pogonias Thorell, 1891

Plexippus paykulli (Audouin, 1826)

Theridion sp of Theridiidae family in an irregular web associated with a curled up dry leaf

Dome shaped horizontal web of *Cyrtophora* sp. Thorell, 1887 in open forest canopy

A typical web of *Gasteracantha cuspidata* Koch, 1837

Figure 2. Spiders of Agroecosystem, Andaman & Nicobar Islands.

Web of *Cyclosa* sp.

Hersilia sp. Audouin, 1826 of family Hersilidae

Fecenia protensa female, in its nest of a rolled up leaf

Oxyopes sunandae Tikader, 1970

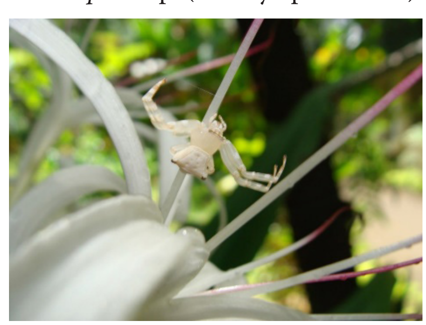
Olios sp.

Dendolycosa sp.in its pseudo-orb web

Tylorida sp. Thorell, 1891 of family Tetragnathidae

Heteropoda sp. (Family Sparassidae)

Camaricus formosus Thorell, 1887



Thomisus andamanensis Tikader, 1980

Figure 3. Spiders of Agroecosystem, Andaman & Nicobar Islands

Figure 3. **(a, c)** Web of *Gastercantha* sp. and **(b, d)** *Cyrtophora* sp.

Figure 4. **(a, b)** Planar web of *Argiope aemula* and *Poltys bhabanii* and **(c, d)** Web of *Nephhila pilipes* Fabr.

