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Studies on the Abundance, Temporal Distribution and Diversity of Spiders (Arachnida: Araneae) Associated with Lemon Trees, Sohag Governorate, Egypt

Fathey E. Soliman, Tarek G. Ismail, Alaa Y. Moustafa and Safa M. El-Masry.*

Zoology Department, Faculty of Science, Sohag University, Egypt

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Abstract: Spiders have an important role in the agroecosystems. They are effective in suppressing the pest populations as biological controllers. This study aimed to study the abundance, temporal distribution and diversity of spiders in an agriculture research site at Jazirat Shandweel, Sohag District, Sohag Governorate, Egypt. The sampling was carried out monthly from January to December 2016 using the beating and hand picking methods. One thousand, seven hundred and twenty-nine individuals were identified and classified into fifteen species belonging to fifteen genera and twelve families. The temporal variations in spider families revealed that; four families; Theridiidae, Cheiracanthiidae, Salticidae and Linyphiidae, were the most abundant. Spider's community was classified into two categories; hunting spiders and the web-building ones. The hunting spiders were more abundant than the web building ones. The most species-rich family was Salticidae, while the most individuals-rich family was Theridiidae. The Shannon index exhibits the monthly variation in spider diversity that ranged between 0.83 and 2.28. The evenness index values were high and ranged between 0.4 and 0.95 revealing absence of dominance of a single species.
Keywords: Agroecosystem, Diversity, Guilds, Population abundance, Temporal distribution.

1 Introduction

Although spiders are considered timid creatures, they are worldwide abundantly distributed and one of the top predators in the agroecosystems. In addition to their silk and venom productions, their importance extends to include medical importance, suppressing pest abundance and regulating insect populations in the agroecosystems [1].

Spiders comprise a significant portion of the ecological niches, a remarkable diversity of predation strategies and exhibit taxon and guild specific responses to environmental changes [2, 3, 4]. Despite of their importance as biological control agents, very little is known of the ecological role of spiders as pest controllers [2].

Numerous studies have been dealt with the relationships between vegetation structure and the composition of spider communities, since vegetation is an important factor involved in web site selection [1, 4, 5]. Spiders are strongly affected by microclimatic factors and vegetation structure [6] as shading [7]; litter type and depth that provide different hunting sites, web attachment points, and shelters against predators [8, 9, 10, 11]. Habitat requirements vary for every spider species, consequently; spider species composition may be an indicator of changes in niches quality [9].

Citrus lemon is an important species in Egypt and one of the major export crops. Large numbers of spiders inhabit Lemon orchards [12, 13, 14] and various species of sac spiders participate in the control of lepidopterous pests, mites and thrips in citrus orchards [15].

The present study aimed to investigate the abundance and temporal distribution of spider's families, genera and species associated with Lemon trees in an orchard at Jazirat Shandweel, Sohag District, Sohag Governorate, Egypt.

2 Materials and Methods

Study Area: Sampling was carried out in an area cultivated with lemon trees (about 3.29 Km^2), that is situated near the Agriculture Research Center (26º 38′ 4.23″ N and 31º 39′ 28.4″ E) at Jazirat Shandweel, Sohag District, Sohag Governorate, Egypt (Fig. 1 A and B). The trees are planted in 2010 in a systematic manner with

*Corresponding author e-mail: Safa_elmasry@yahoo.com

nearly five meters interval, forming seven lines parallel to the road and eight lines perpendicular to the road. The density of trees in this area is nearly 0.05 per square meter. The roots of the trees are surrounded with dense weeds, especially milky weeds forming a vegetation cover above the ground. These weeds were trimmed by cutting. The irrigation system of the orchard was every fifteen days in summer and twenty-one days in winter. During the period of investigation, no herbicides or pesticides were used. The human subjected the area to disturbance, mainly, during irrigation and lemon fruit harvesting. Some animals were observed temporarily visiting the area as reptiles (lizards and snakes), birds (doves, domestic sparrows and crows) and rats.

Study period and sampling plan: The study was carried out monthly for a period of 12 months from January to December 2016. According to the arrangement of Lemon trees, eight lines named; A1 to A8 (starting from Western to Eastern directions) were set and perpendicularly crossed by seven lines named; B1 to B7 (starting from South to North direction). The numbers of trees in the studied area are 56 trees, of these 13 trees were died (Fig. 1 B and Fig. 2). One line of trees was sampled per month; therefore, the eight lines cover a period of eight months (January to August). To complete the period of investigation, the sampling of the lines A1 to A4 was repeated in the period from September to December 2016. The number of trees per line varied greatly and ranged from three to seven. To avoid bias in the data because of few trees in transects AI and AIV, their data were pooled and treated as one line.

This gives a total of 72 points (trees) for collecting spiders Within 12 months collecting period. Spiders were collected by two methods, hand picking and beating. In the first method, spiders that found on trees' stems and their close branches were pushed to enter inside plastic jars. In the second method, a white cloth sheet (2.5×2 m) was laid on the ground beneath the branches of the tree. Three branches from each side of the tree were shaken vigorously with hand for one minute and then beaten five times with thick large stick to dislodge spiders. This was followed by quick collecting of spider's specimens in labelled plastic jars before they run away and transferring it to the laboratory for identification. The spiders were preserved in labelled bottles containing 70% ethanol.

Identification of Spiders: Identification of the collected species was carried out by the help of the following keys; [16, 17, 18, 19, 20, 21, 22]. Also, El-Hennawy, the Egyptian expert in the identification of Egyptian spiders, confirmed the spider's identification.

Data Analysis: The analyzed data includes family numbers, abundance, species richness (number of species) and species abundance (number of individuals). The diversity of the species was calculated using Shannon-Wiener index (H) and the evenness index of the species (J) [23].

Analysis of variance (ANOVA) was used to examine the differences in abundance and composition of spider's families and species.

