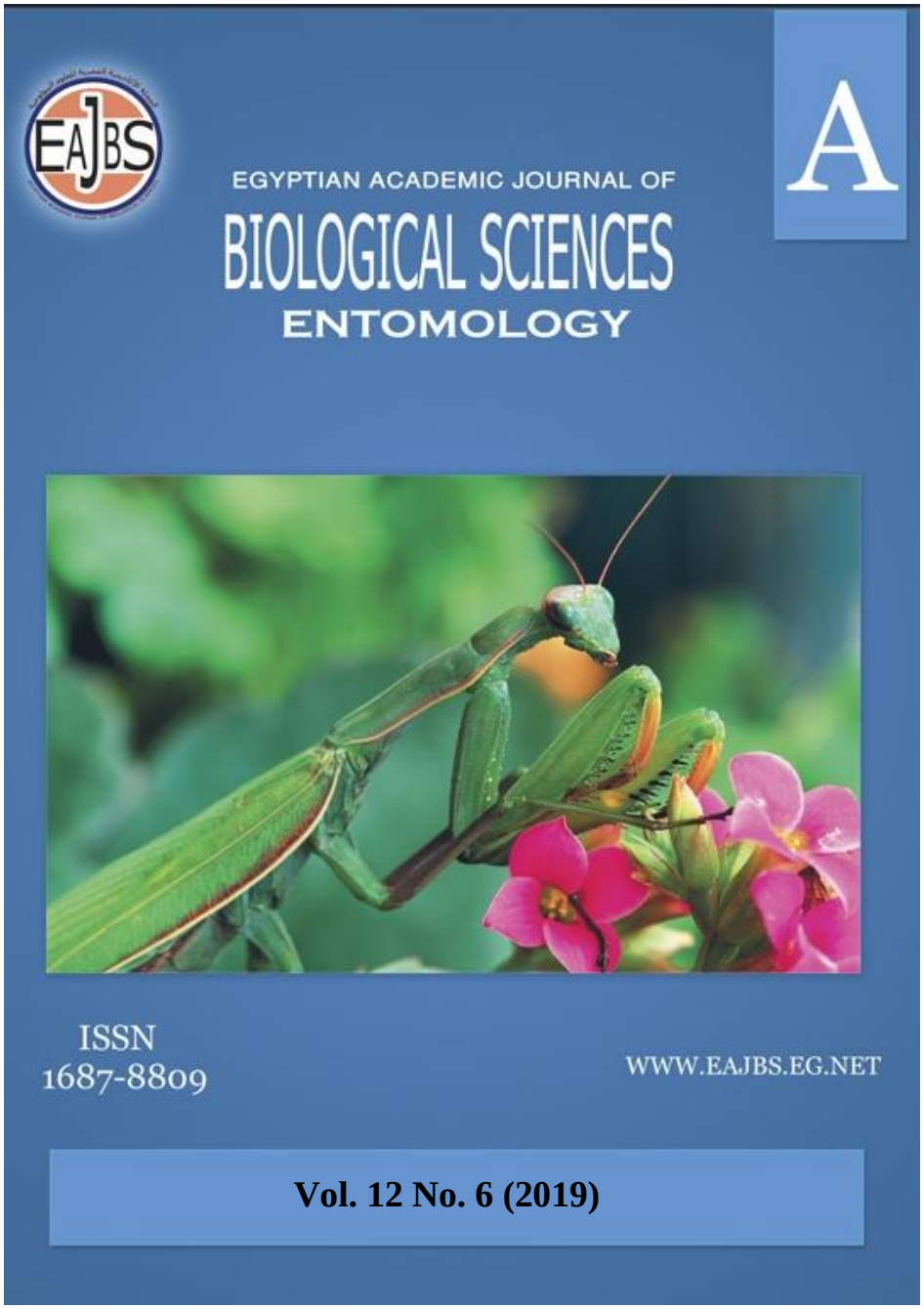

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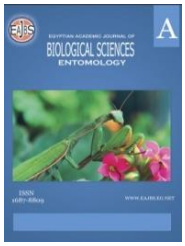