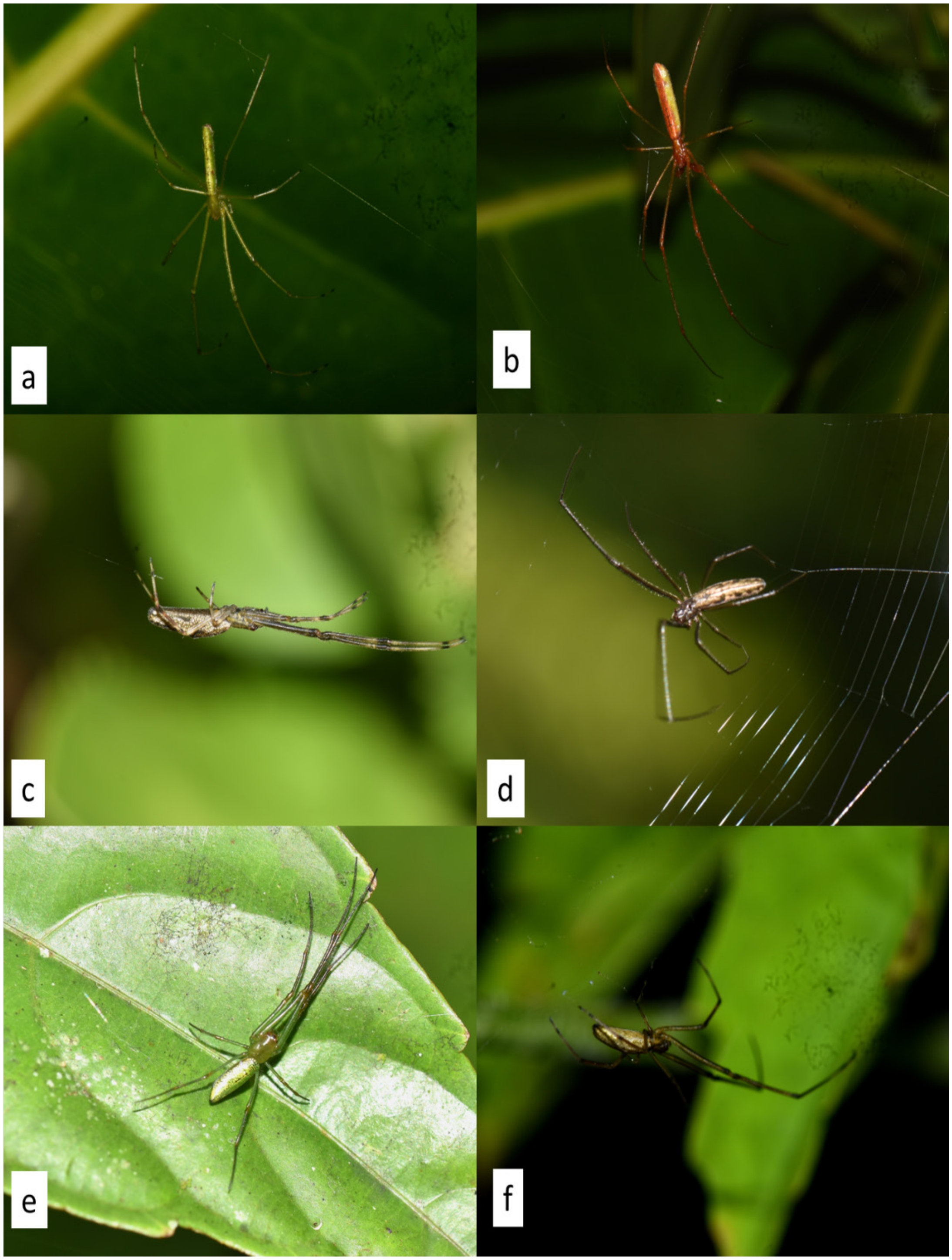


Figure 5. Habitat selection and habitus images of *Tetragnatha* sp. **(a, b)** *Tetragnatha sutherlandi* Gravely, 1921; **(c, d)** *Tetragnatha caudata* Emerton, 1884; **(e, f)** *Tetragnatha coelestis* Pocock, 1901.

Table 2. Showing each sample set of spiders from the study sites

Sl. No.	Name of the species	Male	Female	Immature
	ARANEIDAE (Simon, 1895)			
1.	*Bijoaraneus mitificus* (Simon, 1886)	2	5	1
2.	*Argiope aemula* Walckenaer, 1841	*	14	3
3.	*Cyclosa centrodes,* (Thorell, 1887)	*	18	2
4.	*Cyclosa neilensis* Tikader, 1977	*	11	1
5.	*Cyclosa rates* (Thorell, 1892)	*	13	5
6.	*Cyrtophora cicatrosa* Stoliczka, 1869	*	29	10
7.	*Cyrtophora moluccensis* Doleschall, 1857	4	16	3
8.	*Thelacantha cuspidata* Koch, 1837	3	36	10
9.	*Thelacantha brevispina* (Doleschall, 1857)	6	44	12
10.	*Gastercantha diadesmia* Thorell, 1887	4	16	5
11.	*Gasteracantha kuhlii* Koch, 1837	7	22	9
12.	*Gasteracantha hasselti,* Koch,1838	3	14	7
13.	*Nephila pilipes* Fabricius, 1793	2	5	3
14.	*Parawixia dehaani* (Doleschall, 1859)	1	6	1
15.	*Poltys pogonias* Thorell, 1891	2	5	1
16.	*Singa haddooensis* Tikader, 1977	1	8	1
17.	*Nephilengys malabarensis* Walckenaer, 1841	1	6	1
	CORINNIDAE (Karsch, 1880)			
18.	*Oedignatha andamanensis* Tikader, 1977	5	13	2
	CTENIDAE (Keyserling, 1877)			
19.	*Bowie andamanensis* (Gravely, 1931)	1	17	5
20.	*Bowie kapuri* (Tikader, 1973)	3	7	8
	CLUBIONIDAE Wagner, 1887			
21.	*Clubiona submaculata* (Thorell, 1891)	1	13	8
	GNAPHOSIDAE Pocock, 1898			
22.	*Drassodes andamanensis* Tikader, 1977	14	24	21
	HERSILIIDAE Thorell, 1870			
23.	*Hersilia savignyi* Lucas, 1836	2	9	1
	LYCOSIDAE Sundevall, 1833			
24.	*Pardosa birmanica* Simon, 1884	1	18	3
25.	*Pardosa sumatrana* Thorell, 1890	21	31	8
26.	*Pardosa thalassia* Thorell, 1891	6	17	12
	OXYOPIDAE Thorell, 1870			
27.	*Hamadruas insulana* Thorell, 1891	1	9	12
28.	*Oxyopes sp.* 1	2	6	7
29.	*Oxyopes longinquus* Thorell, 1891	6	15	14
30.	*Oxyopes sitae* Tikader, 1970	6	18	11
	PHOLCIDAE (Koch, 1850)			
31.	*Artema atlanta* Walckenaer, 1837	8	27	2