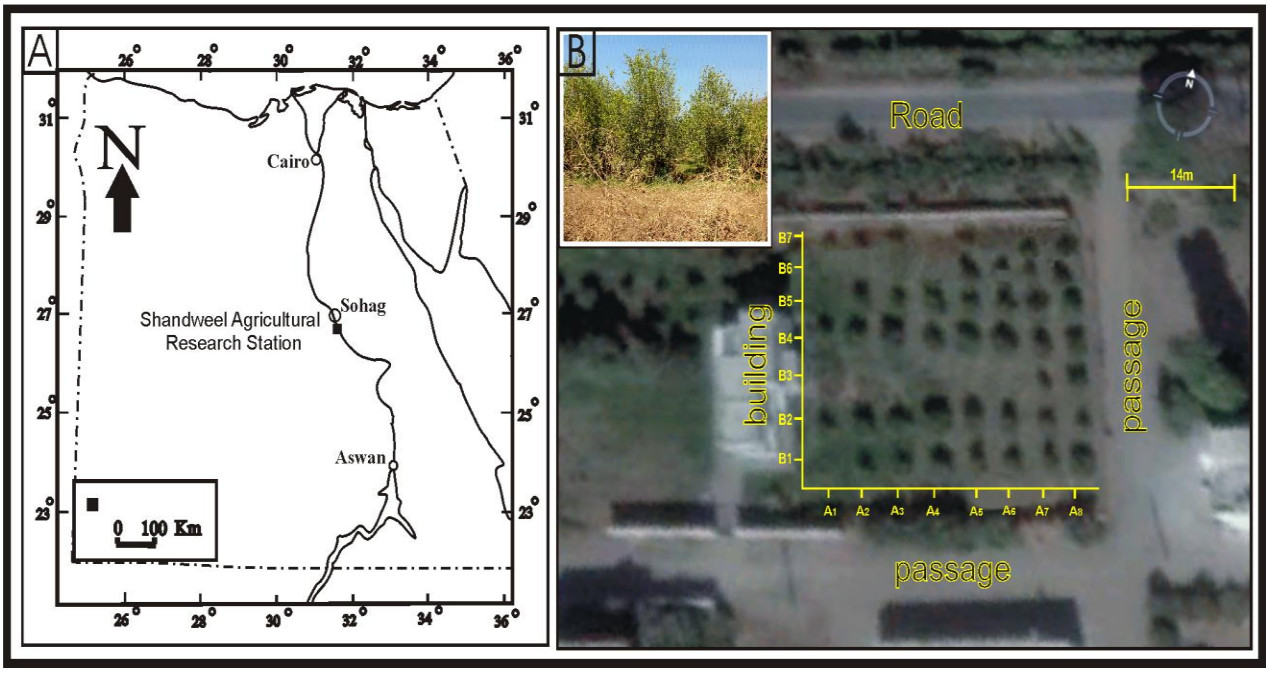

Fig. 1. A map showing the location of the studied site at Sohag Governorate (A) and a Google image showing the Lemon trees sampled area (B).

3 Results

3.1 Environmental Physical Factors

Monthly variations in the mean air temperature, mean relative humidity and mean wind speed were summarized according to the Central Laboratory for Agriculture Climate (CLAC) at the Agriculture Research Center, in Jazirat Shandweel, Sohag, from January to December, 2016 and represented in Figure (3). The mean air temperature was almost high in summer months and low in winter months. The mean relative humidity was high in winter and low in summer months. The wind direction fluctuated between North to North-West. The climatic features of the area were high temperatures (annual average, 23.4°C), high relative humidity (annual average, 44.1 %) and moderate winds (annual average speed, 20.1Km/ h).

3.2 Community Structure and Guilds

One thousand, seven hundred and twenty-nine individuals were collected from the Lemon trees and belonging to 15 species of 15 genera, and 12 families (Table 1). According to their foraging strategies, spiders were categorized into two main groups: web-building and hunting spiders. The two categories were further divided into guilds depending on web characters and searching activity (Fig. 4). Web-building spiders include: orb weavers (families: Araneidae and Uloboridae), hackled-band weavers (family: Dictynidae), sheet-web weavers (family: Linyphiidae) and cobweb spiders (family: Theridiidae). Hunting spiders included: nocturnal hunters (families: Gnaphosidae and Lycosidae), agile hunters (families: Oxyopidae and Salticidae), Ambushers hunters (families: Philodromidae and Thomisidae) and swift hunters (family: Cheiracanthiidae). Comparing abundance among different families of spiders based on their two searching activity types (web building and hunters) revealed that, hunting spiders were more abundant than the web-building ones ($F = 10.45$; $df = 143$; $P < 0.002$). Among web-building spiders, which had the highest density (65.5 % of the total), the cobweb spiders (Theridiidae) and sheet-web weavers (Linyphiidae) recorded the highest densities; 45.6 and 8.8 % of the total; respectively. While, among hunting spiders (34.5 % of the total), the swift hunters (Cheiracanthiidae) and agile hunters (Oxyopidae and Salticidae) had the highest densities; 13.6 and 8.7 % of the total; respectively (Table 1 and 3). Also, guild composition showed significant difference ($F = 26.16$; $df = 143$; $P = 0.001$) that was attributed to cob-web spiders' abundance.

Temporal fluctuation in species richness for web-building and hunting spiders is shown in (Table 2 and Fig. 5). The most species-rich family was Salticidae; (hunting spiders) with three species occurred in five months; March, June, July, August and November (constituting 20 % of the collected species), followed by Araneidae; (web building spiders) containing two species represented in five months. The rest of the families were represented by only one species (about 6.7 % each).

3.3 Temporal Fluctuation of Individuals in the Different Families

The most abundant family was Theridiidae (web building spiders) comprising 789 individuals (45.63 % of the total collected individuals) ($F = 17.64$, $df = 142$, $P < 0.0001$), followed by Cheiracanthiidae (hunting spiders) with 236 individuals (13.65 % of the total). The two families: Lycosidae and Oxyopidae were considered rare as each of which was represented by less than five individuals during the course of the investigation (Figs. 6 and 7).

Monthly fluctuation in abundance of spider families is shown in (Table 3 and Fig. 8 and 9). Araneidae and Theridiidae, were present during the 12 months of collection. Theridiidae shows clearly two successive high peaks in June and July with 127 and 164 individuals; respectively and a third moderate peak in March with 106 individuals. Araneidae showed fluctuation with three successive peaks in winter months. The highest peak was in January with 16 individuals. In spite of the absence of Linyphiidae in March and November, it showed two high peaks of density in May and September with 29 and 65 individuals; respectively. Since the density of Uloboridae was low and absent in March and August, its fluctuation was slight with only one peak in September with 13 individuals. Family Dictynidae that was absent in seven months of the collection period, showed only one peak in December with 18 individuals.

