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The Relationship Between Vegetation Type and Population Density-Diversity of Spiders in Certain Vegetable Crops

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Abstract: The experiment was carried out on three different vegetable crops, Cucumber *Cucumis sativus* L. (Cucurbitaceae), eggplant *Solanum melongena* L. (Solanaceae) and okra Abelmoschus *esculentus* L. (Malvaceae), during summer 2021, to investigate the effect of vegetation type on spider density and diversity. For this study, the pitfall trap method was used to collect spiders from the soil surface to ensure a comprehensive representation of all spider guilds. During this study, 20 species belonging to 6 families were collected. The results showed that a total of 374, 285 and 194 individuals belonging to 18, 17 and 15 species were recorded in okra, cucumber and eggplant fields respectively. Species diversity was greater in okra cultivation. Results also indicated that the Lycosidae family was the most abundant and dominant, representing 71.75%, followed by the Linyphiidae family of 90 individuals representing 10.55% of the whole obtained population. The most dominant species were *Wadicosa fidelis* 152, 98 and 67 individuals and *Pardosa injucunda* 111, 69 and 52 individuals in okra, cucumber and eggplant respectively. It is inferred from this study that the type of plant can have an impact on spider communities.

1 Introduction

Spiders are cosmopolitan natural enemies of the agro-ecosystem. Moreover, they are among the most abundant predatory arthropods, so they are highly affected by plant composition, including terrestrial species (Lafage et al 2019). They have great potential as good bioindicators (Pearce and Venier 2006).

Spiders are well-known taxonomically in comparison with other invertebrate groups and can be identified without costly tools or apparatus (Oxbrough et al 2005, Cardoso 2009). Also, spiders are considered useful indicators for the comprehensive diversity of invertebrates because they seem to be related to herbivorous food webs (Wise 1995, Willett 2001).

Spiders are considerably more abundant, diverse, and functionally important among all terrestrial invertebrates (Mammola et al 2017). Furthermore, they are prevalent in various habitats, as well as being crucial to conserving biodiversity (Michalko et al 2019, Milano et al 2021).

Plant compositions influence microclimates and, as a result, invertebrate communities (Lia et al 2022). Spider populations are heavily impacted by alterations in plant structure, ecosystem dynamics, soil, moisture and temperature (Bonte et al 2002, Marfil et al 2016, Rodriguez-Artigas et al 2016).

Therefore, the purpose of this work is to investigate the spider density and diversity in certain vegetable crops, and the effect of vegetation type on spider abundance and dominance.

2 Materials and Methods

2.1 Experiment design

This experiment was carried out on three vegetable crops; cucumber, *Cucumis sativus* L. (Cucurbitaceae); okra, *Abelmoschus esculentus* L. (Malvaceae); eggplant, *Solanum melongena* L. (Solanaceae) at Fayoum Governorate, Egypt during Summer season from March to June 2021. The study area comprises ¼ feddan split into 3 plots ($350m^2$ /crop), using a Randomized Complete Block Design. All normal agricultural practices were conducted throughout the study, and no pesticides were used.

2.2 Method of spider collection

The pitfall traps method was used to collect spiders as defined via way of means of Slingsby and Cook (1986). Traps consisted of plastic cups that were 10 cm deep and 7 cm in diameter. Ten traps for each crop were handed out and filled with water and a very tiny amount of detergent to lessen the water surface tension. The traps are placed where the surface of the cup is at ground level. Sampling was undertaken weekly and lasted for 24 hours. The obtained spiders were preserved in small labeled flasks containing 70% ethyl alcohol and a very small drop of glycerin for identification.

2.3 Spider identification

Individuals were identified at the species level according to Levi (2002), El-Hennawy (2006) and Platnick (2012).

2.4 Data analysis

2.4.1 Dominance and frequency

As Weis Fogh (1948) classification, the frequency of spiders was divided into three categories; families representing >50% considered 'constant', 25-50% considered 'accessory', and <25% considered 'accidental'.

The dominance values were determined as follows: succedent (<1%), resident (1−5%), subdominant (>5−10%), dominant (>10−30%), eudominant (>30%).

2.4.2 Guild composition

Collected spiders during this study were classified into guilds according to Uetz et al (1999). Classification of spider guilds was based on ecological characteristics known relating to the foraging manner, web type and microhabitat use for the family or for major species representing each family (Nyffeler and Benz 1987, Young and Edwards 1990, Nyffeler et al 1992, Uetz et al 1999).