Sl. No.	Name of the species	Male	Female	Immature
32.	*Pholcus kapuri* Tikader, 1977	*	21	3
	PISAURIDAE (Simon, 1890)			
33.	*Dendrolycosa gitae* (Tikader, 1970)	*	3	*
34.	*Hygropoda gracilis* (Thorell, 1891)	*	2	*
	PSECHRIDAE (James, 1989)			
35.	*Fecenia protensa* Thorell, 1891	*	3	*
	SALTICIDAE Blackwall, 1841			
36.	*Asemonea tenuipes* O.P. Cambridge, 1869	5	14	3
37.	*Cosmophasis miniaceomicans* (Simon, 1888)	2	18	*
38.	*Cytaea albolimbata* Simon, 1888	3	18	8
39.	*Thiania bhamoensis* Thorell, 1887	5	9	4
40.	*Epocilla calcarata* (Karsch, 1880)	*	14	7
41.	*Menemerus albocinctus* Keyserling, 1890	4	6	*
42.	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)	*	13	6
43.	*Phidippus yashodharae* Tikader, 1977	2	16	*
44.	*Plexippus paykulli* (Audouin, 1826)	*	12	7
45.	*Pseudicius andamanius* (Tikader, 1977)	1	8	5
	SPARASSIDAE Bertkau, 1872			
46.	*Heteropoda venatoria* (Linnaeus, 1767)	2	37	19
	TETRAGNATHIDAE(Menge,1866)			
47.	*Leucauge tessellata* (Thorell, 1887)	22	4	5
48.	*Leucauge tristicta* (Thorell, 1891)	1	3	1
49.	*Tetragnatha andamanensis* Tikader, 1977	14	1	1
50.	*Tetragnatha delumbis* Thorell, 1891	1	25	1
51.	*Tetragnatha foliferens* Hingston, 1927	7	3	9
52.	*Tetragnatha mandibulata* Walckenaer, 1841	3	2	1
	THERIDIIDAE (Sundevall, 1833)			
53.	*Meotipa andamanensis* (Tikader, 1977)	1	5	1
54.	*Argyrodes chiriatapuensis* Tikader, 1977	1	3	1
55.	*Nihonhimea indica* (Tikader, 1977)	1	7	1
	THOMISIDAE (Sundevall, 1833)			
56.	*Camaricus formosus* Thorell, 1887	2	8	2
57.	*Oxytate greenae* (Tikader, 1980)	6	3	*
58.	*Runcinia insecta* (L. Koch, 1875)	*	4	*
59.	*Runcinia kinbergi* Thorell, 1891	4	6	*
60.	*Thomisus andamanensis* Tikader, 1980	7	5	1
	ULOBORIDAE (Thorell, 1869)			
61.	*Uloborus krishnae* Tikader, 1970	*	25	1
62.	*Miagrammopes albomaculatus* Thorell, 1891	2	13	*

* = Represents unidentified/not observed during the period of the survey

Composition

The total number of species per family is shown in Table 3. The families with the highest number of species richness were the orb web weaving spiders (Araneidae) with 16 species, followed by jumping spiders (Salticidae:10 species). The long-jawed spider (Tetragnathidae) came third (6 species) while crab spiders (Thomisidae) and Lynx spiders (Oxyopidae) were next (5 and 4 species respectively). Comb-footed spiders (Theridiidae) and wolf spiders (Lycosidae) represented 3 species each while others had less than 3.

Spider Communities of Agro-Ecosystem

The family composition of the foliage-dwelling spider community of these sites was investigated using the methods described above. The results are summarized in Table 4, which demonstrates the distribution of spider families from various agroecosystems of South Andaman. The highest number of individuals collected using this method belongs to the family Araneidae (N = 211), followed by Salticidae (N = 190), Lycosidae (N = 117), and Oxyopodidae (N = 107), while the least number of individuals were collected from the family Pisauridae (N = 5) and Psechridae (N = 3), the pseudo-orb web weaving families.