In the hunting spiders, two families: Cheiracanthiidae and Gnaphosidae were recorded during the 12 months of collection. Cheiracanthiidae revealed two high peaks in September and April (35 and 30 individuals; respectively) and two low peaks in February and July (each with 22 individuals), while the abundance of Ganphosidae was obvious with three peaks, one in September (24 individuals) and two in February and May (each with 15 individuals). Salticidae that was present in 11 months showed three peaks in January, June and December with 26, 23 and 26 individuals; respectively. Each of Lycosidae and Oxyopidae was recorded in two months period, (July and August, March and May; respectively) and were absent during the rest of collecting period. The collected number of individuals of Lycosidae and Oxyopidae was few; therefore, no fluctuation can be detected. The abundance of Philodromidae showed a low pattern of temporal distribution during most of the year with a single peak in September with 31 individuals. Thomisidae had low abundance and a peak in March with 9 individuals.

The present data revealed that highest family abundance was in summer (562 individuals), due to the high abundance of web-builders in this season (422 individuals). Abundance in spring and autumn was almost equal (398 and 392, respectively), while abundance in the winter was low (377 individuals). The Abundance of hunting spiders was higher than web-builders in autumn.

3.4 Diversity Indices

Both Shannon-Wiener (Ḥ) and Equitability (evenness) (J̇) indices were used to evaluate the diversity of all the species and individuals of the Lemon trees spider community (Fig. 10). Data were pooled, monthly, for all species populations to calculate both the indices. Monthly changes in the two diversity indices for the spider community showed similar trends. Shannon index ranged between 0.83 and 2.28 during March and September; respectively. The evenness index minimum value was 0.40 in March, while its maximum value was 0.95 in September.

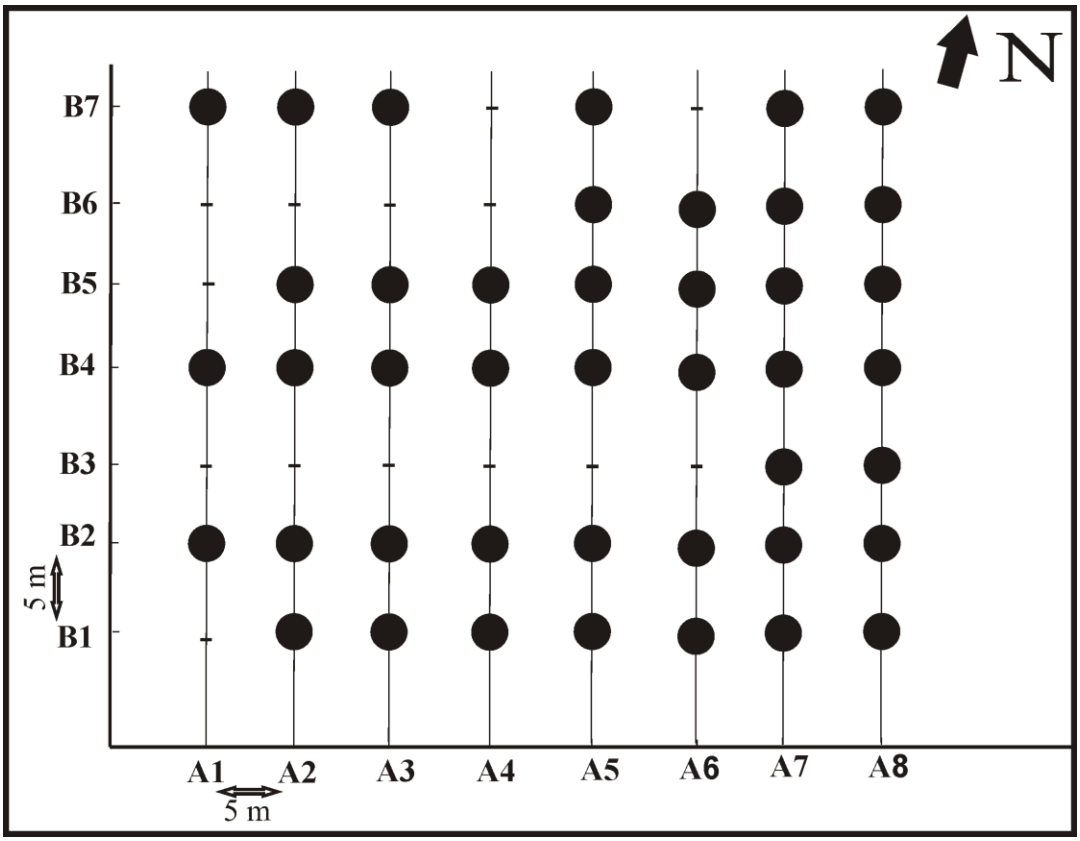

Fig. 2. The arrangement of lemon trees in the studied orchard and the sampling plan.

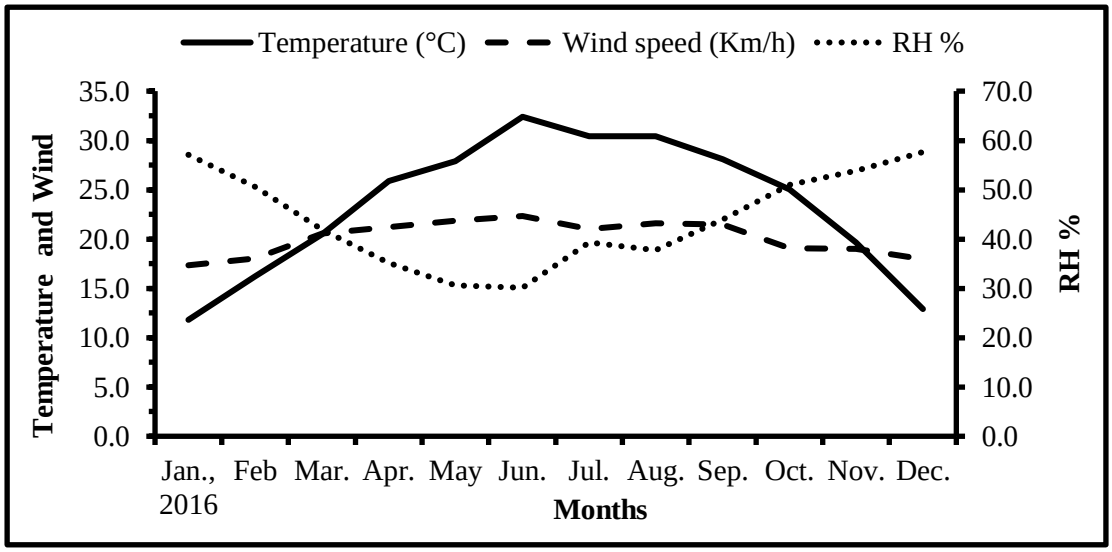

Fig. 3. The mean values of air temperature, relative humidity and wind speed during the study period.