2.4.3 Species diversity, dominance and similarity

The diversity of species was calculated using the Shannon-Wiener index, $H' = -\Sigma (Ni/N) \ln (Ni/N)$ (the formula used by Shannon and Wiener 1964). Species dominance was calculated using the Simpson index (Somerfield et al 2008)

$D = \Sigma (Ni/N) 2$ whereas Ni= the individuals of a species N= the individuals of all species.

Species similarity was determined using Sørensen's index of similarity (Sørensen 1948), $S = 2n_t /n_x + n_y$ where n_t is the shared species in two samples x and y.

3 Results and Discussion

3.1 Spider activity

Table 1 and **Fig 1** show the population fluctuation of spiders collected by pitfall traps in cucumber, okra and eggplant fields during the summer 2021 season. A population of spiders was observed at the beginning of the season with few numbers (4, 2 & 3 individuals) on the 9th of March. Then the population gradually increased with fluctuating numbers to reach (31, 34 & 15 individuals) on the 18th of May.

The population peak was recorded on the 1st of June in cucumber (46 individuals) and okra (57 individuals), while eggplant was recorded (23 individuals).

The number of all spiders collected throughout this study reached (285, 374 & 194 individuals) for cucumber, okra and eggplant respectively. The population of spiders reached the highest number in June, with a monthly average (36.3, 49.0 and 31.3 individuals respectively). El-Gepaly et al (2018) affirmed that the spider population in weeds reached its peak in June 2021.

Table 1. Population fluctuation of spiders collected by pitfall traps in cucumber, okra and eggplant fields during 2021 season

Sampling date	Crop					
	Cucumber	**Average/ month**	**Okra**	**Average/ month**	**Eggplant**	**Average/ month**
09/03/2021	4	8.25	2	5.25	3	4.75
16/03/2021	4		4		2	
23/03/2021	10		8		5	
30/03/2021	5		7		9	
06/04/2021	6	12.5	16	19.5	8	7.00
13/04/2021	4		16		6	
20/04/2021	25		27		9	
27/04/2021	15		19		5	
04/05/2021	21	25.75	28	32.00	16	13.25
11/05/2021	17		26		10	
18/05/2021	31		34		15	
25/05/2021	34		40		12	
01/06/2021	46	36.33	57	49.00	23	31.33
08/06/2021	28		49		32	
15/06/2021	35		41		39	
Total	**285**		**374**		**194**	

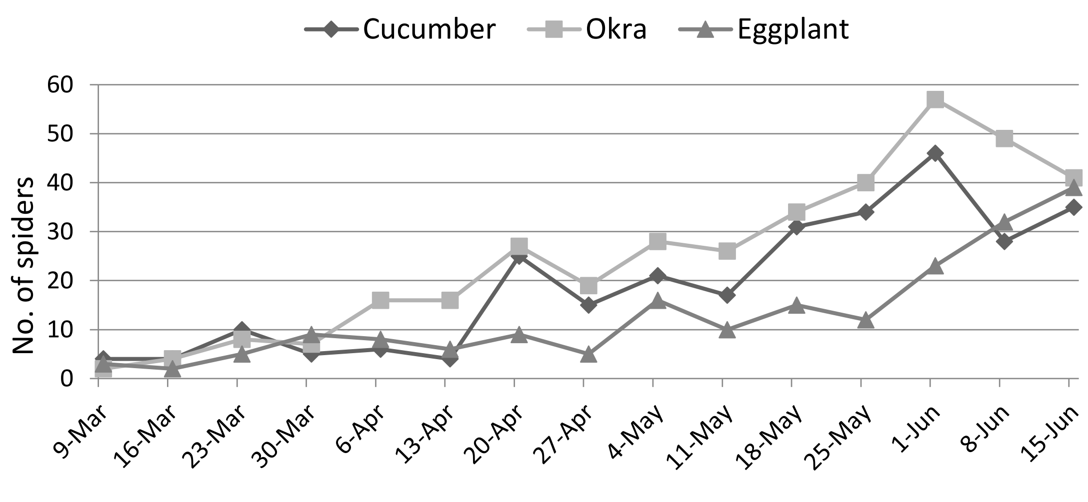

Fig 1. Population fluctution of spiders collected by pitfall traps in cucumber, okra and eggplant fields during 2021 season