Preliminary Study of Araneofauna (Arachnida: Araneae) Inhabiting Quinoa Plants at Fayoum Governorate, Egypt

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ABSTRACT

A survey of spider community composition and diversity associated with quinoa plants was carried out at Fayoum governorate, Ibshway region, Aboksa village from September to April during two successive winter seasons, 2016/2017 and 2017-2018. Pitfall traps were used. Numbers of collected spiders were pooled and analyzed for species diversity using Shannon-Wiener Index, evenness, Simpson Index and Sørensen Quotient of Similarity. A total of399 spiders grouped in 11 families belonging to 23 genera and more than 23 species. First season received 124 individuals belonged to 20 genera, 20 species of 8 families, while second season received 275 individuals belonged to 21 genera, 21 species of 10 families. Four families contained 92.5% of the total collected spiders; they are Lycosidae, Linyphiidae, Theridiidae and Gnaphosidae. Lycosidae was the most abundant family (55.99%) followed by Linyphiidae (25.81%). The other remaining families represented 18.75% of the total catch. Guild structure analysis revealed seven feeding guilds namely, stalker, ground runner, ambusher, space weaver, wandering sheet spiders, sensing and space web. Guild structure varied, in the first season, Wandering sheet and ground running representing 12.53 and 12.78 % of the total spiders while the second season, wandering sheet and ground running representing 12.28 and 48.12% of the total spiders and had the highest species richness.

INTRODUCTION

Quinoa is a very old crop belongs to the genus *Chenopodium quinoa* Willd. (Caryophyllales, Amaranthaceae). Quinoa was used thousand years ago by Andean people (Rasmussen et al. 2003). It is grown for its edible seeds in some cases and places. Green leaves are eaten as vegetables. After harvest, the seeds must be processed to remove saponin which gives bitter taste for unprocessed seeds (Gee *et al.*, 2006). Quinoa was introduced to Egypt few years ago as pseudocereal crop. Quinoa requires cool temperature especially during flowering, for most genotypes, and short day length to flower and produce seeds. Therefore quinoa fits to the Egyptian winter climate (Oelke *et al.*, 2015). Quinoa seeds contain essential amino acids, Calcium, Phosphorus, iron and high amount of protein. Due to these essential amino acids and high content of protein (Shukla and Ohri, 2006), quinoa can improve and replace part of animal protein, especially in poor rural areas. Quinoa has a high nutritive value because its grains contain high protein quality and quantity as well, all

essential amino acids and trace elements and vitamins. Quinoa has the ability to adapt to different ecological environments and climates (Rasmussen *et al.,* 2003). Spiders are clearly an integral part of global biodiversity since they play important role in ecosystem as predators and important role in food chain of the ecosystem (Sharma *et al.,* 2010). The presence of several natural enemies associated with quinoa has been observed, including exotic and native species i.e. Lycosidae and Salticidae. Also, natural enemies like Araneae showed distinct patterns of abundance with regard to the quinoa and the time of the season (Yabar *et al.,* 2002). This study sheds light on the taxonomic spider assemblages "family guild composition" from quinoa plants and to the spider communities, concerning relative abundance, species richness, guild composition, Shannon-Wiener index (H), Simpson index (S), and evenness (e) to quantify the community structures of spiders among two successive winter seasons.

MATERIALS AND METHODS

a. Experimental Design:

Survey and abundance of spiders were studied at Fayoum governorate, Ibshway region, Aboksa village from September to April during two winter seasons, 2016/2017 and 2017-2018. Commercial Quinoa seeds were used in this study in area of 700 m^2. Quinoa seeds (Egypt 1) were sowed during last week of September in rows 70 cm apart. Five to ten seeds were planted in holes distanced at 25 cm. All plants received fertilizers at the rate of 90: 40: 100 N: P: K in addition to two sprays with calcium chloride and two sprays with trace elements (Fe – Zn – Mn and Mo). Spiders were collected by using pitfall traps method as described by Southwood (1978) and Slingsby & Cook (1986). Twenty pitfall traps were placed every 7 days. Samples were sorted in the laboratory; collected spiders were kept in glass vials containing 70% ethyl alcohol and some droplets of glycerine for identification.