Table 3. Number of species representing each family

Sl. No.	Family	Representing Species
1.	Araenidae	17
2.	Corinnidae	1
3.	Ctenidae	2
4.	Clubionidae	1
5.	Gnaphosidae	1
6.	Hersilidae	1
7.	Lycosidae	3
8.	Oxyopidae	4
9.	Pholcidae	2
10.	Pisauridae	2
11.	Psechridae	1
12.	Salticidae	10
13.	Sparassidae	1
14.	Tetragnathidae	6
15.	Theridiidae	3
16.	Thomisidae	5
17.	Uloboridae	2

From Table 4, we can see that Araneidae, Theridiidae, Salticidae, Pholcidae, and Oxyopidae were observed in all eleven sites, representing 100% coverage. Families like Uloboridae, Gnaphosidae, and Thomisidae were collected from nine sites, representing 81.12% of the sample. The least sample set was obtained from Psechridae, with a coverage of 18.18% from two sites. In a very crude way, it can be stated that a sample set of 19 individuals can be seen for the family Araneidae and a sample set of 17 for Salticidae. The widest range of variation was seen in orb-web weaving spiders, where only one sample of *Gasteracantha cuspidata* Koch, 1837, was collected from Manjery, while on the other side, 78 were collected from Wandoor, comprising *Cyclosa neilensis*, Tikader, 1977, *Cyrtophora cicatrosa* Stoliczka, 1869, and *Gastercantha diadesmia* Thorell, 1887.

The result from Table 5 indicates that the paddy field serves as a better host than others *i.e.* Mango, Beetle Nut and Coconut in providing a varied array of pests for spiders. As we can see most of the samples were collected from paddy fields (N = 185) and mango farms (N = 182) due to the incoming pests in these two sites. Both show an average of 10 sample sets of spiders with the most deviation in the Paddy field of ± 4.60. This amount of SE may account for a high variation in spiders collected ranging from 0-78 which was noted before. In the case of the samples collected from the mango farm at least one individual was observed for every sampling made for both seasons. Next to these, an average of 9 spider samples were caught from banana plantations. The least spider individuals were represented in the case of Chilly Farm comprising 23 individuals with an average of only one sample set.

The results for four diversity indices derived from PAST are presented below in Table 6. The maximum dominance is seen in Chilly and the least in coconut plantations. The data from pitfall trap sampling was excluded from this because it was applied only in the dry season. For both diversity indices Shannon H' and Simpson 1-D coconut plantation spider samples showed a high diversity. The least was found in the chilly farm (Table 5). As we move further into evenness for the eleven sites we can see Banana, Chilly and Mango show the same value as Buzas and Gibson's evenness of 0.70. Again, the highest value of 0.85 can be found in Coconut plantations

Table 4. Descriptive statistics for the distribution of spider families from various agro-ecosystems of South Andaman

Family	Descriptive statistics			Number of represented agro-ecosystems	Percent representation (%)
	N	Range	Mean ± SE		
Araneidae	221	1-81	19.59 ± 7.54	12	100
Corrinidae	20	0-7	1.82 ± 0.86	4	36.36
Ctenidae	41	0-19	3.73 ± 1.70	8	72.73
Clubionidae	22	0-7	2.00 ± 0.82	5	45.45
Gnaphosidae	59	0-13	5.36 ± 1.25	9	81.82
Hersilidae	12	0-9	1.09 ± 0.84	2	18.18
Lycosidae	117	2-23	10.64 ± 2.22	11	100
Oxyopidae	107	1-23	9.73 ± 2.27	11	100
Pholcidae	61	2-14	5.55 ± 1.13	11	100
Pisauridae	5	0-3	0.45 ± 0.28	3	27.27
Psechridae	3	0-2	0.27 ± 0.19	2	18.18
Sparassidae	58	0-25	5.27 ± 2.35	5	45.45
Salticidae	190	2-41	17.27 ± 3.32	11	100
Thomisidae	48	0-14	4.36 ± 1.32	9	81.82
Theridiidae	98	2-17	8.91 ± 1.50	11	100
Uloboridae	41	0-9	3.73 ± 0.98	9	81.82