Table 2. Spiders collected from cucumber, eggplant and okra fields during 2021 season

Family	Species
Gnaphosidae Pocock, 1898	*Drassodes lutescens* (C. L. Koch, 1839)
	Micaria dives (Lucas, 1846)
	Trachyzelotes jaxartensis (Kroneberg, 1875)
	Zelotes laetus (O.P.-Cambridge, 1872)
Linyphidae Blackwall, 1859	*Erigone dentipalpis* (Wider, 1834)
	Mermessus denticulatus (Banks, 1898)
	Prinerigone vagans (Savigny, 1825)
	Sengletus extricatus (O. Pickard-Cambridge, 1876)
Lycosidae Sundevall, 1833	*Hogna ferox* (Lucas, 1838)
	Pardosa injucunda (O.Pickard-Cambridge, 1876)
	Trochosa urbana O.Pickard-Cambridge, 1876
	Wadicosa fidelis (O.Pickard-Cambridge, 1872)
Philodromidae Thorell, 1870	*Philodromus cinereus* O.Pickard-Cambridge, 1876
	Thanatus albini (Audouin, 1825)
Salticidae Blackwall, 1841	*Ballus piger* O.Pickard-Cambridge, 1876
	Phlegra flavipes Denis, 1947
	Salticus mendicus O.Pickard-Cambridge, 1876
Theridiidae Sundevall, 1833	*Kochiura aulica* (C.L. Koch, 1838)
	Steatoda erigoniformis (O.Pickard-Cambridge, 1872)
	Theridion melanostictum O.Pickard-Cambridge, 1876

3.2 Spider richness and restriction

Table 2 shows that a total of 285, 374 and 194 individuals belonging to 6 families and 17, 18 and 15 species, were recorded in cucumber, okra and eggplant fields respectively.

Lycosidae was the highest dominant and abundant family with (192, 290 & 130 individuals respectively), and the most abundant species was *Wadicosa fidelis* (98, 152 & 67 individuals respectively) followed by *Pardosa injucunda* (69, 111 & 52 individuals respectively) in cucumber, okra and eggplant respectively (**Table 3**). Štokmane and Spuņģis (2016) referred to that many studies proved that lycosids, collected by the pitfall trap method, nearly continually dominate (Kowal and Cartar 2012). Males comprised (80.4, 80.7 & 79.9% respectively), while females represented (11.9, 12.0 & 13.4% respectively) and juveniles recorded (7.7, 7.2 & 6.7% respectively) of the total number. The sex ratio reached (6.74♂:1♀, 6.71♂:1♀ & 5.96♂:1♀ respectively) in cucumber, okra and eggplant, respectively.

3.3 Dominance and frequency

As shown in **Table 4** family Lycosidae was the most dominant and considered constant 'C' with values (67.37, 77.54 & 67.01% respectively). Zaki and Ali (2019) investigated that the family Lycosidae comprised 70% of the whole spiders collected by pitfall traps from onion field. Moreover, this result is consistent with that found by Weeks and Holtzer (2000) who found that lycosid spiders represented 56% of the whole number of spiders.

The most dominant species were *Wadicosa fidelis* and considered eudominant 'E' with values (34.4, 40.6 & 34.5 % respectively) followed by *Pardosa injucunda* and considered dominant 'D' (24.2, 29.7 & 26.8% respectively) of the total number of spiders in cucumber, okra and eggplant respectively. Likewise, Rizk et al (2015) indicated that *W. fideles* and *Pardosa* spp. were the most dominant spider species in some medicinal plants. Structure complication of vegetation leads to an increased food diversity of spiders, hence promoting rapid population growth, and that leads to rising spider densities.

3.4 Guild composition

Effects of plant habitat, vegetation structure diversity and micro-environment are considered the prevalent explanation for spider guild patterns (Halaj et al 1998) besides, habitat structure maintains diverse spider assemblage. In addition, structurally simple crops may not help to develop an abundant and species-rich spider fauna. The hunting species were exceedingly active in widely opened vegetation habitats (Haddad et al 2009).