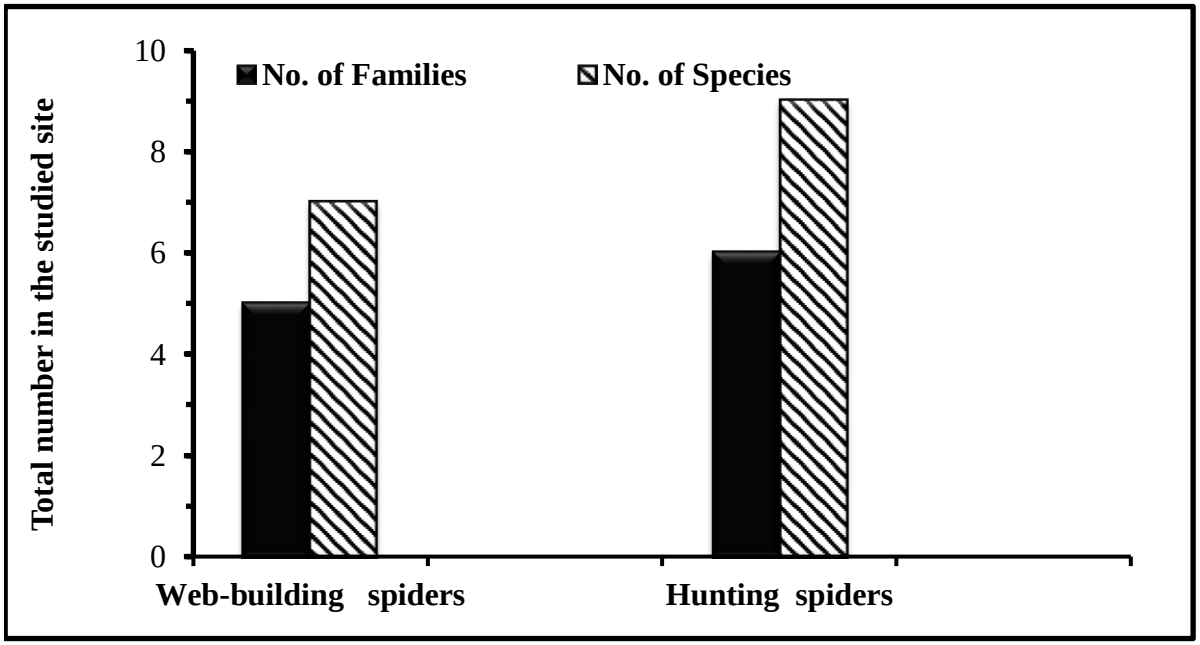

Fig. 4. The number of families and species in the two investigated groups; (web-building and hunting spiders) in the Lemon trees site.

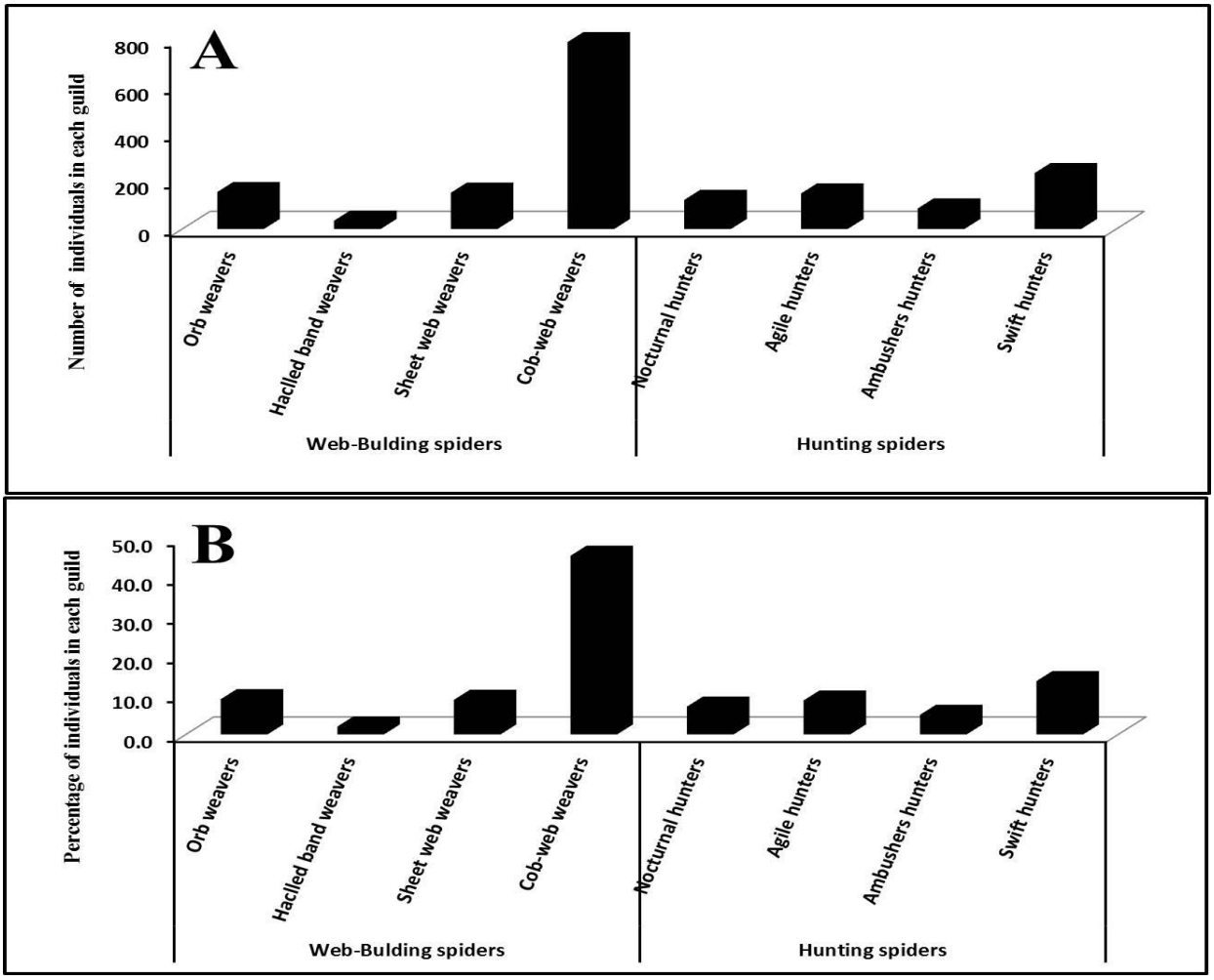

Fig. 5. A and B; Numbers and percentages of the investigated individuals in each guild in the lemon trees site.