Table 5. Descriptive statistics for spider density from various agro-ecosystems of South Andaman

Spiders	Agro-Ecosystems of South Andaman										
	Paddy	Banana	Betel nut	Coconut	Tomato	Brinjal	Okra	Green Gram	Papaya	Chilies	Mango
N	185	165	123	112	68	78	87	45	35	23	182
Range	0-78	0-44	0-27	0-16	0-18	0-22	0-23	0-14	0-7	0-9	1-41
Mean ± S.E.	10.88 ± 4.60	9.71 ± 2.84	7.24 ± 1.70	6.59 ± 1.13	4.00 ± 1.39	4.59 ± 1.69	5.12 ± 1.60	2.65 ± 0.92	2.06 ± 0.62	1.35 ± 0.64	10.71 ± 2.45

Table 6. Diversity Indices for various agro-ecosystems of South Andaman

Diversity Index	Agro-Ecosystems of South Andaman										
	Paddy	Banana	Betel nut	Coconut	Tomato	Brinjal	Okra	Green Gram	Papaya	Chilly	Mango
Dominance_D	0.20	0.12	0.10	0.08	0.15	0.17	0.14	0.16	0.14	0.23	0.10
Simpson_1-D	0.80	0.88	0.90	0.92	0.85	0.83	0.86	0.84	0.86	0.77	0.90
Shannon_H	2.03	2.28	2.48	2.61	2.02	2.02	2.11	2.04	2.12	1.72	2.53
Evenness_ e^H/S	0.54	0.70	0.75	0.85	0.84	0.75	0.75	0.77	0.83	0.70	0.70

which depicts that a high number of spider species build their guilds for this particular host. Although a maximum number of samples were covered from paddy and mango, coconut hosts a wide variety of pests which appeals to the spider fauna to be so diversified as in the results (Table 6). The least value for Buzas and Gibson's evenness was shown in the case of Paddy Field. There can be a twofold answer to this first will be the declination in pest species that are present there and the second one due to the seasonal effect also there was less canopy coverage in the dry season.

Microhabitat Utilization of Spiders

The species abundance was in the order Araneidae > Salticidae > Lycosidae > Sparassidae> Oxyopidae > Thomisidae > Tetragnathidae > Clubionidae > Theridiidae > Gnaphosidae > Uloboridae > Hersilidae > Filistatidae > Scytodidae. Salticidae exhibited the highest generic diversity followed by Araneidae and Lycosidae. The population of Araneids and Lycosids alone was more than 50% of the total population. Males of *Argiope aemula, Cyclosa neilensis, Cyclosa centrodes, Cyclosa oatesi, Cyrtophora cicatrosa, Pardosa sumatrana, Scytodes* sp., *Oxytate greenae, Uloborus krishnae* not observed during the survey.

In vegetable fields, the predominant presence of web-building spiders was observed, with notable species including *Cyclosa* sp., *Thelacantha brevispina*, *Leucauge decorata*, and *Uloborus krishnae* (Table 7). Conversely, hunting spiders, such as *Pardosa birmanica*, *Pardosa thalassia*, *Plexippus paykulli*, and *Heteropoda venatoria*, were predominantly sighted. Interestingly, the populations of Oxyopids and Tetragnathids were negligible in cabbage and coriander agroecosystems, and Thomisids were not observed at all. During the survey and spider collection process, meticulous attention was given to documenting the microhabitats utilized by the spiders. Three main types of microhabitats were identified, including those within the web, on plants or branches, and on the ground. Among web-building spiders, webs were observed on the ground (epigeal), between the ground and plants (basal), and between adjacent plants and branches (foliar). Hunting spiders utilized microhabitats such as mulch and litter on the ground, ground crevices, the ground surface, foliage, plants, and pseudostems, including dried leaves. Furthermore, the study highlighted the consistent presence of the Oxyopidae family across all vegetable fields, especially in the later stages. In contrast, hunting spiders belonging to the Sparassiade and Lycosidae families were predominantly found in banana and beetle nut plantations. Night surveys conducted between 6:00 PM and 8:00 PM revealed Araneidae spiders constructing webs in paddy plantations, while Tetragnathidae spiders were observed in tomato cultivations.

