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Presence of spiders in strata of lemon trees (*Citrus limon*), Montevideo, Uruguay

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ABSTRACT

Spiders present a variety of foraging strategies and prey preference, the presence of them in agroecosystems represents a dominant component among predators. Citrus fruits are significantly profitable crops and are among the most widely produced fruits and popular in the world, being in Uruguay main export fruit. Traditional pest control is performed using pesticides, causing a negative impact on spiders. The objective was to determine the distribution of the spider community in lemon crops (*Citrus limon*) at vertical strata and soil, comparing their abundance, richness and diversity of species, between a conventional crop (CC) *vs.* abandoned crop (AC). Spiders were collected manually in four vertical strata on lemon tree, stratum-0 was by pitfall traps. 1900 spiders (63% in CA and 37% in CC) at the vertical strata were collected, 84 species sharing. The stratum-0 was the most abundant (4866 ind.). The spiders at the strata level showed greater abundance, species richness and diversity, in stratum-0, stratum-3 and stratum-4, being distributed according to the structures and physiognomy of lemon tree. Only five species were present in all strata including stratum-0: *Metaltella* sp.1 (Amphinectidae), *Aysha* sp.1 (Anyphaenidae), *Parawixia* sp.1, *Araneus lathyrinus* (Araneidae), *Achaearanea hirta* (Theridiidae). The analysis of the results shows how the spider community is distributed in the different strata of the lemon tree, taking advantage of the structural physiognomy of the plant. Also demonstrating, how agricultural management practices can influence the spider community.

Keywords: Lemon Crops, Agroecosystems, Natural Enemies Native.

INTRODUCTION

Spiders (Arachnida, Araneae) are generalist predatory arthropods, present a variety of foraging strategies and prey preference (AGUILAR 1977; WISE 1993; NENTWIG 1988; RINALDI 1998; BENAMÚ 1999; BENAMÚ & AGUILAR 2001; BENAMÚ *et al.* 2017a, BENAMÚ 2020). According to Sunderland (1999), the presence of spiders in agroecosystems represents a dominant component among predators over the community of herbivorous and detritivore arthropod species; interacting and complementing with other natural enemies. However the number of spiders is reduced in the crops, for agricultural management, agrochemical use, spatial distribution of crops, reduction and fragmentation of habitats, among others (YOUNG,EDWARS 1990; NYFFELER *et al.* 1994; ÖBERG *et al.* 2007), including decreasing diversity.

According to RYPSTRA *et al.* (1999), the diversity and density of the spider community is associated with the structural complexity of the environment, associated plants with different physiognomy, would offer different structures or microhabitats (VIERA *et al.* 1996; BENAMÚ, 2004), changing their appearance according to grow (BENAMÚ 2001), affecting the physical separation of predators and pests, changing the efficiency and relative preference of prey capture (SYMONDSON *et al.* 2002).

Citrus fruits are significantly profitable crops and are among the most widely produced and popular fruits in the world (DUGO & DI GIACOMO 2002; LIU *et al.* 2012). In Uruguay, the citrus are the main export fruit, lemon being the third most widely produced citrus fruit (DIEA 2020). These have a physiognomy that favors the formation of refuges and microhabitats that determine the diversity of spiders (RIECHERT & LOCKLEY 1984; BREENE *et al.* 1993). In these environments, spiders are capable of colonizing and selecting habitats, responding positively to greater structural complexity (RINALDI 1998). The objective of this study was to determine the distribution of the spider community in lemon crops (Citrus limon) at vertical strata and soil, comparing their abundance, richness and diversity of species, between a conventional crop vs. abandoned crop.

METHODOLOGY

Study area

Realized in a crop field lemon (Montevideo, Uruguay), with a total area of 35 ha, predominantly a conventional agricultural system with citrus trees 16 years old (34º51’53.6 “S, 56º16’51.2” W) and another 2 ha, characterized by the presence of abandoned lemon trees (34º51’52.8 ”S, 56º17’09.7” W), without management or exploitation for 5 years, with citrus trees 19 years old, separated from the rest of the crops (0.3 km) by a vegetal curtain of acacias (*Acacia longifolia*). The canopy radius of the lemon trees varied between 1.30 - 1.50 m. (Fig.1)

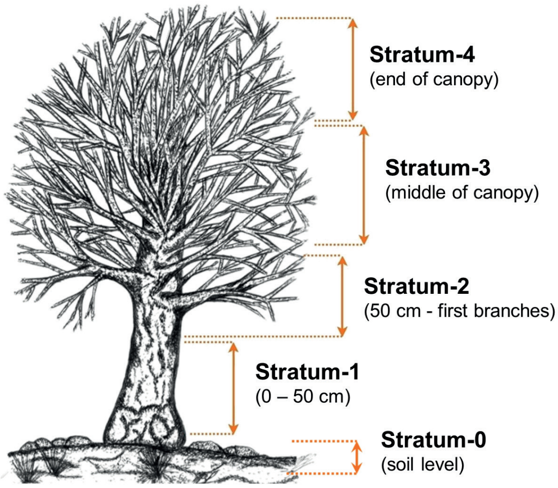
Figure 1. Location of the study area of lemon crops.

Source: Google Earth (2022).

Collection of spiders

The samplings were carried out from November 2001 to November 2002, in an area of 1.0 ha with 417 plants for each agricultural system: abandoned crop (AC) and conventional crop (CC). The collection of spiders was manual, 10 plants were taken at random for each agricultural system, with four replicas every 15 days; to capture spiders in the tree canopy, the foliage shaking technique using an entomological umbrella (70 x 60cm) and manual capture on tree trunk, considering the different strata of the plant: stratum-1 (0-50 cm up the tree trunk), stratum-2 (up 50 cm from the tree trunk to the first branches, buds or foliar terminals), stratum-3 (middle part of the canopy of the tree) and stratum-4 (from the middle of the canopy to the upper end) (Fig. 2. The collection with pitfall traps was considered as "stratum-0", it consisted of 500 ml plastic cups with a saturated saline solution + detergent, spaced 10 m apart, for a period of 15 days, placed at the base of the citrus tree, taking 10 plants at random with three replicates. All samples were fixed in 75° alcohol.