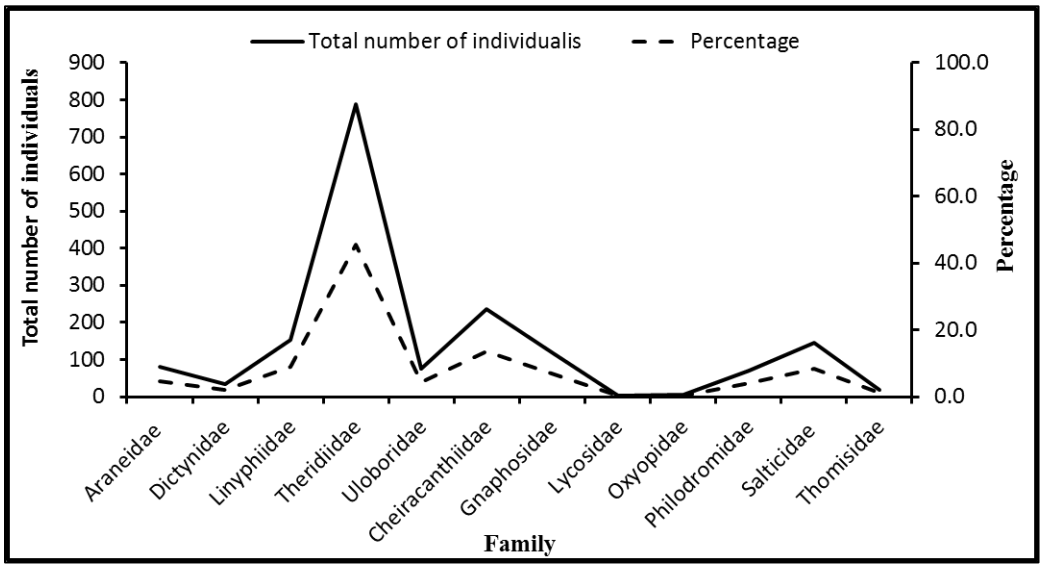

Fig. 6. Number and percentage of individuals in each recorded Family in Lemon trees site.

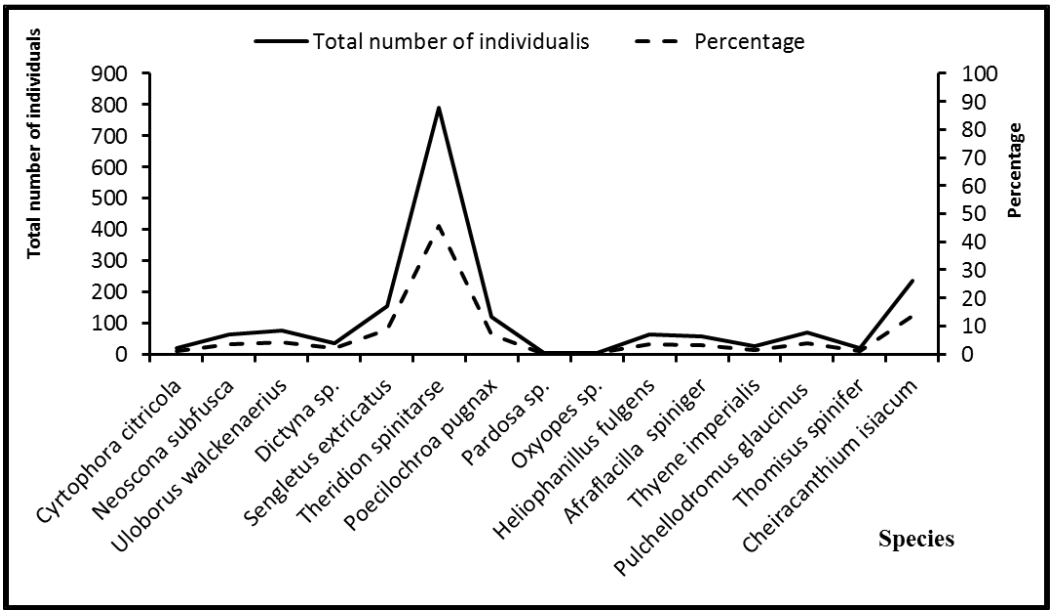

Fig. 7. Number and percentage of individuals in each recorded species in Lemon trees site.

