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Ecology of spiders in pomegranate orchard: Implications for integrated pest management (IPM)

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Abstract
The article discusses the functional ecology of spider families represented in pomegranate plantation. The main objective of the study is to focus on role of spiders in pest control in economically important pomegranate orchard. Spiders were sampled with active searching and gentle tapping in a study spanning one year. A total of 1226 individuals belonging to 80 genera and 35 families were sampled. An ecological guild classification generated a total of eight guilds. Overall, our study highlights the importance of spiders in Integrated Pest Management (IPM) in pomegranate orchard.

Keywords: pomegranate, functional ecology, spider diversity, guild, integrated pest management (IPM)

Introduction

Spiders are ubiquitous, abundant, primarily carnivorous and share arthropods as their main prey. They employ various methods to hunt on arthropods in all kinds of ecosystems and their role in agricultural ecosystem in limiting pest population is well documented (Wise, 1993) [21]. Their numbers often exceed 100 per square meter, which equates to 1 million spiders per hectare (Coleman and Crossley, 1996) [3]. Foraging characteristics like foraging strategy (type of web and method of hunting), prey range (either stenophagous or euryphagous), vertical stratification (ground or vegetation) and circadian activity (diurnal or nocturnal) are used to build their guild structure (Cardoso *et al*, 2011) [2]. Studies of spiders within pomegranate plantation were mostly of general account (Sarma *et al*, 2013; Sugumaran *et al*, 2019) [12, 17] and attempts to investigate functional ecology are very few. There are still large gaps in research that needs detailed investigations to explore role of spiders in agro-ecosystems in regulating pests. Spiders' diversity and their interaction in the Horticultural crops, Agricultural landscape, and orchards and vine yards have been investigated (Kacar, 2015; Salman *et al*,2019; D' Alberto *et al*, 2012) [8, 11, 4]

Agriculture remains and will continue so as the backbone of Indian economy. Government of India aims to double farmer's income by 2022. 'Zero-Budget Farming' has been one of the principal focus of Budget 2019-20. Pomegranate (*Punica granatum* L.) is a favourite fruit crop grown in arid and semi-arid landscapes in many parts of world and it has high demand in domestic and international market. Solapur district in Maharashtra is one of the leading producers of pomegranate. Attempts have been made to investigate ecology and role of various predators and parasitoids in regulating pests on pomegranate (Sreedevi *et al*., 2006; Sreedevi and Vereghese, 2007; Mani and Krishnamurhy, 1995; Awadallah *et al*., 1999) [14,15,10,1]. The role of spiders in controlling insect pests on pomegranate has also been addressed by few studies (Temerak, 1981; Ghavami, 2008) [18,5].

Methodology

The spider data used in this study was obtained from three pomegranate orchards (17°42'41.3"N 72°49'33.3"E; 17°42'41.78"N 75°49'34.49"E; 17°45'15.70"N 76° 1'33.51"E) situated near Solapur city, Maharashtra state. Spiders were surveyed using gentle tapping of branches, shoots and active searching. An overall of 30 surveys were made in a yearlong study conducted in the year 2021-22. 10 plants per survey per site were intensively surveyed for documenting spider dynamics. Each sampling effort was of 5 hours duration performed between 8:00am to 1:30pm. Efforts were made to document spiders from variety of niches or microhabitats ranging from subsoil layers, litter samples, bark, foliage and top canopy layer. The main goal of the sampling was to record functional ecology of spiders that can be taken to build their guild structure. Spiders were identified up to family, genera and species level using standard keys for identification of spiders (Tikader,1987; Jocqué *et al*, 2006; Sebastian *et.al*, 2009; WSC,2022) [19, 7, 13, 22]. The identified spider families (N=35) were classified in to guilds as per the method described by Cardoso *et al*, (2011) [2] with minor changes. The families recorded in our study were evaluated by classifying them using binary codes based on 16 ecological characteristics (Table. 2.2- based on Cardoso *et al*, 2011) [2]. Hierarchical clustering with UPGMA algorithm was employed to construct dendrogram based on Bray-Curti's similarity measure to depict the guild structure. Furthermore, we compared the percentage representation of families, species and abundance in each spider guilds. Statistical analysis was performed by using PAST Software (Version.4.11) Hammer *et al*, 2001[6].