Figure 2. Representation of all the strata studied in lemon crop tree (*Citrus limon*) in Montevideo, Uruguay.



Source: Author.

The idea of using different collection methods was to register most of the spider community found in the lemon crop, on the soil, trunk and canopy. The taxonomic determination of spiders was carried out using the keys of DIPPENAAR-SCHOEMAN & JOCQUÉ (1997), UBICK *et al.* (2005) and BENAMÚ (2007). The specimens of each sample were deposited in the Collection of the Faculty of Sciences of the University of the Republic (Montevideo, Uruguay). For the classification at the guild spiders it took into consideration to UETZ *et al.* (1999), DIAS *et al.* (2010) and CARDOSO *et al.* (2011).

Statistical analysis

An estimate of the abundance and richness of species was made. The diversity of each stratum in both agricultural systems was determined by applying the Shannon-Wiener (H ‘) diversity index, based on the proportion of species abundance, of the Pielou uniformity index (J’), expressed by the relationship between observed diversity and maximum expected diversity (MAGURRAN 1988). To evaluate the existence of significant statistical differences in the strata with different agricultural systems, it was calculated through the Hutcheson *t* test (MAGURRAN 1988), using PAST 3.5 (ØYVIND 2019). The evaluation of the patterns in the composition of the araneofauna in the different strata of the lemon crop, the Bray Curtis similarity index (BioDiversity Pro 2.0; MCALEECE *et al.* 1997) was used.

RESULTS

Abundance and taxonomic composition

In the four vertical strata of lemon trees, a total of 1900 spiders were collected (63% in AC and 37% in CC), sharing 84 species in common. The stratum-1 of the AC was represented by 0.66% of the total of spiders and in CC 6.5%, in stratum-2 the AC presented 14.8% and in CC 12.7%; while for stratum-3 the AC it was 62.8% and for CC it was 51.5%, for stratum-4 the CA presented 21.8% and in CC 29.6%. The predominant families in the four strata for both lemon crops were Araneidae, Anyphaenidae, Amphinectidae, Clubionidae, Theridiidae and Thomisidae (Table 1). The stratum-0 represented by the pitfall traps reached a total of 4866 collected spiders (62% in AC and 38% in CC) at ground level, predominantly the families Corinnidae, Gnaphosidae, Hahniidae, Linyphiidae, Lycosidae, Tetragnathidae and Titanoecidae (Table 1). The family Actinopodidae (Mygalomorphae) was captured only in this stratum, mostly in the CC, registering only male individuals.

Male spiders predominated in stratum-0 of AC, while juveniles in stratum-3 of AC and CC, female spiders were mainly distributed in stratum-0 in both lemon crops. In the stratum-1 AC low activity compared spiders was observed at the other strata (Fig. 3).

Table 1. Composition of guilds, families and species of spiders distributed in vertical strata and soil, in the lemon crop (*Citrus limon*) in Montevideo, Uruguay.

AC: abandoned crop, CC: conventional crop.

Spiders Guilds	Families	Species	Stratum-0 Traps		Stratum-1 Manual		Stratum-2 Manual		Stratum-3 Manual		Stratum-4 Manual	
			AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)
Orb web weavers	Araneidae	*Araneus lathyrinus* (Holmberg, 1875)	0.10	0.16	0.17	0.29	8.07	5.44	38.52	33.38	14.39	21.49
	Araneidae	*Araneus* sp.1 Clerck, 1757						0.14		0.29		
	Araneidae	*Araneus* sp.2 Clerck, 1757				0.14						
	Araneidae	*Argiope* sp. Audouin, 1827		0.05								
	Araneidae	*Cyclosa* sp. Menge, 1866								0.14		
	Araneidae	*Micrathena Ucayali* (Levi, 1985)							0.25			
	Araneidae	*Parawixia audax* (Blackwall, 1863)	0.07	0.05		0.14	0.50	0.43	0.25	0.86		0.72
	Araneidae	*Parawixia* sp. Pickard-Cambridge, 1904	0.03									
	Araneidae	Morpho sp.1					0.08		0.08			0.14
	Araneidae	Morpho sp.2								0.14	0.08	
	Tetragnathidae	*Glenognatha lacteovittata* (Mello--Leitão, 1944)	9.68	9.04								
	Tetragnathidae	*Leucauge* sp. White, 1841					0.08					
	Pholcidae	*Physocyclus* sp. Simon, 1893	0.03	0.05								
	Scytodidae	*Scytodes thoracica* (Latreille, 1802)		0.11		0.29						
	Theridiidae	*Achaearanea hirta* (Taczanowski, 1873)	0.20	0.21		0.29		1.15	0.33	2.15	0.25	
	Theridiidae	*Achaearanea* sp.1 Strand, 1929					0.67		2.50		0.75	