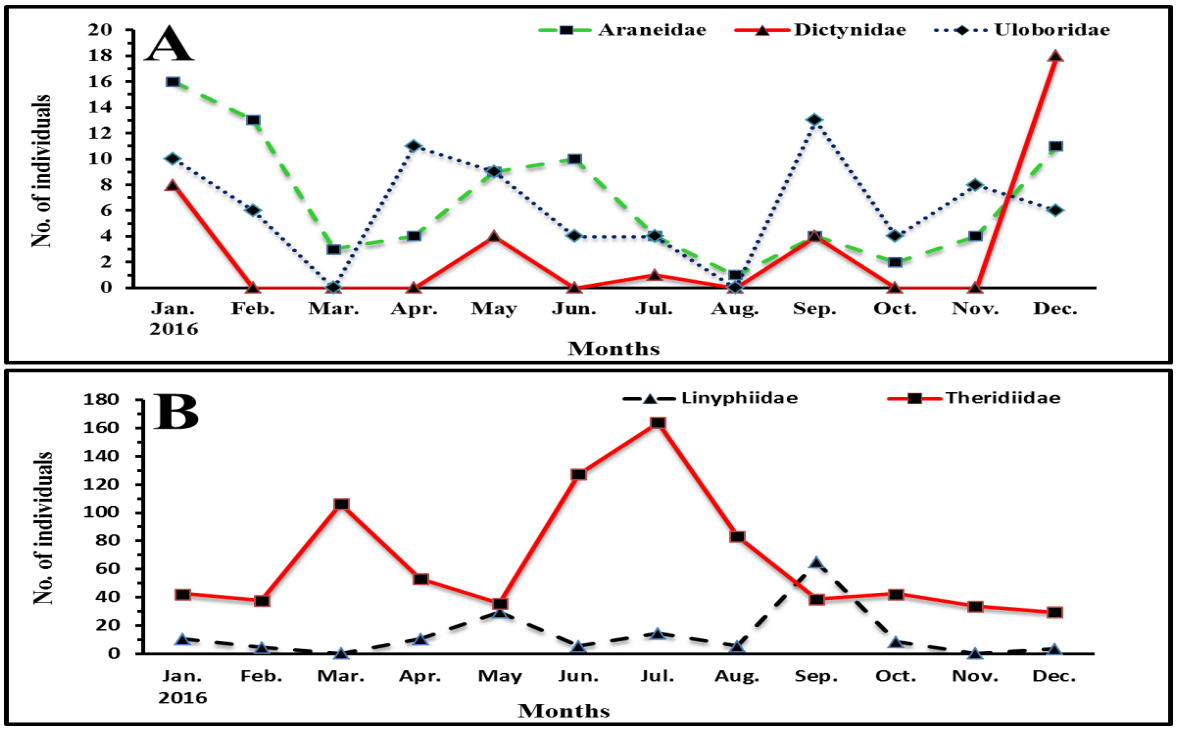

Fig. 8. A and B. Monthly fluctuation of number in individuals at the Lemon trees site (families of web-building spiders).

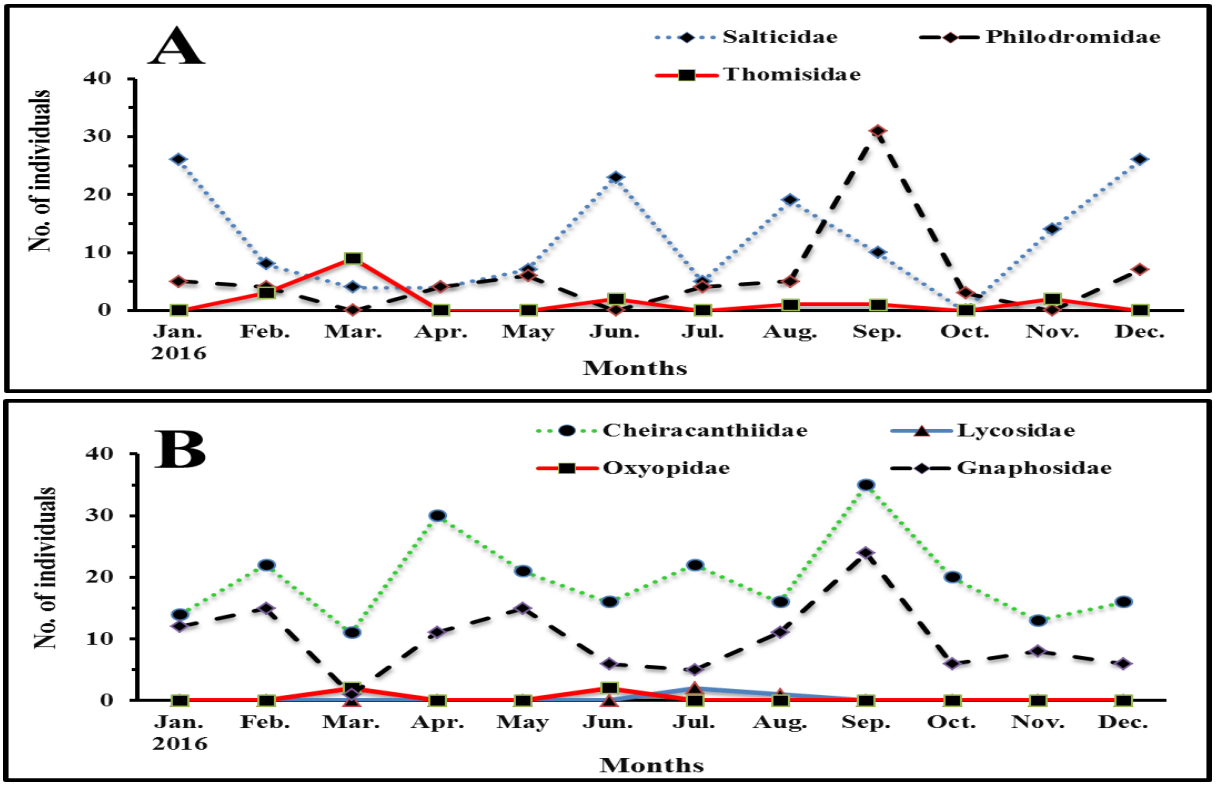

Fig. 9. A and B. Monthly fluctuation in number of individuals at the Lemon trees site (families of hunting spiders).