Table 3. The richness of spider species inhabiting cucumber, okra and eggplant fields during during 2021 season

	Cucumber					**Okra**					**Eggplant**				
Families and taxa names	♂	♀	***j***	**Σ**	**Total**	♂	♀	***j***	**Σ**	**Total**	♂	♀	***j***	**Σ**	**Total**
Gnaphosidae															
Drassodes lutescens	2			2		4			4		2			2	
Micaria dives	5			5	21					13	3			3	13
Trachyzelotes jaxartensis	2		1	3		2			2						
Zelotes laetus	9	1	1	11		7			7		5	1	2	8	
Linyphidae															
Erigone dentipalpis						4			4		3			3	
Mermessus denticulatus	16	2		18	38	12		1	13	30	10			10	22
Prinerigone vagans	2			2		7			7						
Sengletus extricatus	15	3		18		6			6		8	1		9	
Lycosidae															
Hogna ferox	14	2	5	21		19	3	5	27		8		1	9	
Pardosa injucunda	58	8	3	69	192	89	15	7	111	290	47	3	2	52	130
Trochosa urbana	4			4							2			2	
Wadicosa fidelis	74	16	8	98		114	25	13	152		39	21	7	67	
Philodromidae															
Philodromus cinereus	3			3	14	2			2	8					10
Thanatus albini	7	1	3	11		5		1	6		9		1	10	
Salticidae															
Ballus piger	1			1	5	3			3	10	2			2	5
Phlegra flavipes	4			4		2			2		3			3	
Salticus mendicus						5			5						
Theridiidae															
Kochiura aulica	4		1	5	15	2			2	23					14
Steatoda erigoniformis	9	1		10		15	2		17		12			12	
Theridion melanostictum						4			4		2			2	
Total	229	34	22	**285**		302	45	27	**374**		155	26	13	**194**	

Obtained spiders were divided into guild groups; stalkers, ground running, ambushers, space weavers and wandering spiders. Memah et al (2014) mentioned that spiders were classified into seven spider guilds namely: ground runners, wandering sheet eavers, stalkers, ambushers, foliage runners, orb-weavers and space web builders. As well, Tsai et al (2006) reported that spider families were grouped into five guilds: (1) orb-weaver, (2) space weaver, (3) ground weaver, (4) foliage runner, (5) ground runner.

In this study, despite species richness in the okra habitat being more than in cucumber and eggplant, ambushers and wandering sheet spiders were fewer than in cucumber and eggplant habitats. **Table 5** revealed that the highest species richness was ground running (Lycosidae and Gnaphosidae) representing (74.7, 81.0 & 73.7 %), followed by a wandering sheet (Linyphiidae) with less value (13.3, 8.0 & 11.3 %) of the total spiders in cucumber, okra and eggplant respectively. Lia et al (2022) defined spiders into five main guilds namely: ground runners, ground weavers, foliage runners, orb-weavers and space weavers. Moreover, they indicated that ground runner spiders were the most dominant in a corn field, and the major family was Lycosidae.

3.5 Species diversity and similarity

Results in **Table 6** showed the biodiversity of collected spiders of different vegetable crops (cucumber, okra and eggplant) using Shannon-Wiener and Simpson indices of diversity. Spiders collected from okra

Table 4. Percentage and dominance of spider species inhabiting cucumber, okra and eggplant fields

Families and taxa names	Cucumber					Okra					Eggplant				
	No.	Sp.%	Dom.	F.%	Freq.	No.	Sp.%	Dom.	F.%	Freq.	No.	Sp.%	Dom.	F.%	Freq.
Gnaphosidae				7.37	**A**				3.48	**A**				6.7	**A**
Drassodes lutescens	2	0.7	**Sr**			4	1.07	**R**			2	1.03	**R**		
Micaria dives	5	1.75	**R**								3	1.55	**R**		
Trachyzelotes jaxartensis	3	1.05	**R**			2	0.53	**Sr**							
Zelotes latus	11	4.71	**R**			7	1.87	**R**			8	4.12	**R**		
Linyphidae				13.33	**A**				8.02	**A**				11.34	**A**
Erigone dentipalpis						4	1.07	**R**			3	1.55	**R**		
Mermessus denticulatus	18	6.32	**Sd**			13	3.48	**R**			10	5.15	**Sd**		
Prinerigone vagans	2	0.7	**Sr**			7	1.87	**R**							
Sengletus extricatus	18	6.32	**Sd**			6	1.64	**R**			9	4.64	**R**		
Lycosidae				67.37	**C**				77.54	**C**				67.01	**C**
Hogna ferox	21	7.37	**Sd**			27	7.22	**Sd**			9	4.64	**R**		
Pardosa injucunda	69	24.21	**D**			111	29.68	**D**			52	26.8	**D**		
Trochosa urbana	4	1.4	**R**								2	1.03	**R**		
Wadicosa fidelis	98	34.39	**E**			152	40.64	**E**			67	34.54	**E**		
Philodromidae				4.91	**A**				2.14	**A**				5.15	**A**
Philodromus cinereus	3	1.05	**R**			2	0.53	**Sr**							
Thanatus albini	11	4.71	**R**			6	1.64	**R**			10	5.15	**Sd**		
Salticidae				1.75	**A**				2.67	**A**				2.58	**A**
Ballus piger	1	0.35	**Sr**			3	0.8	**Sr**			2	1.03	**R**		
Phlegra flavipes	4	1.4	**R**			2	0.53	**Sr**			3	1.55	**R**		
Salticus mendicus						5	1.34	**R**							
Theridiidae				5.26	**A**				6.15	**A**				7.22	A
Kochiura aulica	5	1.75	**R**			2	0.53	**Sr**							
Steatoda erigoniformis	10	3.51	**R**			17	4.55	**R**			12	6.19	**Sd**		
Theridion melanostictum						4	1.07	**R**			2	1.03	**R**		
Total	**285**					**374**					**194**				