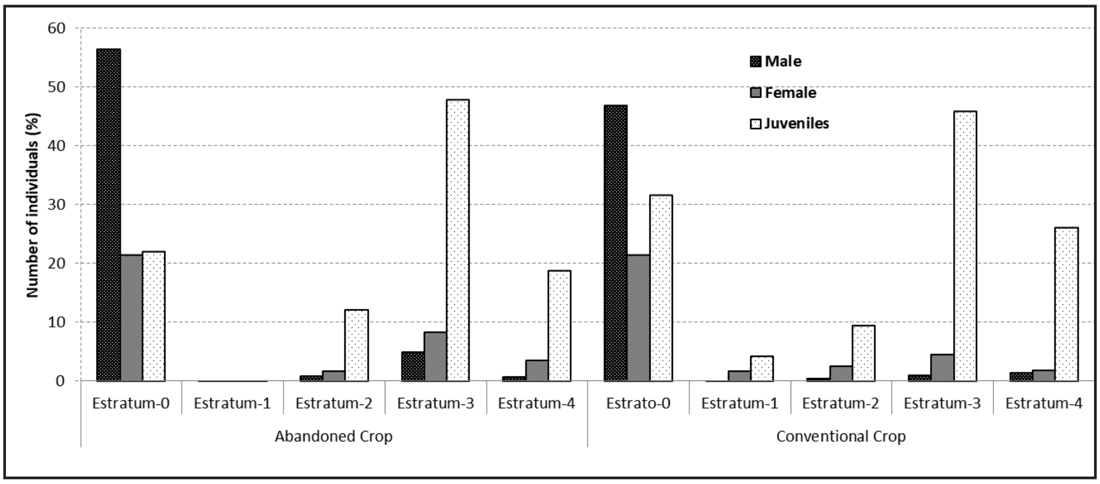
Spiders Guilds	Families	Species	Stratum-0 Traps		Stratum-1 Manual		Stratum-2 Manual		Stratum-3 Manual		Stratum-4 Manual	
			AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)
Irregular web weavers	Theridiidae	*Achaeatanea* sp.2 Strand, 1929						0.29	0.25	0.14	0.08	
	Theridiidae	*Achaeranea* sp.3 Strand, 1929		0.05				0.14	0.83	0.29	0.42	
	Theridiidae	*Achaeranea* sp.4 Strand, 1929			0.17							
	Theridiidae	*Anelosimus ethicus* (Keyserling, 1884)					0.25		0.75		0.33	
	Theridiidae	*Anelosimus studiosus* (Hentz, 1850)					0.42		1.16	0.43	1.00	0.14
	Theridiidae	*Argyrodes nephilae* Taczanowski, 1873		0.05			0.08		0.17	1.29	0.08	0.43
	Theridiidae	*Dipoena cordiformis* Keyserling, 1886	0.80	0.11								
	Theridiidae	*Euryopis pumicata* (Keyserling, 1886)	2.77	0.43								
	Theridiidae	*Euryopis* sp.1 Menge, 1868	0.03									
	Theridiidae	*Euryopis* sp.2 Menge, 1868	1.17	0.05								
	Theridiidae	*Theridion calcynatum* Holmberg, 1876					0.25	0.29	0.58	0.14	0.08	0.14
	Theridiidae	*Theridion frondeum* Hentz, 1850					0.08		0.33	0.43	0.08	
	Theridiidae	*Theridion* sp.1 Walckenaer, 1805	0.03			0.14			0.08			
	Theridiidae	*Theridion* sp.2 Walckenaer, 1805				0.14					0.08	
	Theridiidae	*Theridion* sp.3 Walckenaer, 1805							0.08			
	Theridiidae	*Pholcomma* sp. Thorell, 1869	0.03	0.11								
	Theridiidae	Morpho sp.1		0.05								
	Titanoecidae	*Goeldia* sp. Keyserling, 1891	1.23	6.90						0.14		
Wandering irregular sheet web weavers	Linyphiidae	*Drapetisca alteranda* Chamberlin, 1909	11.08	5.46	0.17		0.08			0.14	0.17	
	Linyphiidae	*Erigone montevidensis* (Keyserling, 1878)	7.91	16.53								
	Linyphiidae	*Erigone* sp.1 Audouin, 1826	0.03	0.11								
	Linyphiidae	*Erigone* sp.2 Audouin, 1826	1.10	3.58								
	Linyphiidae	*Erigone* sp.3 Audouin, 1826		0.37								
	Linyphiidae	*Lepthyphantes* sp.1 Menge, 1866	0.03	0.59								
	Linyphiidae	*Lepthyphantes* sp.2 Menge, 1866		0.05								
	Linyphiidae	*Lepthyphantes* sp.3 Menge, 1866	0.03	0.11								
	Linyphiidae	*Linyphia* sp.1 Latreille, 1804	0.03									
	Linyphiidae	*Meioneta* sp. Hull, 1920	0.03	0.43								
	Linyphiidae	Morpho sp.1	2.14	3.48					0.17			0.29
	Linyphiidae	Morpho sp.2	0.07	0.05								
	Linyphiidae	Morpho sp.3	0.13	0.48								
	Linyphiidae	Morpho sp.4	0.03									
	Linyphiidae	Morpho sp.5	0.03									
	Linyphiidae	Morpho sp.6	0.03									
Sheet web weavers	Amaurobidae	*Amaurobius* sp.1 C. L. Koch, 1837	0.27	1.93		0.57						
	Amaurobidae	*Amaurobius* sp.2 C. L. Koch, 1837	0.07	0.43	0.08					0.14		
	Amphinectidae	*Metaltella* sp.1 Mello-Leitão, 1931	0.20	0.96	0.08	1.86	0.25	1.15	1.25	2.72	0.42	1.29
	Amphinectidae	*Metaltella* sp.2 Mello-Leitão, 1931		0.05								
	Hahniidae	*Antistea* sp. Simon, 1898	3.50	0.86								
	Hahniidae	*Neoantistea* sp. Gertsch, 1934	0.43	0.11								
Trap door	Actinopodidae	*Actinopus* sp. Perty, 1833	0.03	0.16								
	Philodromidae	*Thanatus* sp. C. L. Koch, 1837		0.16								