Daily Activity Pattern

The observations of orb-weaving spiders in this study revealed a notable flexibility in their feeding behaviour, manifesting both during the day and at night (Table 8). This dual activity pattern suggests a diurnal and nocturnal lifestyle for these spiders. Notably, among the orb-weaving spiders, *Bijoaraneus mitificus* (Simon, 1886) exhibited an intriguing variation in activity patterns. While the immature stages of this species were occasionally active during the day, the adult stages primarily displayed nocturnal behaviour. In addition, the web-building spiders under scrutiny, representing the families Pisauridae, Theridiidae, and Psechridae, demonstrated feeding activities predominantly during daytime within their webs. However, it is noteworthy that remnants of prey from nocturnal species were also identified in their webs. This dual feeding behaviour, encompassing both diurnal and nocturnal activities, adds complexity to the ecological dynamics of these spider families. The coexistence of diurnal and nocturnal feeding patterns among these spiders underscores their adaptability and suggests nuanced strategies for exploiting food resources in their respective environments.

Discussion

This contemporaneous investigation unequivocally underscores the pivotal role played by spiders as effective bio-control agents in agro-ecosystems. The dynamic composition of arachnofauna exhibits fluctuations synchronized with crop periods and prey abundance. Except for the Tetragnathidae family, all spider families were consistently present throughout the study duration. Noteworthy patterns emerged, such as the abundance of the genus Tetragnatha during initial crop development, while the genus Argiope, particularly *A. aemula*, predominated in advanced crop stages. The Lycosidae and Thomisidae families, represented by the genera

Table 7. Microhabitat used by spiders in all agro-ecosystems

Sl. No.	Spider Species	Microhabitat
	ARAENIDAE CLERCK,1757	
1.	*Bijoaraneus mitificus* (Simon, 1886)	In sunny areas resting on the web between two, in grasses
2.	*Argiope aemula* Walckenaer, 1841	In sunny areas resting on a web between two plants, in grasses
3.	*Cyclosa centrodes,* (Thorell, 1887)	Between the pseudostems, petioles and hanging leaves
4.	*Cyclosa neilensis* Tikader, 1977	Between the pseudostems, petioles and hanging leaves
5.	*Cyclosa oatesi* (Thorell, 1892)	Between the pseudostems, petioles and hanging leaves
6.	*Cyrtophora cicatrosa* Stoliczka, 1869	In the web between pseudostems nearer to the ground
7.	*Cyrtophora moluccensis* Doleschall, 1857	Between two plants, spaces between chopped pseudostems, fallen dried leaves and hanging leaves
8.	*Gasteracantha cuspidata* Koch, 1837	Between two banana plants, between the uppermost leaves
9.	*Thelacantha brevispina* (Doleschall, 1857)	Between two banana plants, between the uppermost leaves
10.	*Gastercantha diadesmia*, Thorell,1887	Between two banana plants, between the uppermost leaves
11.	*Gasteracantha kuhlii*, Koch, 1837	Between two banana plants, between the uppermost leaves
12.	*Gasteracantha hasselti,* Koch,1838	Between two banana plants, between the uppermost leaves
13.	*Nephilengys malabarensis* Walckenaer, 1841	Between two large blades of grass and the top of trees
14.	Nephila pilipes Fabricius, 1793	Between two large blades of grass and top of trees, near electric poles
15.	*Parawixia dehaani* (Doleschall, 1859)	On the web nearer to the ground, in mulch
16.	*Poltys pogonias* Thorell, 1891	In sunny areas resting on a web between two plants, in grasses
17.	*Singa haddooensis* Tikader, 1977	In sunny areas resting on a web between two plants, in grasses
	CLUBIONIDAE Wagner, 1887	
18.	*Clubiona submaculata* (Thorell, 1891)	Rolled-up leaves, on foliage, under dead leaves, during the daytime in retreat in convoluted leaves
	GNAPHOSIDAE Pocock, 1898	
19.	*Drassodes andamanensis* Tikader, 1977	On ground surface, in leaf litter, under mulch
	HERSILIIDAE Thorell, 1870	
20.	*Hersilia savignyi* Lucas, 1836	On the bark of mango and coconut tree
	LYCOSIDAE Sundevall, 1833	
21.	*Pardosa birmanica* Simon, 1884	On the ground, among the mulch, in leaf litter, in-ground crevices
22.	*Pardosa sumatrana* Thorell, 1890	On the ground, among the mulch, in leaf litter, in-ground crevices
23.	*Pardosa thalassia* Thorell, 1891	On the ground, among the mulch, in leaf litter, in-ground crevices
	OXYOPIDAE Thorell, 1870	
24.	*Hamadruas insulana* Thorell, 1891	On foliage
25.	*Oxyopes* sp. 1	On bushes
26.	*Oxyopes longinquus,* Thorell, 1891	On bushes
27.	*Oxyopes sitae,* Tikader, 1970	On bushes