b. Identification of Spiders:

Spiders were identified according to Kaston (1978), Oger (2002), Ovtsharenko and Tanasevitch (2002a,b,c), Proszynski (2003), Huber (2005), Platnick (2012). Juvenile spiders were mostly identified to family or to genus. Voucher specimens were preserved in 70% alcohol and deposited in a reference collection lodged in the Plant Protection Research Institute.

c. Data Analysis:

Spider Community:

The community structure of soil spiders was described using the species richness, Shannon-Wiener "H" and Simpson indices "S". The Shannon-Wiener index "H" is one of the most common ecological indexes, providing an indication of community stability under the balance of nature and may respond differently of geographical, developmental, or physical factors. Higher number of "H" indicates higher number of species, higher relative abundance and species evenness, so, it means increase in diversity. While Simpson index "S" is more responsive to changes in importance of most dominant species, it is a measure of dominance (i.e., the probability of two randomly selected individuals will be of the same species) (Nestle *et al.* 1993). A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance. The two indices were calculated as described by Ludwig and Reynolds (1988):

$$\mathbf{H'} = -\Sigma\ (ni/n)\ \ln\ (ni/n) \text{ and } \mathbf{S} = \Sigma\ (ni/n)^2$$

Where n*i* is the number of individuals belonging to the i^{th} of "S" taxa in the sample and "n" is the total number of individuals in the sample.

$$\textbf{Species Evenness} = i / Ln((s-1) / Ln(n))$$

Where, i = Shannon Diversity Index, s = Number of Species Recorded, n = Total Number of Individuals in the Sample.

Sørensen Quotient of Similarity:

To compare guild comparison between microhabitats of spiders in the two seasons, Sørensen's quotient of similarity (Sørensen, 1948) was applied to the number of species and individuals of spiders in the two seasons. It was used to determine the similarities of spider species composition among the communities. Sørensen's original formula was intended to be applied to presence/absence data, QS = 2 C/A + B, Where A and B are the number of species in samples A and B, respectively, and C is the number of species shared by the two samples; QS is the quotient of similarity and ranges from 0-1.

Frequency and Abundance Values:

The frequency values of the most abundant species were classified into three classes according to the system adopted by Weis Fogh (1948); “Constant species” more than 50% of the samples, "accessory species" 25-50 % of the samples and "accidental species" less than 25%. On the other hand, the classification of dominance values were done according to Weigmann (1973) system in which the species were divided into five groups based on the values of dominance in the sample; Eudominant species (>30% individuals), dominant species (>10-30% individuals), subdominant (5-10% individuals), recedent species (1-5% individuals) and subrecedent species (<1% individuals).

Guild Composition:

Spiders collected during this study were divided into seven guilds according to spider’s web-building and prey-catching behavior as described in classification by Uetz *et al.* (1999).

RESULTS AND DISCUSSION

Table (1) shows that spiders collected recorded 399 individuals representing 11 families, 23genera, and more than 23 species. The 11 families found in quinoa plants in two seasons represented 27.5% of the 40 families recorded in Egypt (El-Hennawy, 2006).

These results agree with that of Sharma *et al.* (2010) who found that 117 specimens were collected, 44 species were identified belonging to 12 Families.

Survey of Spiders Inhabiting Quinoa Plants:

Table (1) shows that, in the first season, a total of 124 spiders inhabiting quinoa plants were collected; they represented 8 families, 20 genera and 20 species. Juveniles comprised 16.94%; while adults average 83.06%. The sex ratio was 0.17 ♀: 1 ♂. Of the most abundant species, 2 ranked in the top, *Sengletus extricatus* (31 individuals) and *Wadicosa fidelis* (26 individuals). In the second season, a total of 275 spiders inhabiting quinoa plants were collected; they represented 10 families, 21 genera and 19 21 species. Juveniles comprised 44.72%; while adults average 55.27%. The sex ratio was 0.26 ♀: 1 ♂. Of the most abundant species, 2 ranked in the top, *Wadicosa fidelis* (26 individuals) and *Pardosa* sp. (34 individuals). The same results were obtained by Kacar (2015) who found that 45 different spider species were recorded, from the 244 spider individuals from 172 sampling areas Adult/juvenile rate observed was 42%, and male/female rate was 48%, with most juveniles being female.