Spiders Guilds	Families	Species	Stratum-0 Traps		Stratum-1 Manual		Stratum-2 Manual		Stratum-3 Manual		Stratum-4 Manual	
			AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)
	Thomisidae	*Misumena vatia* (Clerck, 1757)							0.08			
	Thomisidae	*Misumena* sp. Latreille, 1804					0.08					
	Thomisidae	*Misumenoides* sp.1 Pickard-Cambridge, 1900	0.43	0.21								
Ambush	Thomisidae	*Misumenoides* sp.2 Pickard-Cambridge, 1900	0.67	0.21								
hunters	Thomisidae	*Misumenoides* sp.3 Pickard-Cambridge, 1900							0.25			
	Thomisidae	*Misumenops* sp.1 Pickard-Cambridge, 1900	0.03				0.42	0.29	0.17	0.72	0.08	
	Thomisidae	*Misumenops* sp.2 Pickard-Cambridge, 1900	0.03	0.05								
	Thomisidae	*Misumenops* sp.3 Pickard-Cambridge, 1900	0.10									
	Thomisidae	*Misumenops* sp.4 Pickard-Cambridge, 1900					0.33		1.58	0.14	0.08	
	Thomisidae	*Misumenops* sp.5 Pickard-Cambridge, 1900	0.03									
	Oxyopidae	*Oxyopes* sp. Latreille, 1804	0.17	0.05			0.08					
	Salticidae	*Euophris* sp. C. L.Koch, 1834	0.03	0.05				0.43				
	Salticidae	*Lyssomanes* sp. Hentz, 1845	0.07						0.42		0.17	
	Salticidae	*Peckhania* sp. Simon, 1900	0.17	0.11								
	Salticidae	*Phlegra* sp. Simon, 1876		0.27								
	Salticidae	*Plexippus* sp.1 Simon, 1900							0.33			0.14
	Salticidae	*Plexippus* sp.2 Simon, 1900	0.03	0.05						0.14		0.14
	Salticidae	*Plexippus* sp.3 Simon, 1900	0.10	0.05					0.08	0.14		
	Salticidae	Morpho sp.1	0.17	0.11								
	Salticidae	Morpho sp.2	0.30	0.86		1.72		0.43	0.08	0.29		
	Salticidae	Morpho sp.3	0.03									
	Salticidae	Morpho sp.4	0.03						0.17	0.14		
	Salticidae	Morpho sp.5	0.03									
	Salticidae	Morpho sp.6	0.10	0.11								
Stalker	Salticidae	Morpho sp.7	0.13									
hunter	Salticidae	Morpho sp.8		0.16								
	Salticidae	Morpho sp.9	0.03						0.08			
	Salticidae	Morpho sp.10	0.03	0.05								
	Salticidae	Morpho sp.11	0.03				0.08					
	Salticidae	Morpho sp.12									0.08	
	Salticidae	Morpho sp.13							0.08			
	Salticidae	Morpho sp.14		0.05		0.14	0.08		0.08		0.08	
	Salticidae	Morpho sp.15	0.03									
	Anyphaenidae	*Anyphaena* sp.1 Sundevall, 1833	0.07	0.96			0.17		0.17			
	Anyphaenidae	*Anyphaena* sp.2 Sundevall, 1833	0.03	0.05			0.08			0.14	0.42	
	Anyphaenidae	*Aysha prospera* Keyserling, 1891	0.33	0.54			0.25	0.72	1.50	0.57	0.33	1.29
	Anyphaenidae	*Aysha* sp.1 Keyserling, 1891	0.13	0.48		0.14		0.43	1.00	0.72	0.08	0.43
	Anyphaenidae	*Aysha* sp.2 Keyserling, 1891	0.03									
	Anyphaenidae	*Wulfila* sp. Pickard-Cambridge, 1895	0.13	0.11			0.50		1.75		0.33	
	Anyphaenidae	*Xiruana* sp.1 Brescovit, 1997	0.17	0.05			0.42	1.15	3.41	2.72	1.00	1.43
Foliage	Anyphaenidae	*Xiruana* sp.2 Brescovit, 1997	0.03	0.05			0.75		3.41	2.15	0.42	1.29
hunter	Anyphaenidae	*Morpho* sp.1	0.07									

Spiders Guilds	Families	Species	Stratum-0 Traps		Stratum-1 Manual		Stratum-2 Manual		Stratum-3 Manual		Stratum-4 Manual	
			AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)	AC (%)	CC (%)
runners	Anyphaenidae	*Morpho* sp.2	0.03									
	Anyphaenidae	*Morpho* sp.3							0.08			
	Anyphaenidae	*Morpho* sp.4	0.10									
	Clubionidae	*Clubiona* sp. Latreille, 1804		0.21			0.75	0.29	0.58	0.86	0.50	0.14
	Clubionidae	Morpho sp.1		0.11								
	Clubionidae	Morpho sp.2	0.13	0.05								
	Clubionidae	Morpho sp.3	0.17									
	Liocranidae	*Agroeca* sp. Westring, 1861	0.03									
	Segestridae	*Segestria* sp. Latreille, 1804				0.14						
	Sparassidae	*Heteropoda* sp. Latreille, 1804										0.14
	Corinnidae	*Castianeira* sp.1 Keyserling, 1879	1.97	0.37								
	Corinnidae	*Castianeira* sp.2 Keyserling, 1879	1.60	0.27								
	Corinnidae	*Castianeira* sp.3 Keyserling, 1879	5.11	1.28								
	Corinnidae	*Falconina* sp.1 Brignoli, 1985	5.01	4.55								
	Corinnidae	*Falconina* sp.2 Brignoli, 1985	0.23	0.11								
	Corinnidae	Morpho sp.1	0.27	0.27								
	Corinnidae	Morpho sp.2	0.03									
	Ctenidae	*Asthenoctenus* sp. Simon, 1897	0.77	1.07								
	Ctenidae	*Ctenus* sp. Walckenaer, 1805	0.20	0.16								
	Ctenidae	Morpho sp.1	0.23	0.05								
	Ctenidae	Morpho sp.2	0.07	0.05								
	Disderidae	*Dysdera crocata* C. L. Koch, 1838	0.13	0.54								
	Gnaphosidae	*Drassodes* sp. Westring, 1851	0.03	0.05								
Ground hunter runners	Gnaphosidae	*Drassyllus frigidus* (Banks, 1892)	0.47	0.86								
	Gnaphosidae	*Drassyllus* sp.1 Chamberlin, 1922	0.27	0.05								
	Gnaphosidae	*Drassyllus* sp.2 Chamberlin, 1922	1.40	3.69		0.14						
	Gnaphosidae	*Eilica* sp. Keyserling, 1891	0.23	0.16								
	Lycosidae	*Aulonia* sp. C. L. Koch, 1847	0.07	4.71								
	Lycosidae	*Diapontia* sp. Keyserling, 1877	0.10									
	Lycosidae	*Lycosa carbonelli* Costa & Capocasale, 1984	0.47	0.11								
	Lycosidae	*Lycosa poliostoma* (C. L. Koch, 1847)	2.87	10.11								
	Lycosidae	*Lycosa thorelli* (Keyserling, 1877)	0.10									
	Lycosidae	*Lycosa* sp. Latreille, 1804	1.03	0.91								
	Lycosidae	*Schizocosa mallitiosa* (Tullgren, 1905)	0.50	7.76								
	Lycosidae	Morpho sp.1	28.90	4.44								
	Lycosidae	Morpho sp.2	0.30									
	Lycosidae	Morpho sp.3		0.05								

Source: Author.