Result

Species richness and abundance

A total of 35 families have been recorded from three pomegranate orchard plots. Of the total abundance of 1226 individuals from 35 families, the most abundant family was Linyphiidae with 163 individuals (13.29%) followed by Theridiidae with 159 individuals (12.96%), Araneidae with 125 individuals (10.19%) and Lycosidae with 117 individuals (9.54%) (Table). Other families with individuals between 50 to 100 are Salticidae with 95 individuals (7.74%), Titanoecidae with 81 individuals (6.60%), Dictynidae with 73 individuals (5.95%), Oonopidae with 72 individuals (5.87%)) and Thomisidae with 50 individuals (4.07%).

Guild structure of spiders associated with pomegranate plants

As depicted in the UPGMA analysis (Fig.2) the hierarchical clustering of families has generated a total of 08 guilds for the data on spider families pooled from three sites. The percentage representation of families and abundances represented in each guild (Table 1.) reveals that at family level, (Fig.1) Other Hunter (OH) guild is represented with 8 families (22.85%) and Ground Hunter (GH) with 7 families (20.00%) are most abundant guilds followed by Space Web Weavers (Sp WW) and Sheet Web Weavers with 4 families (11.42%) each.

As far as abundance is concerned, Other Hunters (OH) guild with 385 individuals (31.40%) is most abundant followed by Space Web Weavers (Sp WW) with 314 individuals (25.61%), Ground Hunters with 246 individuals (20.06%) and Orb Web Weavers (OWW) with 142 individuals (11.58%).

Table 1: List of spider families, guild and abundance.

Sr. No.	Spider Guild	No. Spider Families	Abundance	Spider families
Web-builder Guilds				
1	Orb Web Weavers (OWW)	03	142	Araneidae, Tetragnathidae, Uloboridae
2	Space Web Weavers (Sp WW)	04	314	Dictynidae, Pholcidae, Theridiidae, Titanoecidae
3	Sheet Web Weavers (Sh WW)	04	51	Eresidae, Hahniidae, Ochyroceratidae, etrablemmidae
4	Sensing Web Weavers (Se WW)	04	27	Filistatidae, Hersiliidae, Oecobiidae, Idiopidae
TOTAL		15	534	
Non-web Guilders				
5	Specialists (SP)	3	9	Palpimanidae, Zodariidae, Mimetidae
6	Ambush Hunters (AH)	2	51	Sicariidae, Thomisidae
7	Ground Hunters (GH)	7	247	Corinnidae, Gnaphosidae, Liocranidae, Lycosidae, Trachelidae, Oonopidae, Prodidomidae
8	Other Hunters (OH)	8	385	Oxyopidae, Clubionidae, Salticidae, Cheirancanthiidae, Linyphiidae, Philodromidae, Scytodidae, Sparassidae
TOTAL		20	692	
Grand Total		35	1226	