Table 1: Species richness of the collected spiders inhabiting quinoa plants, first year from November 2016 - April 2017 and second year from November 2017 - April 2018.

Families &taxa names	1st year						2nd year					
	♂	♀	j	Σ	Total	%	♂	♀	j	Σ	Total	%
Lycosidae												
Wadicosa fidelis	8	6+4▲	12	26	44	34.92	9	14+1▲	116	139	177	64.36
Pardosa sp.	10	1	2	13			34			34		
Hogna ferox	2		3	5			4			4		
Gnaphosidae												
Micaria dives	2	1		3	6	4.76	2			2	15	5.45
Zelotes sp.	1			1			5	1		6		
Unidentified species	2			2			4	2	1	7		
Linyphidae												
Sengletus extricatus	29	2		31	50	39.68					53	19.27
Mermessus denticulatus	6	2		8			11	1	1	13		
Prinerigone vagans	8	2		10			2		1	3		
Erigone sp.	1			1								
Unidentified species							26	8	3	37		
Philodromidae												
Thanatus albini	4			4	4	3.17	2	1		3	4	1.45
Pulchellodromus glaucinus								1		1		
Salticidae												
Thyene imperialis	1	1		2	5	3.97					4	1.45
Heliophanus sp.							1			1		
Phlegra flavipes							1			1		
Unidentified species	3			3			2			2		
Theridiidae												
Kochiura aulica	1			1	8	6.35	5	2		7	16	5.82
Enoplognatha gemina	2			2			8			8		
Euryopis sp.	2			2								
Steatoda ertgonitormis	1			1								
Unidentified species	2			2			1			1		
Dysderidae												
Dysdera crocata	1			1	1	0.08						
Thomisidae												
Thomisus spinifer							1			1	1	0.36
Oecobiidae												
Oecobius sp.							1			1	1	0.36
Dictynidae	2		4	6	6	4.76	2	1		3	3	1.09
Pholcidae									1	1	1	0.36
Total	88	15	21	124			121	31	123	257		
	124+4▲						275+1▲					

▲: Egg sac

Frequency and Abundance Values:

Table (2) shows the frequency and abundance values of the most abundant spiders. Family Lycosidae was considered "Constant" in the 2nd season according to Weis Fog system which occupied 64.36% of the collected spiders. Members of this family: *Wadicosa fidelis* was the most common member recorded Eudominant according to Weigmann classification of dominance.

The present results agree with that of Shuang-lin and Bo-ping (2006) indicated that Lycosidae was dominant family and occupied more than 60 % of individual community.

Also, Rizk *et al.* (2012) indicated that members of Lycosidae were represented by three most

common species, *Wadicosa fidelis*, *Pardosa injucanda* and *Pardosa* sp. and all their developmental structures were collected by pitfall traps below the four examined plants (the spearmint, castor bean, roselle and red pepper).

Family Richness and Generic Diversity:

Out of the 193 genera recorded in Egypt (El-Hennawy, 2006), 23 genera were recorded in this study (Table 2). Families Linyphiidae and Theridiidae were the dominant family in this biome with maximum generic diversity 4 genera, followed by Lycosidae (3), Salticidae (3) and Gnaphosidae (2) genera, while families Dysderidae, Thomisidae and Oecobiidae were represented by only one genus.

Table 2: The dominance-frequency relationship of spider communities associated with quinoa plants, first year from November 2016 - April 2017 and second year from November 2017 - April 2018.