Figure 3. Relative abundance of spiders collected by strata in two lemon crop (*Citrus limon*) in Montevideo, Uruguay.

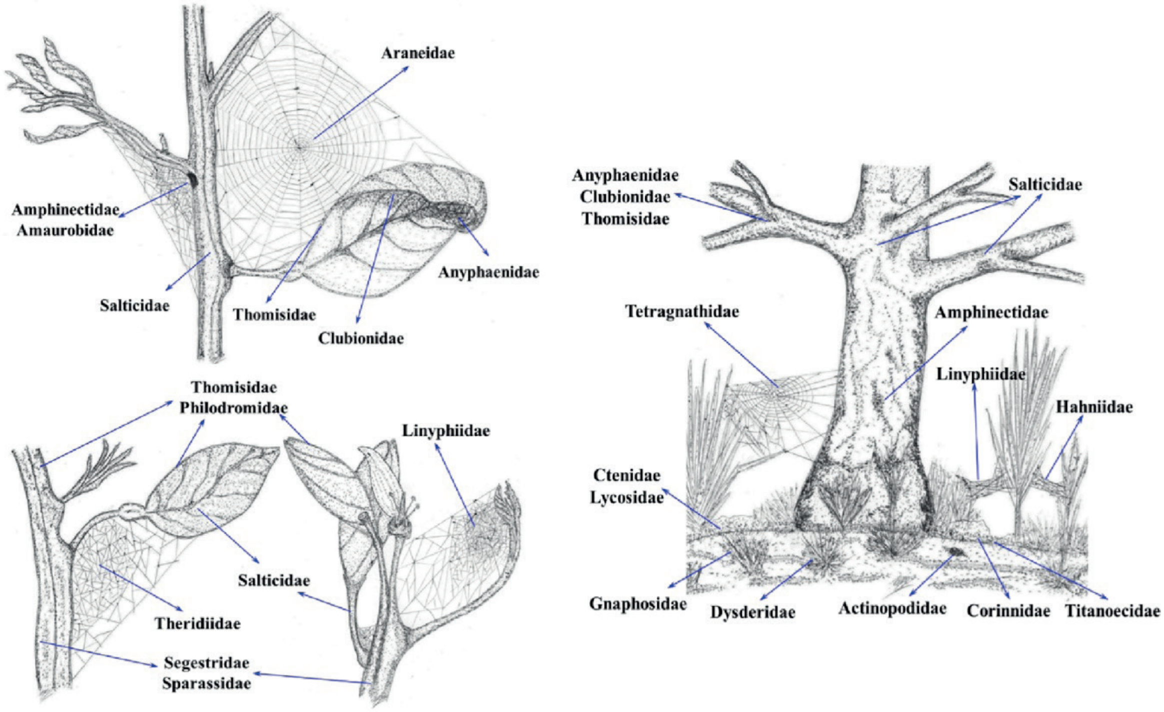


Source: Author.

Richness, species diversity and similarity

The total species richness (manual sampling + pitfall traps) in the AC was 121 and the CC 100 species, sharing including 33 species, of which only five species were present in all strata including the stratum-0: *Metaltella* sp.1 (Amphinectidae), *Aysha* sp.1 (Anyphaenidae), *Parawixia* sp.1, *Araneus lathyrinus* (Araneidae), *Achaearanea hirta* (Theridiidae) (Table 1). The spiders were found distributed in the different suggested strata for this study (Figure 2), giving as a result, and without taking into consideration the different collection methods, that the highest abundances, species richness and diversity of spiders were registered in the stratum -0, stratum-3 and stratum-4 of AC and CC, distributed according to the different structures and physiognomy of the lemon tree (Fig. 4), in many cases sharing species among them (Table 1).

Figure 4. Spatial location of the different families of spiders, at the structural level and physiognomy of the lemon tree (*Citrus limon*) in Montevideo, Uruguay.



Source: Author.

During the manual collection that corresponded to the vertical strata of the lemon trees, in the AC 49 species were captured (40.5% of the total species), in the CC 41 species (41%), where stratum-3 was the richest in comparison to the other strata in both lemon crops (Table 2). For both lemon crops, the highest species richness was obtained by the Theridiidae family, being present in stratum-2, stratum-3 and stratum-4. However, the most abundant species was *Araneus lathyrinus* (Araneae), being present in the four strata, being more abundant in stratum-3 (463 individuals in AC and 233 in CC). The stratum-2 of CC was characterized by presenting greater diversity according to the Shannon index (H'= 2.07), compared to the rest of the strata. Although the only vertical stratum that presented statistically significant differences compared to the others, was stratum-4 (Table 2). The more uniform distribution of the abundance of species, was registered in stratum-1 according to the AC index equitability of Pielou (J = 0.96); while the greatest species dominance was observed in the stratum-4 of CC (D = 0.53) (Table 2).

In the collection with pitfall traps (stratum-0), 96 species (79.3% of the total species) were captured in the AC and 83 species (83%) in the CC, being the most abundant Lycosidae Morpho sp.1; *Drapetisca alteranda*, *Erigone montevidensis* (Linyphiidae); *Castianeira* sp. 3, *Falconina* sp. 1 (Corinnidae), *Antistea* sp. (Hahnniidae) (Table 1).