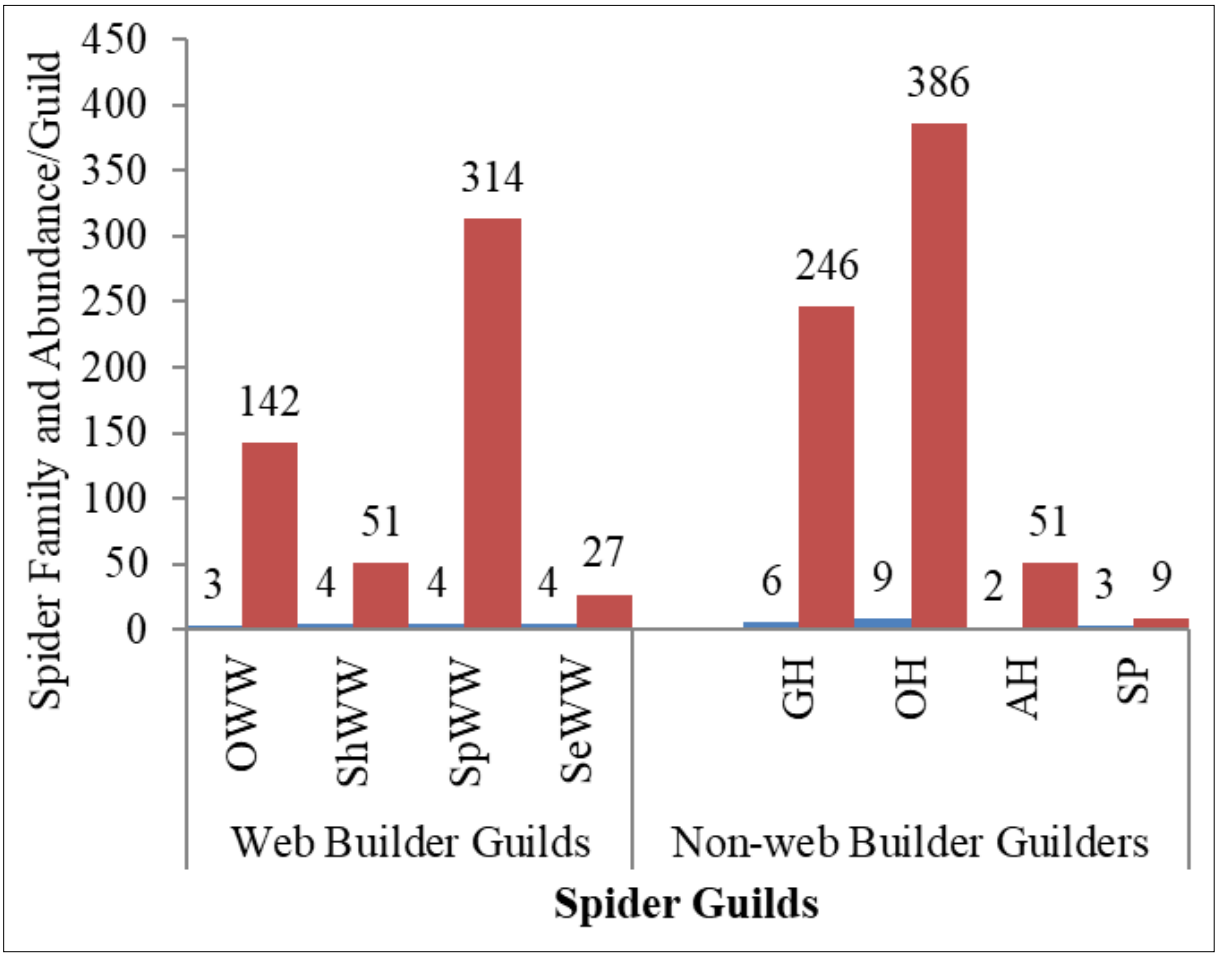

Fig 1: The number of spider families and abundance represented in each guild.