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)

No.: Number of spiders
Sp.: Species
Dom.: Dominance
F.: Family
Freq.: Frequency

Table 5. Guild classification of spider species inhabiting cucumber, okra and eggplant fields

	Families and foraging guild	Cucumber				Okra				Eggplant				Common species	Total species
		Species richness	Number of species	Unique species	%	Species richness	Number of species	Unique species	%	Species richness	Number of species	Unique species	%		
Hunting Spider	**Stalkers**				1.75				2.67				2.58		
	Salticidae	5	2	0		10	3	1		5	2	0		2	3
	Ground running				74.74				81.02				73.71		
	Lycosidae	192	4	1		290	3	0		130	4	1		3	4
	Gnaphosidae	21	4	1		13	3	0		13	3	0		2	4
	Ambushers				4.91				2.14				5.15		
	Philodromidae	14	2	1		8	2	1		10	1	0		1	2
Web building	**Space weavers**				5.26				6.15				7.22		
	Theridiidae	15	2	0		23	3	1		14	2	0		1	3
	Wandering sheet				13.33				8.02				11.34		
	Liyphiidae	38	3	0		30	4	1		22	3	0		2	4
Total		285	17	3		374	18	4		194	15	1		11	20

Table 6. Comparison of diversity and dominance of collected spider species from cucumber, okra, and eggplant fields

	Cucumber	Okra	Eggplant
Shannon-Wiener Index	2.24	2.25	1.98
Simpson Index	0.23	0.26	0.21

(374 individuals) were larger than the number collected from cucumber and eggplant (285 and 194 individuals) respectively. So, a higher number of species inhabited okra field (18 species) more than cucumber (17 species) and eggplant (15 species).

The similarity index between cucumber and okra recorded the highest value as habitats of spider species with a value (86%), while the lowest value of similarity was recorded between okra and eggplant (79%).

This boosts the findings of many other studies which indicated that the vegetation type has a major effect on the spider communities. (Uetz 1999, Buchholz 2010, Torma et al 2014). This is also consistent with Geldenhuys et al (2021) pointed out that other vegetation variables, such as plant growth, plant density and plant waste have positively affected many of the biodiversity responses. Many studies (Galle and Schweger 2014, Rodriguez-Artigas et al 2016) have indicated that spider communities can be influenced by several biological and environmental factors. On the other hand, Lia et al (2022) indicated that vegetation structure has a significant effect on spider assemblage in intricate habitats, with the potential conservation of a higher abundance of spiders.

4 Conclusion

The objective of this study is to clarify whether spider assemblages are affected by different vegetation. Our results showed that the okra field harbored several spiders greater than that found in cucumber and eggplant fields, also spider species were more diverse and abundant in okra. Although the studied crops were grown in the same season, and the same normal agricultural practices were applied, nevertheless, there was a variation in the population density of spiders. This can be attributed to some other factors, such as the nature of the growth and the height of the plant, and the relationship of this to change the microclimate in the plant environment, as well as the structure of the roots and its exudates, which may affect microorganisms and invertebrates in the soil. As a result, the nutrition, activity and density of spiders can be affected by changing these factors.

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