In both lemon crops, the highest species richness was represented by the family Linyphiidae (10 species), followed by Salticidae (8 species), Corinnidae (6 species), Lycosidae, Theridiidae and Gnaphosidae (all with 5 species). Being the most abundant species in stratum-0, Lycosidae Morpho sp. 1 with 866 individuals in AC and 83 in CC, followed by *Drapetisca alteranda* (CA: 332, CC: 102), *Erigone montevidensis* (CA: 237, CC: 309) (Linyphiidae), *Castianeira* sp.3 (CA: 153, CC: 24), *Falconina* sp.1 (CA: 150, CC: 85) (Corinnidae). However the species *Metaltella* sp.1 (Amphinectidae); *Aysha* sp.1 (Anyphaenidae); *Parawixia* sp.1, *Araneus lathyrinus* (Araneidae); *Drapetisca alteranda* (Lyniphiidae) and *Achaearanea hirta* (Theridiidae) were present in the other vertical strata of the lemon trees. The stratum-0 of CC obtained a greater diversity than AC, presenting significant statistical differences, which was corroborated by the equitability index, obtaining a greater dominance of species in AC (Table 2).

Table 2. Diversity estimators at the strata level in lemon crop trees (*Citrus limon*), with two agricultural managements in Montevideo, Uruguay.

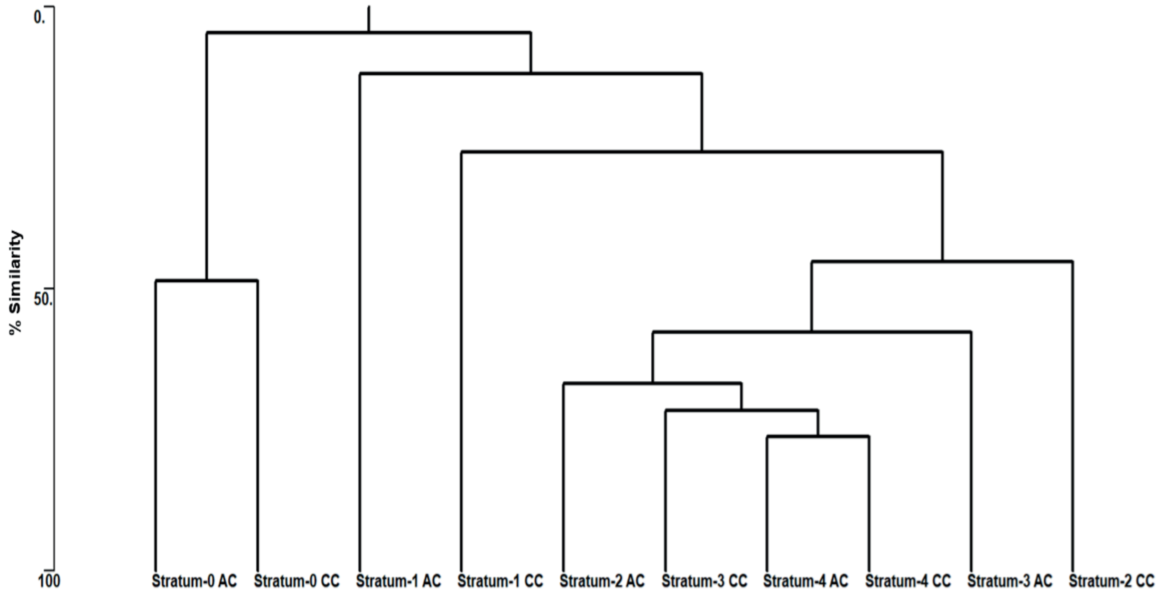
	Stratum-0* (Pt)		Stratum-1 (Mc)		Stratum-2 (Mc)		Stratum-3 (Mc)		Stratum-4 (Mc)	
	CA	CC	CA	CC	CA	CC	CA	CC	CA	CC
Individuals (N)	2997	1869	8	43	178	89	756	360	262	207
Species richness (S)	96	83	5	14	25	15	37	28	26	16
Dominance (D)	0.121	0.071	0.219	0.189	0.311	0.217	0.386	0.43	0.445	0.534
Shannon (H´)	2.835	3.115	1.56	2.067	2.004	2.074	1.81	1.617	1.612	1.227
Equitability (J)	0.621	0.705	0.969	0.783	0.623	0.766	0.501	0.485	0.495	0.442
Stadistic test	*t(H´)* = -6.91; *df*= 4509.5; P< 0.05		*t(H´)* = -1.899; *df*= 20.731; P= 0.072		*t(H´)* = -0.401; *df*= 231.04; P= 0.689		*t(H´)* = 1.742; *df*= 733.35; P= 0.082		*t(H´)* = 2.541; *df*= 463.57; P< 0.05	
Similarity	48.54 %		11.76 %		43.45 %		57.71 %		76.33 %	

CA: abandoned crop, CC: conventional crop.; Pt: pitfall traps collection, Mc: manual collection

Source: Author.

There was a greater similarity in the stratum-4 between the two crops (76.33%) followed by stratum-3 (57.71%) (Table 2). Through a phenogram graph, where all the strata of both lemon crops are included, a node of similarity can be observed between strata-4 (AC and CC) and stratum-3 CC (71.7%), followed by rest of the strata. However, the 0-strata (AC and CC) with a similarity of 48.54%, presented a low similarity with respect to the other strata, reaching 4.48% of similarity, having as a node of union the AC-1 stratum with 11.76% of similarity between them (Fig. 5).

Figure 5: Similarity phenogram (Bray Curtis index) relating the different sampling strata in two lemon crop (*Citrus limon*) in Montevideo, Uruguay.