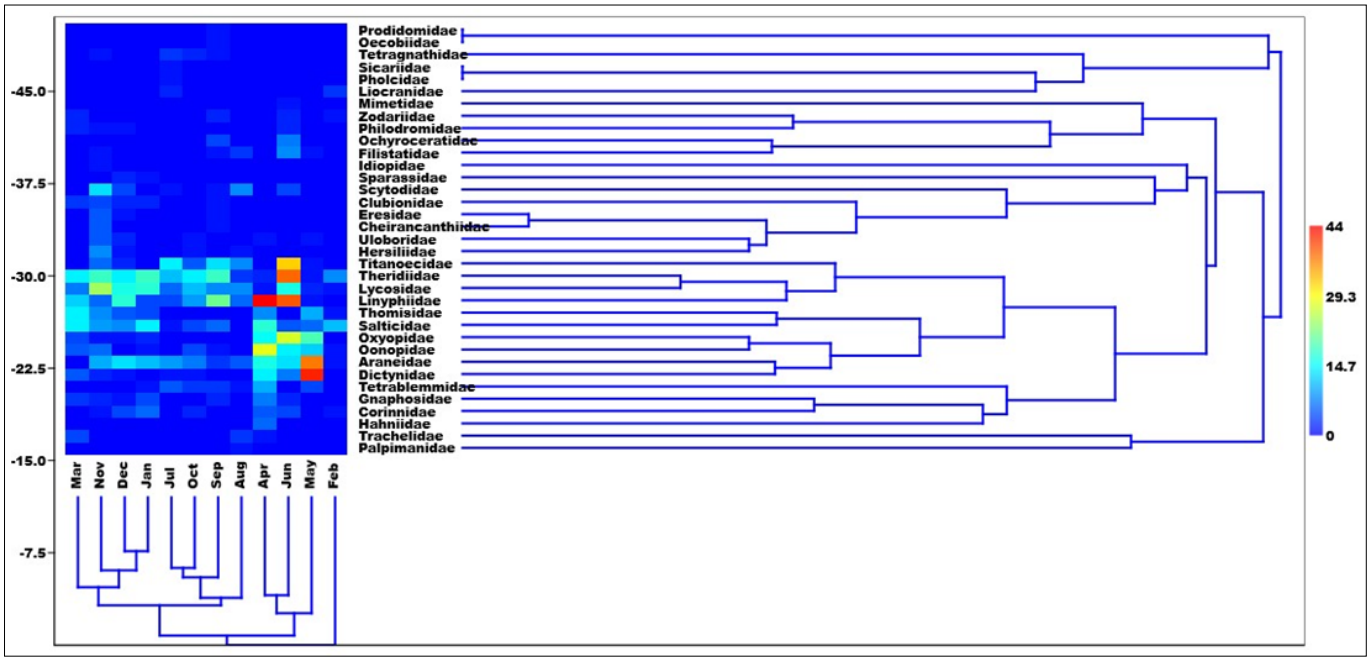

Fig 2: Two-way hierarchical clustering of spider families using Bray-Curti's distance matrix.

Temporal variation in spider dynamics

Cluster and correspondence analysis were performed to reveal seasonal variation in spider dynamics. Three clusters include the cluster of April and May and June months (N=533 spiders); the second cluster of July, August, September and October (N=259 spiders) and the third cluster of November, December, January and March (N=406). February forms a separate line (N=28 spiders). Abundance of spiders was highest during April, May and June months followed by a decline in abundance between the periods July to October and again it peaks during the period between November to March months with the exception of February when the abundance was lowest. The two-way cluster analysis reveals the trend of spider.

Families like Linyphiidae, Dictynidae, Theridiidae, Araneidae, Titanoecidae and Oxyopidae are visible as most dominant during April to June months.

Correspondence analysis of spiders based on monthly sampled data reveals highlights the community dynamics of spiders during. The map of spiders shows that the relative abundance of Corinnidae, Philodromidae, Trachelidae, Lycosidae is more during the months of November, December, January and February. Thomisidae, Araneidae, Oonopidae, Oxyopidae and Tetrablemmidae are especially found in relatively higher abundance during March, April and May months. Spider families Linyphiidae, Zodariidae, Theridiidae, Liocranidae are found in relatively more number during June, July, August, September and October months.