Families &taxa names	1st year					2nd year				
	No.	sp.%	Dom.	F.%	Freq.	No.	sp.%	Dom.	F.%	Freq.
Lycosidae										
Wadicosa fidelis	26	20.63	D	**34.92**	ac	139	50.55	E	**64.36**	C
Pardosa sp.	13	10.32	D			34	12.36	D		
Hogna ferax	5	3.97	R			4	1.45	R		
Gnaphosidae										
Micaria dives	3	2.38	R	**4.76**	ac	2	0.73	Sr	**5.45**	A
Zelotes sp.	1	0.79	Sr			6	2.18	R		
Unidentified species	2	1.59	R			7	2.55	R		
Linyphidae										
Sengletus extricatus	31	24.60	D	**39.68**	ac				**19.27**	A
Mermessus denticulatus	8	6.35	sd			13	4.73	R		
Prinerigone vagans	10	7.94	sd			3	1.09	R		
Erigone sp.	1	0.79	Sr							
Unidentified species						37	13.45	D		
Philodromidae										
Thanatus albini	4	3.17	R	**3.17**	A	3	1.09	R	**1.45**	A
Pulchellodromus glaucinus						1	0.36	Sr		
Salticidae										
Thyene imperialis	2	1.59	R	**3.97**	A				**1.45**	A
Heliophanus sp.						1	0.36	Sr		
Phlegra flavipes						1	0.36	Sr		
Unidentified species	3	2.38	R			2	0.73	Sr		
Theridiidae										
Kochiura aulica	1	0.79	Sr	**6.35**	A	7	2.55	R	**5.82**	A
Enoplognatha gemina	2	1.59	R			8	2.91	R		
Euryopis sp.	2	1.59	R							
Steatoda erigoniformis	1	0.79	Sr							
Unidentified species	2	1.59	R			1	0.36	Sr		
Dysderidae				**0.79**	A					
Dysdera crocata	1	0.79	Sr							
Thomisidae									**0.36**	A
Thomisus spinifer						1	0.36	Sr		
Oecobiidae									**0.36**	A
Oecobius sp.						1	0.36	Sr		
Dictynidae	6	4.76	R	**4.76**	A	3	1.09	R	**1.09**	A
Pholcidae						1	0.36	Sr	**0.36**	
Total	**124**					**275**				

Frequency (abundance), by Weis Fog
> 50 % = Constant (C)
25 - 50 % = Accessory (ac)
> 25 % = Accidental (A)

Dominance, by Weigmann
> 30 % = Eudominant (E) 1 - 5 % Recedent (R)
10 - 30 % = Dominant (D) > 1 % = Subrecedent (Sr)
5 - 10 % = Subdominant (sd)

Species Richness:

From table (2), among the 23 species of spider recorded during this study, 20 species of 8 families were recorded in 1st season and 21 species of 10 families in 2nd season. All families except Dysderidae, Thomisidae and Oecobiidae were noted inhabiting quinoa field in both seasons. A total of 10 species had common occurrence in both season. In first season, the dominant species were *Sengletus extrricatus* (31 indv.), *Wadicosa fidelis* (26 indv.), and *Pardosa* sp. (13 indv.), while in the second season they were *Wadicosa fidelis* (139 indv.) and *Pardosa* sp. (34 indv.).

Spider Guild Composition (Functional groups):

The collected spiders can be divided into seven functional guilds (Table 3) based on their foraging behavior in the field as described by Uetz *et al.* (1999).

Table 3: Guild classification of spider taxa associated with quinoa plants

	Families and foraging guild	1st year				2nd year				Common species	Total species
		species richness	Number of species	Unique species	%	species richness	Number of species	Unique species	%		
Hunting Spider	**1- Stalkers**				1.25				1.00		
	Salticidae	5	1	1		4	2	2		0	3
	2- Ground running										
	Lycosidae	44	3	-	12.78	177	3	-	48.12	3	3
	Dysderidae	1	1	1			-	-		0	1
	Gnaphosidae	6	2	-		15	2	-		2	2
	3- Ambushers										
	Philodromidae	4	1	-	1.00	4	2	1	1.25	1	2
	Thomisidae	-	-	-		1	1	1		0	1
Web building (Aerial Web)	**4- Space weavers**										
	Theridiidae	8	4	2	3.51	16	2	-	4.76	2	4
	Dictynidae	6	1	-		3	1	-		1	1
	5- Wandering sheet				12.53				13.28		
	Liyphiidae	50	4	2		53	2	-		2	4
	6- Sensing web				0				0.25		
	Oecobiidae	-	-	-		1	1	1		0	1
	7- Space web				0				0.25		
	Pholcidae	-	-	-		1	1	1		0	1
Total		124	17	6		275	17	6		11	23