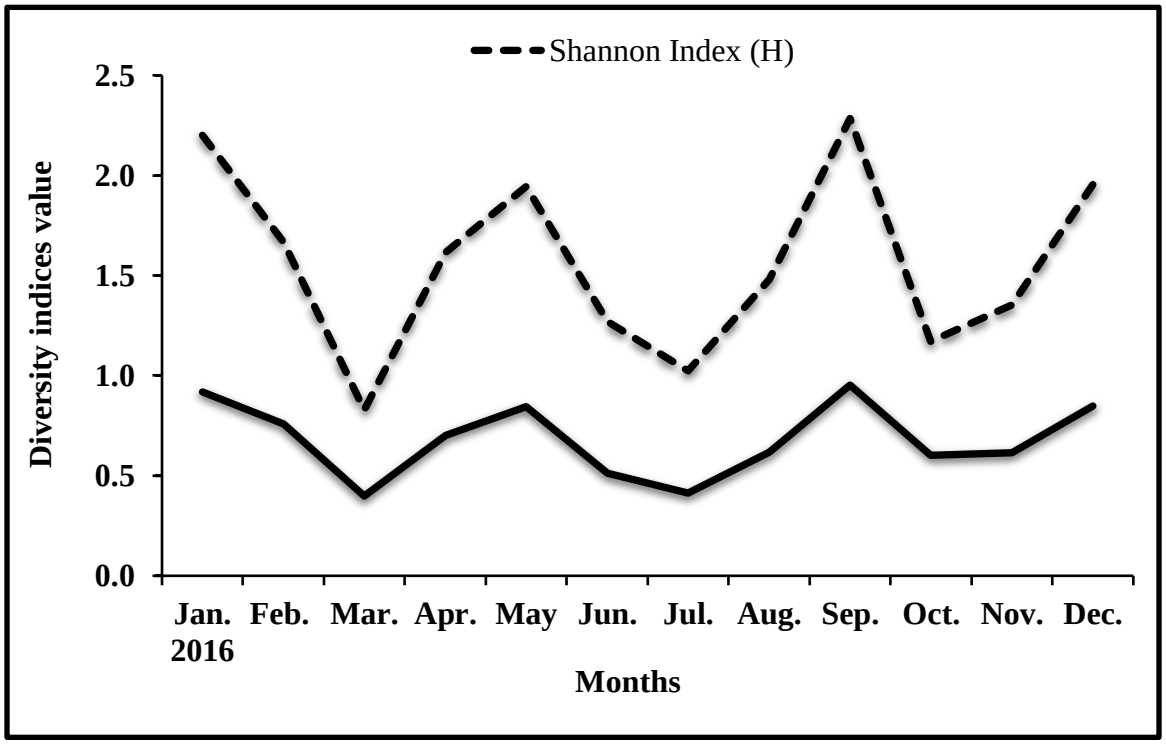

Fig. 10. Diversity indices: Shannon-Wiener and evenness (equitability) for the pooled spider's populations.

Table 1. Number of spider's families, species and individuals arranged by guild in the Lemon trees site.

Group	Guild	Guild		Family	Family		Species	Species	
		No.	%		No.	%		No.	%
Web-building spiders	Orb weavers	156	9.02	Araneidae	81	4.86	*Cyrtophora citricola*	19	1.1
							Neoscona subfusca	62	3.59
				Uloboridae	75	4.34	*Uloborus walckenaerius*	75	3.3
	Hackled-band weavers	35	2.02	Dictynidae	35	2.2	*Dictyna* sp.	35	2.02
	Sheet web weavers	153	8.85	Linyphiidae	153	8.35	*Sengletus extricates*	153	8.35
	Cob-web weavers	789	45.63	Theridiidae	789	45.63	*Theridion spinitarse*	789	45.63
Total	4	1133	65.5	5	1133	65.5	6	1133	65.5
Hunting spiders	Nocturnal Hunter	123	7.1	Gnaphosidae	120	6.94	*Poecilochroa pugnax*	120	6.94
				Lycosidae	3	0.17	*Pardosa* sp.	3	0.17
				Oxyopidae	4	0.23	*Oxoypes* sp.	4	0.23
	Agile Hunter	150	8.7	Salticidae	146	8.44	*Heliophanillus fulgens*	64	3.7
							Afraflacilla spiniger	57	3.3
							Thyene imperialis	25	1.45
	Ambushers Hunter	87	5.0	Philodromidae	69	3.99	*Pulchellodromus glaucinus*	96	3.99
				Thomisidae	18	1.04	*Thomisus spinifer*	18	1.04
	Swift Hunter	236	13.6	Cheiracanthiidae	236	13.65	*Cheiracanthium isiacum*	236	13.65
Total	4	596	34.5	7	596	34.5	9	596	34.5

Table 2. The number of the spider species in each family at Lemon trees site during the study period.

Family	Month											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Araneidae	2	1	1	2	1	2	1	1	2	1	1	1
Dictynidae	1	0	0	0	1	0	1	0	1	0	0	1
Linyphiidae	1	1	0	1	1	1	1	1	1	1	0	1
Theridiidae	1	1	1	1	1	1	1	1	1	1	1	1
Uloboridae	1	1	0	1	1	1	1	0	1	1	1	1
Cheiracanthiidae	1	1	1	1	1	1	1	1	1	1	1	1
Ganphosidae	1	1	1	1	1	1	1	1	1	1	1	1
Lycosidae	0	0	0	0	0	0	1	1	0	0	0	0
Oxyopidae	0	0	1	0	1	0	0	0	0	0	0	0
Philodromidae	1	1	0	1	1	0	1	1	1	1	0	1
Salticidae	2	1	3	2	2	3	3	3	1	0	3	2
Thomisidae	0	1	1	0	0	1	0	1	1	0	1	0

Table 3. Monthly fluctuation in number of individuals in each family at Lemon trees site.

Family	Month												
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Araneidae	16	13	3	4	9	10	4	1	4	2	4	11	81
Dictynidae	8	0	0	0	4	0	1	0	4	0	0	18	35
Linyphiidae	10	4	0	10	29	5	14	5	65	8	0	3	153
Theridiidae	42	37	106	53	35	127	164	83	38	42	33	29	789
Uloboridae	10	6	0	11	9	4	4	0	13	4	8	6	75
Cheiracanthiidae	14	22	11	30	21	16	22	16	35	20	13	16	236
Ganphosidae	12	15	1	11	15	6	5	11	24	6	8	6	120
Lycosidae	0	0	0	0	0	0	0	2	1	0	0	0	3
Oxyopidae	0	0	0	2	0	0	2	0	0	0	0	0	4
Philodromidae	5	4	0	4	6	0	4	5	31	3	0	7	69
Salticidae	26	8	4	4	7	23	5	19	10	0	14	26	146
Thomisidae	0	3	9	0	0	2	0	1	1	0	2	0	18

4 Discussions

The diversity of the Egyptian spiders is still incomplete because of the little and sporadic work in this field. [22] listed 405 spider species belonging to 204 genera and 41 families from different regions in Egypt. In Sohag Governorate, the only available work revealed the presence of 21 spider families comprising 43 spider species [24,25]. They collected spiders randomly from different vegetable crops and fruit fields (tomato, potato, corn, bean, mango, lemon, fig, guava and grapes) that were distributed in different regions in Sohag Governorate and pooled the data for the analysis without illustrating the effect of plant type on spider abundance.