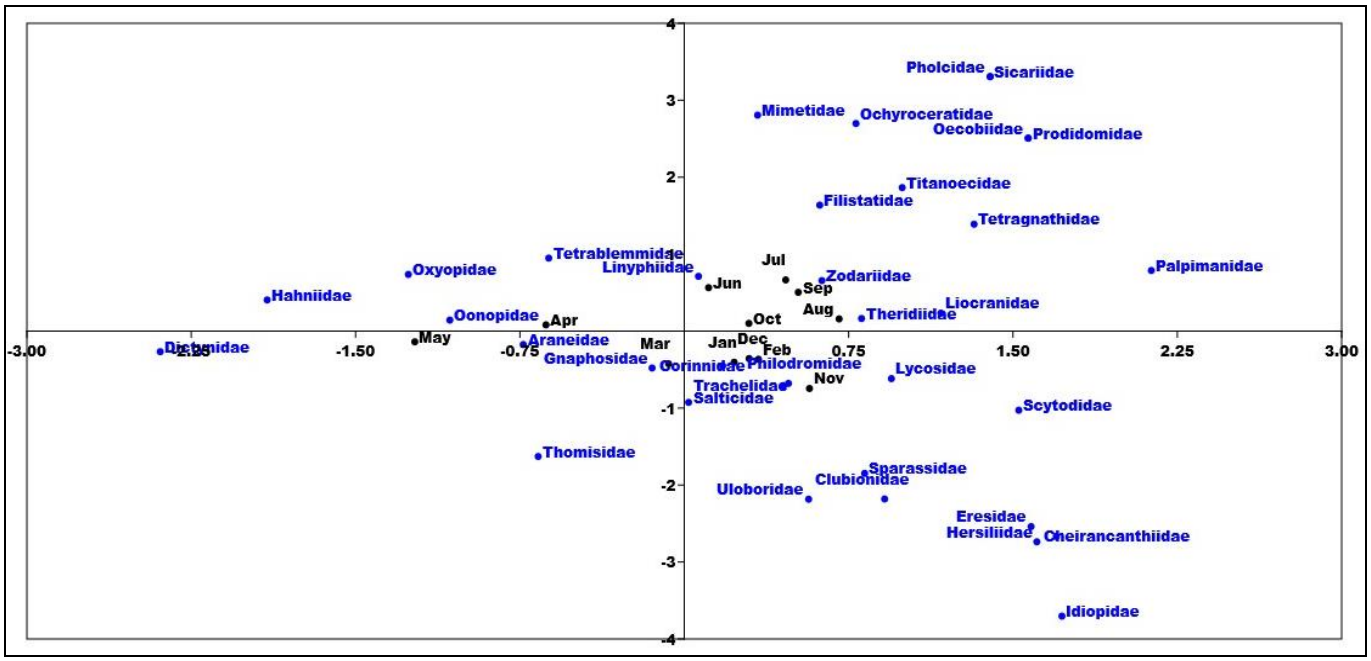

Fig 3: Correspondence analysis of spider families based on monthly abundance.

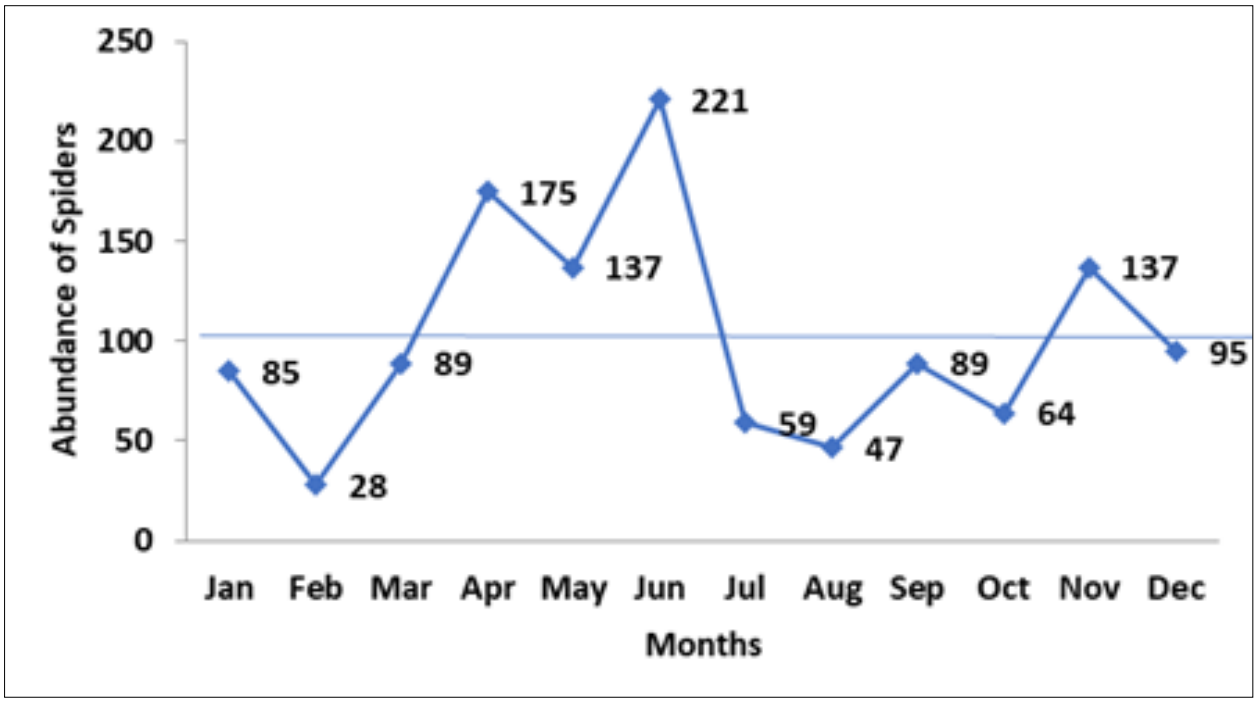

Fig 4: Monthly variation in the spider abundance.