Sl. No.	Spider Species	Microhabitat
	SALTICIDAE Blackwall, 1841	
28.	*Asemonea tenuipes* O.P.-Cambridge, 1869	On the leaves, in leaf litter, in mulch, under the leaves
29.	*Cosmophasis miniaceomicans* (Simon, 1888)	On the leaves, in leaf litter, in mulch, under the leaves
30.	*Cytaea albolimbata* Simon, 1888	On the leaves, in leaf litter, in mulch, under the leaves
31.	*Thiania bhamoensis* Thorell, 1887	On the leaves, in leaf litter, in mulch, under the leaves
32.	*Epocilla calcarata* (Karsch, 1880)	On the leaves, in leaf litter, in mulch, under the leaves
33.	*Menemerus albocinctus* Keyserling, 1890	On the leaves, in leaf litter, in mulch, under the leaves
34.	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)	On the leaves, in leaf litter, in mulch, under the leaves
35.	*Phidippus yashodharae* Tikader, 1977	On leaf surface, in mulch
36.	*Plexippus paykulli* (Audouin, 1826)	On leaf surface, in mulch
37.	*Pseudicius andamanius* (Tikader, 1977)	On leaf surface, in mulch
	SCYTODIDAE Blackwall, 1864	
38.	*Scytodes thoracica* Latreille, 1802	Under the older folded leaves, loose leaf sheaths, on the ground
	SPARASSIDAE Bertkau, 1872	
39.	*Heteropoda venatoria* (Linnaeus, 1767)	On the ground, in decaying mulch, leaf litter
	TETRAGNATHIDAE (Menge, 1866)	
40.	*Leucauge tessellata* (Thorell, 1887)	On the web between corms, branches extended and spaces between small stems
41.	*Leucauge tristicta* (Thorell, 1891)	On branches extended
42.	*Tetragnatha andamanensis* Tikader, 1977	On the web between corms, branches extended and spaces between small stems
43.	*Tetragnatha delumbis* Thorell, 1891	On branches extended and spaces between small stems
44.	*Tetragnatha foliferens* Hingston, 1927	On the web between corms, branches extended
45.	*Tetragnatha mandibulata* Walckenaer, 1841	On the web between corms, branches extended and spaces between small stems
	THERIDIIDAE (Sundevall, 1833)	
46.	*Meotipa andamanensis* (Tikader, 1977)	On the ground
47.	*Argyrodes chiriatapuensis* Tikader, 1977	On the web associated with *Thelacantha brevispina*
48.	*Nihonhimea indica* (Tikader, 1977)	On the web associated with *Thelacantha brevispina*
	THOMISIDAE (Sundevall, 1833)	
49.	*Camaricus formosus* Thorell, 1887	On foliage and Flowers
50.	*Oxytate greenae* Tikader, 1980	On foliage and Flowers
51.	*Runcinia insecta* L. Koch, 1875	On foliage
52.	*Runcinia kinbergi* Thorell, 1891	On foliage and Flowers
53.	*Thomisus andamanensis* Tikader, 1980	On foliage
	ULOBORIDAE (Thorell, 1869)	
54.	*Uloborus krishnae* Tikader, 1970	Spaces between clusters and fingers of the bunch, below the bunch, underside of the leaves, on pseudostems
55.	*Miagrammopes albomaculatus* Thorell, 1891	Spaces between clusters and fingers of the bunch