The collected families in the present study added one family (Oxyopidae), nine genera (including three unidentified species; *Dictyna* sp., *Pardosa* sp. and *Oxyopes* sp.) and six species (*Neoscona subfusca*, *Poecilochroa pugnax*, *Sengletus extricates*, *Afraflacilla spiniger*, *Heliophanillus fulgens* and *Theridion spinitarse*) to those previously reported one in Sohag Governorate [24,25]. The previous number can be increased by exploring new habitats as desert and aquatic bodies and using new methods of collection.

The present study classifies spiders into two main guilds, web-building and hunting spiders. Other studies classified them into many guilds based on spider foraging strategy, habitat preference, circadian activity and prey range that make the number of recognized guilds varies [26,27]. The present results revealed that, the number of hunting spider families was larger than that of the web-building ones. Web-building species are stationary predators that wait for food to come in their webs, i.e., they feed on moving preys. In contrast, hunting spiders are more active and representatives of various hunting spider families found to feed on both moving and motionless preys [5,28]. They are actively seeking out suitable food due to their higher mobility and have better chances of finding suitable food than web-weavers in the agroecosystem. Furthermore, the branches of the investigated Lemon trees grow vertically and its canopy provides a habitat that leaves open sunny-areas among trees. Such architecture of the vegetation features is not suitable for the web-building spiders and decreases the availability of web places [4,29] which may be the cause of their low number of families compared with the hunting spiders. Also, in these sunny-areas (open canopy) grow dense grass-layer, which support larger populations of hunting spiders [30]. The number of families of hunting spiders were less in their individual abundance than web-builders, this can be attributed to their quick desiccation in very hot and dry seasons [31] or low density of available preys due to grass cutting [32].

Temperature and humidity are two important physical factors for spiders, which have different ranges of physiological tolerances; therefore, these factors alter greatly the abundance and richness of spider species [33, 34]. High summer abundance in the present study can be attributed to high temperature and relative humidity in this season that makes spiders active, as well as, to the canopy and flowering of lemon trees that increase the available preys [35]. While the low abundance in winter suggest the influence of spiders by the severe climatic condition where low temperature decreases the activity of some spiders. Some enter a stage of dormancy, especially hunting spiders [36], while some stages hibernate [35], as well as most of their arthropod prey do [37].

Seasonal fluctuation in the abundance of spider populations was reported in many areas [34, 38, 39, 40, 41]. Some studies reported the dominance of family Araneidae, followed by Salticidae, Thomisidae and Theridiidae, while families Uloboridae, Tetragnathidae, Gnaphosidae, Oxyopidae, Sparassidae and Lycosidae recorded low abundance [42]. Furthermore, some studies reported Salticidae as the dominant family that represents the highest species diversity, while Araneidae is the second largest family in species diversity [43, 44, 45]. Lycosid species (hunting spiders) was found to be the most dominant species in the Lemon trees field in Spain and Pakistan [35, 46] using only pitfall trap method.

Fluctuation in abundance of spider populations can be attributed to variation in vegetation (type, density, architecture and flowering season) that provide spiders with different microhabitats, where web-builders place their webs [47, 48, 49] and for hunter spiders where they found their preys [50]. More diameters, length and a high number of branching (branching complexity) of Lemon trees reflect the high foliage density and biomass that affect spider abundance [51, 52].

Also, some physical factors (temperature, relative humidity, the degree of shadows offered by vegetations) and some biological factors (inter- and intra-competition) affect the spider abundance. Shading is important because it affects the microclimatic conditions of the grasses around the trees [32]. Type and availability of the preys play a major role in the spider species richness [50] but are considered of a secondary importance to that of habitat structural diversity [53,54] because their types and abundance are fluctuating depending on vegetation growth season. Therefore, in the present study, the high number of collected families (12 families) and species richness (15 species) reflects vegetation complexity which spider rely on for their life cycle, either for finding food, building retreats or for web building.

In the present work, the temporal distribution of captured spider species revealed that the three species *P. pugnax*, *T. spinitarse* and *C. isiacum* are found during all the period of investigation. This suggests that these species are competitive under a wider range of conditions and use more prey types than the other collected spider species [55].

Oxyopes sp. and *Pardosa* sp. are hunter spiders represented with few immature stages. The lack of adult lycosids and oxyopids in the samples is probably due to the method of collection. Pitfall trap method (not used in the present study) found to capture highly active adult spiders found hiding among grasses [56].

The diversity indices values, in the present study, indicated that, the spider diversity varied greatly from one month to the other. The reason for this variability could be related to the fact that the Lemon trees number varies monthly (each month has different trees number, Figs 1 and 2). Another possible reason is, the human stress during lemon harvesting which was found to be negatively affected spider richness and abundance and change of the physical structure of the microhabitats [57]. Also, it is expected that climatic changes through seasons would influence the richness and abundance of spiders [58]. In addition to the previous reasons, there are other environmental factors that affect species diversity as seasonality, spatial heterogeneity, competition, predation, habitat type, environmental stability, species composition and productivity [41].

The evenness values were high revealing the absence of the dominance of a single species in spiders' community and the individuals were almost evenly distributed among the different species during most of the year. However, when the plantation area is dominated by one plant (as Lemon trees in the present study), the species diversity is expected to be low compared with other multi-crops cultivated areas [40].

5 Conclusions and Recommendation

The present study was carried out in an area, cultivated with Lemon trees, within an Agriculture Research Center at Jazirat Shandweel, Sohag District, Sohag Governorate, Egypt. The study revealed that Lemon trees provide suitable niches that harbor great numbers of individuals and species of spiders.

One thousand, seven hundred and twenty-nine individuals were identified and classified into fifteen species belonging to fifteen genera and twelve families. Twelve families of the spiders were recorded; five families were web-building and seven families were hunter spiders.

The temporal variations in spider families revealed that; four families, Theridiidae, Cheiracanthiidae, Salticidae and Linyphiidae, were the most abundant. The spider seasonal abundance was influenced by environmental factors as temperature and relative humidity. Also, the present study revealed the importance of vegetation which supports a higher number of spider species due to variety of available microhabitats. Therefore, spider fauna conservation needs to adopt management practices that do not have any negative effects on spider fauna.

The present study implies that the future studies should focus on the relation of spider abundance and vegetation features as branching complexity (diameter, length and high numbers of branches) which form microhabitats for spiders. Also, the comparison between collecting methods is needed to illustrate which method is more effective.

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