Hunting Spiders:

- Stalkers: Salticidae.
- Ground runners: Lycosidae, Dysderidae and Gnaphosidae.
- Ambushers: Philodromidae and Thomisidae.

Web Building Spiders (aerial web):

- Space weavers: Theridiidae and Dictynidae.
- Wandering: Linyphiidae.
- Sensing web: Oecobiidae.
- Space web: Pholcidae.

In the first season, Wandering sheet and ground running represented 12.53% and 12.78 % of the total spiders. Also, in the second season, wandering sheet and ground running represented 13.28% and 48.12% of the total spiders and had the highest species richness.

This is in accordance with Cardoso *et al.* (2001) who suggested that eight guilds were discriminated: (1) sensing, (2) sheet, (3) space, and (4) orb web weavers; (5) specialists; (6) ambush, (7) ground, and (8) other hunters. These results agree with those of Memah *et al.* (2014) who mentioned that the seven spider guilds were orb-weavers, ground runners, space web builders, stalkers, wandering sheet weavers, foliage runners, and ambushers. Moreover,

all habitats were dominated by the orb-weavers, then by the ground runners, and the space web builders. In the kidney bean plants the orb-weaver reached 43% of the samples collected: tomato 42%, maize 40%, and shallot 37%.

Faunal Similarity of Spiders:

Species richness of spiders collected from quinoa plants in second season (275 individuals) was greater than that of first season (124 individuals), Also the number of spider species in 2nd season (21 species) greater than that of 1st season (20 species). Among 22 genera obtained, 6 genera were associated with quinoa in 1st season and 7 genera in 2nd season, while 14 species were recorded in two seasons. To allow a comparison between the habitats of the two seasons, Sørensen's quotient of similarity (QS) was calculated. It is concluded that the two seasons are semi-similar as they recorded 68.29% of similarity.

Monthly Fluctuation of Spiders Populations:

Total monthly counts of spiders collected from quinoa plants occurred in high abundance in March in the 2nd season (62 indv. in 1st season 1 and 152 indv. in 2nd season), while the lowest numbers (0 and 3 indv.) were recorded in December (Fig 1). Similar results were reported by Bogya and Markò (2008) who found that population of spiders were peak in spring.

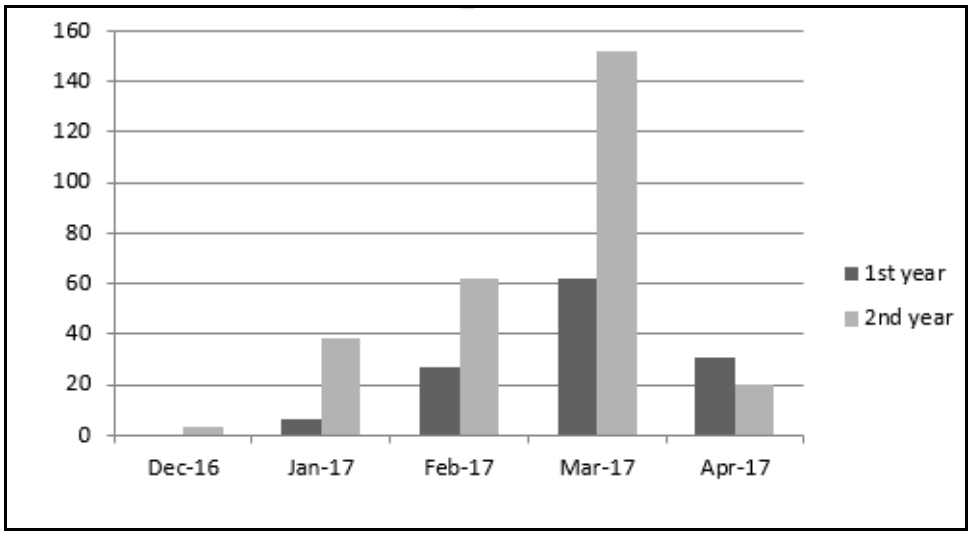

Fig. (1) Total numbers of spiders collected monthly from quinoa plants in two successive seasons