Table 8. The daily rhythm of activity of the spiders

Spiders Group	Spider Species	Type of Activity
Orb Web weaving spider		
Araneidae	*Parawixia dehaani* (Doleschall, 1859)	Diurnal and Nocturnal
	Poltys pogonias Thorell, 1891	Diurnal and Nocturnal
	Cyrtophora moluccensis Doleschall, 1857	Diurnal only
	Bijoaraneus mitificus (Simon, 1886)	Diurnal and Nocturnal
	Argiope aemula Walckenaer, 1841	Diurnal only
Tetragnathidae	*Leucauge pusilla* Thorell, 1878	Diurnal and Nocturnal
	Tetragnatha andamanensis Tikader, 1977	Diurnal only+
	Tetragnatha mandibulata Walckenaer, 1841	Diurnal only
Space Orb Web/ irregular weaving spider		
Theididae	*Meotipa andamanensis* (Tikader, 1977)	Diurnal and Nocturnal++
	Nihonhimea indica (Tikader, 1977)	Diurnal and Nocturnal++
Pisauridae	*Dendrolycosa gitae* (Tikader,1977)	Rarely Diurnal mainly Nocturnal
Psechridae	*Fecenia protensa* Thorell, 1891	Rarely Diurnal mainly Nocturnal
Hunting spiders		
Clubionidae	*Clubiona* sp.	Nocturnal
Sparassidae	*Heteropoda venatoria* (Linnaeus, 1767)	Diurnal and mainly Nocturnal
Lycosidae	*Pardosa sumatrana* Thorell, 1890	
Gnaphosidae	*Drassodes andamanensis* Tikader, 1977	Diurnal and mainly Nocturnal
Hersilidae	*Hersilia savignyi* Lucas, 1836	
Thomisidae	*Camaricus formosus* Thorell, 1887	Diurnal only
	Thomisus andamanensis Tikader, 1980	Diurnal only

+ = *means species may show some diurnal activity but it was not observed during the survey period.*
++ = *represents that the activity stops by late evening.*

Lycosa and Camaricus, respectively, exhibited sustained presence, particularly in the early stages of the crop. A significant genus, Pardosa, thrived in vegetable fields (Okra, Eggplant) and associated banana plantations, capitalizing on the conducive microhabitat created by dense foliage and decomposing organic matter on the ground. This study aligns with findings by Ntonifor *et al*. (2012), corroborating the presence of Heteropoda venatoria in banana field mulches. These spiders, characterized by high fecundity and voracious feeding habits, notably the ground-dwelling raptorial Sparassidae and Lycosidae, constitute a formidable predator potential in cereal fields. The incorporation of such a predator potential into "integrated pest control programs" (Kiritani, 1979) is exemplified by initiatives in Japan, where spider density in rice fields was artificially increased by releasing Drosophila flies. Similarly, reports from the People's Republic of China and South Africa emphasize the introduction of spiders into rice fields and houses, respectively, for biological pest control, underscoring the potential of spiders as effective agents in reducing pest populations. The discussion extends to the intriguing ecological concept of "ecological cells," encompassing abandoned grasslands, hedges, wet areas, etc., serving as reservoirs for predators in agroecosystems. The idea of enlarging the area of these "ecological cells" is posited as a potential strategy to enhance spider density and, consequently, bolster their role in pest control. However, caution is urged, as the expansion of such uncultivated lands may inadvertently lead to an increase in pest incidence. Insights from German fields underscore the significance of spiders within the ground-dwelling predator complex, potentially influencing pest insects like aphids. The interplay between spiders, harvestmen, Carabidae, and Staphylinidae in forming a significant portion of invertebrates captured in pitfall traps is highlighted, suggesting a stabilizing effect on insect populations. Preliminary studies hint at the substantial predatory pressure exerted by the ground-dwelling predator complex on insect populations, aligning with the ecological stabilization hypothesis proposed by Riechert (1974). Furthermore, the findings substantiate the hypothesis that spider populations correlate with prey availability, emphasizing the intricate dynamics between spiders and their prey. The study also delves into the role of mammalian grazers in influencing vegetation cover and, consequently, spider populations. Controlled grazing by cattle revealed a decrease in relative vegetation cover, impacting ground-dwelling spider families such as Gnaphosidae, Lycosidae, and Ctenidae. In conclusion, the multifaceted interactions between spiders, agro-ecosystems, and pest dynamics, advocate for a nuanced understanding and strategic integration of spiders into agricultural pest management programs.

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