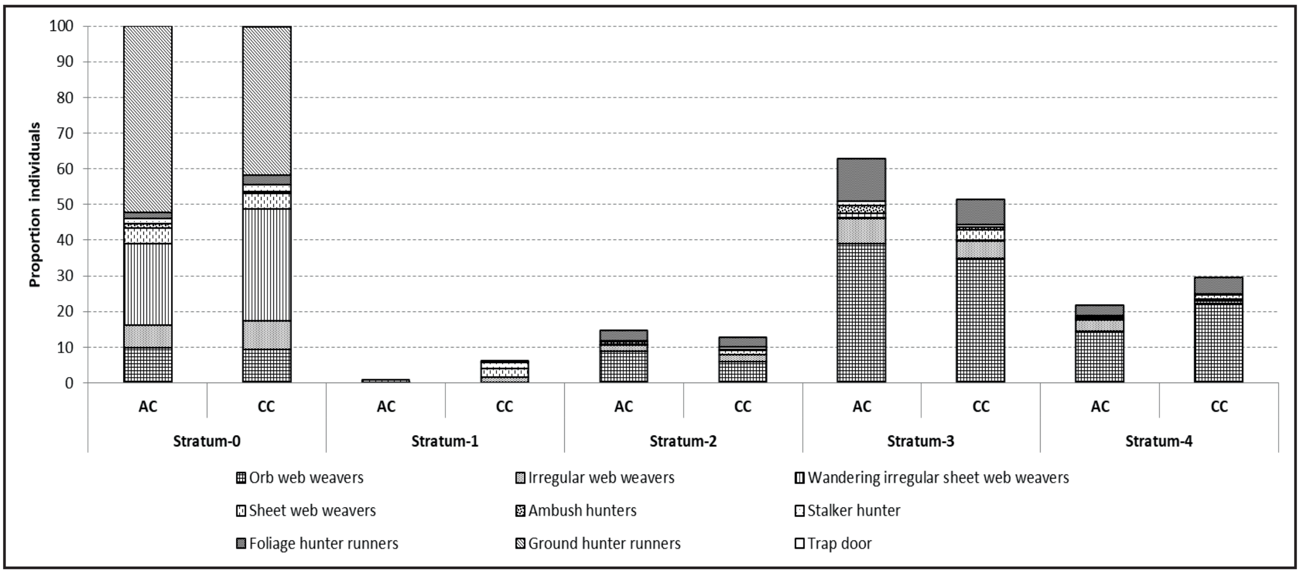
AC: abandoned crop, CC: conventional crop

Source: Author.

Guild spider composition

The spider families present in the vertical strata of the lemon crop, including the spiders registered in pitfall traps (stratum-0), were grouped into nine guilds according to their functional attributes (Table 1). The guilds with the highest abundance in both lemon crops were present in stratum-0, being represented by Ground hunter runners (AC: 52%, CC: 41% individuals), wandering irregular sheet web weavers (AC: 23%, CC: 31% individuals) and orb web weavers (AC: 10%, CC: 9% individuals). While in the vertical strata of lemon trees, they were present mostly in stratum-3, represented mainly by orb web weavers (AC: 39%, CC: 35% individuals), foliage hunter runners (AC: 12%, CC: 7% individuals) and irregular web weavers (AC: 7%, CC: 5% individuals) (Fig. 6).

Figure 6. Proportion of relative abundance in the different spider guilds, distributed at the level of the four vertical strata and soil, in the lemon crop (*Citrus limon*) in Montevideo, Uruguay.



AC: abandoned crop, CC: conventional crop

Source: Author.

For both lemon crops, the guild ground hunter runners showed a greater species richness at the stratum-0 (AC: 26, CC: 23 species), followed by stalker hunter (AC: 17, CC: 12 species) and wandering irregular sheet web weavers (AC: 14, CC: 12 species). However, the richness was diminished at the level of the vertical strata, being stratum-3 the one that presented a greater number of species, represented by irregular web weavers (AC: 11, CC: 8 species), foliage hunter runners (AC: 8, CC: 6 species) and stalker hunter (AC: 8, CC: 4 species).

The greatest diversity observed in stratum-0 for AC was that of stalker hunter (H'= 20.53) and for CC it was ground hunter runners (H' = 2.24), while dominance was maintained by the orb web weavers guild in AC (D = 0.96) and CC (D = 0.94). For the rest of the vertical strata, the greatest diversity was observed in stratum-3 with irregular web weavers guild in AC (H´ = 1.96) and CC (H' = 1.60); where stratum-4 presented the highest species dominance, represented by orb web weavers in AC (D = 0.99) and CC (D = 0.93) (Table 3).

Table 3. Diversity estimators for spider guilds distributed at the level of the four vertical strata and soil, in the lemon crop (*Citrus limon*) in Montevideo, Uruguay.