Rank Abundance of Spider Families:

The collected spider was presented by families in Table (4) to show their abundance. Four families contained 92.5% of the total collected spiders i.e. Lycosidae, Linyphiidae, Theridiidae and Gnaphosidae. The greatest number of collected individuals presented by family Lycosidae (221), Linyphiidae (103), Theridiidae (24) and Gnaphosidae (21). Families Salticidae (9) and Dictynidae (9) were ranked the fifth while family Philodromidae (8) ranked the sixth.

The present results agree with that of Alford (2003) who indicated that a wide range of species can occur in arable fields, of which wolf spiders (Lycosidae) and money spiders (Linyphiidae) are the most abundant ones. Also, Memah *et al.* (2014) found that the most abundance spiders in each habitat type were: tomato with Lycosidae (54 individuals), Araneidae (51), and Theridiidae (29); kidney bean with Lycosidae (58), Mitidae (44), and Araneidae (30); maize with Lycosidae (49), Araneidae (28), and Mitidae (16); and shallot with Lycosidae (36), Araneidae (18), and Mitidae (15). Lycosidae was with the most abundance in kidney bean than in other habitat types, and was also the most dominant in each habitat type.

The biodiversity of spiders inhabiting quinoa plants in the two seasons is compared using Shannon-Wiener "H" and Simpson "S" indices of the diversity (Table 5). The cover plantation of quinoa plants varied in their species richness and recorded the highest population of total number (275 individuals) in 2nd season larger than those obtained in 1st season. Its ecosystem was made of 10 families, 21 genera and 21 species; while the species richness of quinoa plants in 1st season were 124 individuals belonged to 8 families, 20 genera and at least 20 species.

Table 4: Rank abundance of spider families inhabiting quinoa plants.

Families	1st year	2nd year	Total	%
Lycosidae	44	177	221	55.39
Gnaphosidae	6	15	21	5.26
Linyphiidae	50	53	103	25.81
Philodromidae	4	4	8	2.01
Salticidae	5	4	9	2.26
Theridiidae	8	16	24	6.02
Dysderidae	1	0	1	0.25
Thomisidae	0	1	1	0.25
Oecobiidae	0	1	1	0.25
Dictynidae	6	3	9	2.26
Pholcidae	0	1	1	0.25
	124	275	399	

Table 5: Comparison of structure of collected spiders from quinoa plants in two seasons

	First Season Year	Second Year
Shannon-Wiener Index	2.36	1.81
Simpson Index	0.13	0.29
Species Evenness	4.48	2.89

Species Diversity:

Using Shannon-Wiener Index, the biodiversity index calculation indicated that 2nd year was the most divers. The species richness of spider of different families and their equitability (evenness) were higher in 1st season than that of 2nd season (Table 5). According to Simpson index which is a measure of dominance (responsive to changes for the most dominant species), it was found that 2nd season included the highest number of dominant species.

This is in accordance with Kacar (2015) who showed that the Shannon-Wiener diversity index of spider species were generally well distributed among the all samples (H=3.35).Also, Štokmane & Spuņģis (2016) found that the mean Shannon index for vascular plants was 1.44 (± 0.05) and it ranged from 0.49 to 2.10, while the mean evenness was 0.62 (± 0.02) and ranged from 0.23 to 0.85.Also, Tilman *et al.* (2001) and Petchey and Gaston (2006) proved that guild structure implies its quantification. Functional diversity is one of the most important parameters used to explain how ecosystems work and adapt to change.

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