Discussion and conclusion

On the whole, non-web builder' guild constitutes 56.14% individuals (20 families) as compared to 43.55% (15 families) of web-builder families. The abundance web-builder guild is more with 692 individuals (56.44%) as compared to non-web builder guilds with 534 individuals (43.55%). Of these, other hunter guild (OH) which comprise mostly of stalkers and active hunters (Salticidae, Oxyopidae) and also the foliage hunters (Clubionidae, Cheirancanthiidae, Philodromidae, Sparassidae, Scytodidae) form most abundant group of spiders belonging to 8 families and highest abundance of 385 individuals. Ground Hunters (GH) is the second most dominant group with 247 individuals from 7 families. Species from these guilds (OH and GH) are associated with leaves, trunk, fruits and flowers (Fig.5). Many comprehensive studies have also reported stalkers, ambushers and foliage runners as the main predators of insect pests (Uetz *et al*., 1999; Cardoso *et al.*, 2011) [20,2]. The high abundance of Lycosidae may be due to movement of Lycosidae into pomegranate orchard from the adjoining patches. The overall high abundance of GH can be due suitability of microhabitat and microclimatic conditions offered by natural mulching as a management practice that comprise of plant leaves, straw, grass clippings, compost and other agricultural waste along the plantation row. This may also explain the noticeable difference between the abundance of web and non-web builder guilds. The high abundance of orb-web weavers and space-web weavers may be attributed to plant architecture as pomegranate offers enough spaces and niches with bushy appearance with many branches. Many times, the canopies of adjacent plant join offering not just points for web building but also for easy dispersal of spiders. Spiders were observed to use various parts as retreat, for defence, foraging, reproduction and camouflaging in our study.

The changes in the dynamics of spiders show connection with management practice undertaken by farmers. This is reflected in the graphical synthesis of data using correspondence analysis. The rise in spider abundance from March to June correspondence with the beginning of flowering season to fruiting that occurs mainly during this period. The abundance of spiders shows declining trend during post-harvest period between August to October months which then peaks moderately between November to January. This rise in abundance may be attributable to movement of spiders from adjoining agricultural and grassland plots during resting stage of pomegranate before the next cycle. The agro-ecosystem and surrounding grasslands offer good habitats for breeding and then dispersal of spiders during this period. Further detailed understanding is necessary to explore long-term spatio-temporal variation in the spider dynamics according to management practices employed by farmers. Specific associations if any between pomegranate plant and some spider groups needs comprehensive understanding.

Pomegranate, with their bushy nature, thick canopy that is close to ground, shallow root system, many branched shoots, leaves that are either deciduous or evergreen offer perfect habitat, microhabitats and climatic requirements for various species. As pomegranate is grown as a monoculture, pomegranate plants attract a large number of herbivorous insects and hence spiders find these plants suitable for their foraging. Our study reveals that spiders constitute one of the dominant predatory groups with high abundance belonging to eight guilds that range from ground to canopy. This shows their potential to regulate a range of pests from ground to bark to canopy (Fig.5). Our study documents spider's potential in regulating dominant pests such as shot hole borer beetles (*Euwallacea* spp.) in the webs of spiders from families Theridiidae, Titanoecidae and Araneidae. The behavior of spiders belonging to Titanoecidae is unique as their migration from ground to canopy corresponds with phonological changes in pomegranate and the corresponding rise in pest population. While they disperse from ground to canopy, they cover bark, leaves and fruits with their webs so as to provide maximum contribution in controlling diverse pests from ground to canopy (Fig.5) Such behavioural associations between horticultural crops and spiders need

further detailed investigations so that some of the selected species may be promoted for Integrated Pest Management (IPM).

Compare to other similar studies, the family level diversity recorded in our study is far higher. In a study from Wayanad region (Western Ghats) from different plantation Shabnam *et al*, (2021) [16] have recorded spiders belonging to 19 families. A one-year study of Spider diversity within the pomegranate orchards from Israel led to the recording of 1804 individuals belonging to 18 families (Salman *et al*, 2019) [11]. In study on spider fauna associated with temperate orchards (Apple, Pear, Chary) from Kashmir has revealed 51 species of spiders belonging 14 families (Khan A.A, 2011) [9]. The higher family level diversity recorded in our study may be attributed to no-to-moderate level of management, the surrounding heterogeneous habitat comprising of natural semi-arid grassland and traditional crops may have assisted in the dispersal of spiders in the study orchards.

Conflict of interest

Authors declare that there is no conflict of interest

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Fig 5: (A-I). Functional diversity of spiders represented from study area

A. *Thyene imperialis*, B. *Thomisus spectabilis*, C. *Oxytate elongata*, D. *Thomisus lobosus*, E. *Neoscona nautica*, F. *Neoscona sp.*, G. *Hersilia savignyi*., H. *Parasteatoda oxymaculata*, I. *Pandava sp.*

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