		Stratum-0		Stratum-1		Stratum-2		Stratum-3		Stratum-4	
Spiders Guilds	**Indices**	**AC**	**CC**	**AC**	**CC**	**AC**	**CC**	**AC**	**CC**	**AC**	**CC**
Orb web weavers	Individuals	296	174	2	4	105	42	470	243	174	156
	Species richness (S)	4	4	1	3	4	3	4	5	2	3
	Dominance (D)	0.96	0.94	1	0.37	0.86	0.82	0.97	0.92	0.99	0.93
	Shannon (H´)	0.12	0.16	0	1.04	0.32	0.37	0.09	0.22	0.04	0.18
Irregular web weavers	Individuals	189	152	2	6	21	13	85	35	38	5
	Species richness (S)	9	11	1	4	6	4	11	8	10	3
	Dominance (D)	0.28	0.72	1	0.28	0.25	0.43	0.19	0.27	0.19	0.44
	Shannon (H´)	1.48	0.73	0	1.33	1.56	1.07	1.96	1.60	1.89	0.95
Wandering irregular sheet web weavers	Individuals	680	584	2	-----	1	-----	2	1	2	2
	Species richness (S)	14	12	1	-----	1	-----	1	1	1	1
	Dominance (D)	0.37	0.34	1	-----	1	-----	1	1	1	1
	Shannon (H´)	1.21	1.45	0	-----	0	-----	0	0	0	0
Sheet web weavers	Individuals	134	81	2	17	3	8	15	20	5	9
	Species richness (S)	5	6	2	2	1	1	1	2	1	1
	Dominance (D)	0.63	0.29	0.5	0.64	1	1	1	0.90	1	1
	Shannon (H´)	0.79	1.39	0.69	0.55	0	0	0	0.19	0	0
Ambush hunters	Individuals	39	12	-----	-----	10	2	25	6	2	-----
	Species richness (S)	6	4	-----	-----	3	1	4	2	2	-----
	Dominance (D)	0.38	0.29	-----	-----	0.42	1	0.6	0.72	0.5	-----
	Shannon (H´)	1.19	1.29	-----	-----	0.94	0	0.79	0.45	0.69	-----
Stalker hunter	Individuals	45	36	-----	13	3	6	16	5	4	2
	Species richness (S)	17	12	-----	2	3	2	8	4	3	2
	Dominance (D)	0.10	0.24	-----	0.86	0.33	0.5	0.19	0.28	0.37	0.5
	Shannon (H´)	2.53	1.92	-----	0.27	1.10	0.69	1.84	1.33	1.04	0.69
Foliage hunter runners	Individuals	44	49	-----	2	35	18	143	50	37	33
	Species richness (S)	14	10	-----	2	7	4	8	6	7	6
	Dominance (D)	0.11	0.22	-----	0.5	0.19	0.31	0.21	0.27	0.19	0.25
	Shannon (H´)	2.38	1.79	-----	0.69	1.75	1.26	1.71	1.49	1.78	1.5
Ground hunter runners	Individuals	1569	778	-----	1	-----	-----	-----	-----	-----	-----
	Species richness (S)	26	23	-----	1	-----	-----	-----	-----	-----	-----
	Dominance (D)	0.33	0.14	-----	1	-----	-----	-----	-----	-----	-----
	Shannon (H´)	1.78	2.24	-----	0	-----	-----	-----	-----	-----	-----

AC: abandoned crop, CC: conventional crop

Source: Author

DISCUSSION

The greater abundance recorded in AC than in CC, could be due to the structural increase of lemon tree, coinciding with FEBER *et al.* (1998), the increase could offer conditions for a significant number of phytophages as a source of potential consumption for spiders.

The majority presence of male spiders followed by females in stratum-0, would suggest increased sexual activity, relating the mating season, coinciding with the spring seasons

2001 - summer 2002 (BENAMÚ 2004). According to TURNBULL (1973), the occurrence of adults in the crop, mainly on the ground, would indicate that they reproduce in the field. The predominance of juvenile spiders on males and females, in the vertical strata of the plant was notorious, having been reported by COSTA *et al.* (1991) and PÉREZ-MILES *et al.* (1999). This fact was evident in stratum-3; BENAMÚ (2004) related it to the spring season, coinciding with phenological stages of lemon crop (sprouting, flowering and curdled fruit) and possibly capturing prey small size. For DEAN & STERLING (1990), NYFFELER *et al.* (1994) and NYFFELER (1999). Usually juveniles are numerically dominant throughout most of the year in crops fields, representing a dispersal strategy (SUTER 1999, TOPPING 1999) being frequent in this stage of spider development (PEARCE *et al.* 2005).

The greater abundance and richness of spider species in the stratum-0 of the AC compared to CC could be related to the varied vegetation present in this crop (acacias, grasslands, weeds and neighboring crops). LANDIS *et al.* (2005), AMARAL *et al.* (2016) and COTES *et al.* (2018) affirm that in an agroecosystem the growth of spontaneous native plants between crops improves the impact of the natural enemy, providing food, refuge and appropriate hosts, according to DUFFEY (1975) they would contribute to the formation of new habitat structures, conditioning microclimates and variety of biotopes. These new habitats vary according to crop growth, changing the prey capture preference and efficiency of the various spider guilds (YSNEL & CANARD 2000; BENAMÚ 2001, 2010; SYMONDSON *et al.* 2002; LILJESTHTRÖM *et al.* 2002; ARMENDANO 2008); attributing this to the existence of alternative sources of food or prey (BAYRAM & LUF 1993; NORRIS & KOGAN 2005). According to HALAJ *et al.* (2000), there would be an association between weeds and predator abundance, being used as possible natural refuges, increasing the diversity, survival, dispersal and colonization of the crop by spiders (BENAMÚ 2001). In the case of vertical strata, the difference in abundance, species richness and diversity of spiders between AC and CC in the stratum-1 could be interpreted by the different physiognomic structure of habitat. The AC was less diverse in the stratum-1, but more abundant and diverse in weeds, providing varied habitats for spiders, as well as a greater number of alternative preys (COSTELLO & DOANE 1998; YSNEL & CANARD 2000). In CC it could indicate a migration of spiders towards the foliage of trees due to the process of cutting weeds and herbicides use, typical of a commercial crop, being more harmful to the spider community than the use of insecticides (RIECHERT & LOCKLEY 1984, AMALIN & PEÑA, 1999; HAUGHTON *et al.*, 1999; BENAMÚ *et al.* 2010, 2013, 2017b), generating loss of habitats and refuges.

In the stratum-2, there is not a marked difference in species diversity for both lemon crops. However, the CC presented a lower abundance of individuals, probably due to the influence of agricultural activity (typical of an altered system) and that it would be colonized by a low number of species (NYFFELER *et al.* 1994), coinciding with a lower contribution from the epigean fauna and the tree trunk.

The diversity of species in stratum-3 did not show significant differences between the two citrus crops, the plant structure in this stratum benefits weaver spiders, Araneidae and Theridiidae predominating. According to RYPSTRA *et al.* (1999) and VIERA (1995), dense vegetation and plant stratified form diverse microclimates as well as an increase in the availability of silk hooking sites, favoring the various weaver spiders. These elements are even greater in the AC, which consequently presented the largest number of individuals, perhaps due to the lack of agricultural activity and management in these trees. A similar reasoning can be applied to stratum-4, which presented the highest diversity of spider species in the AC. The lower abundance found in stratum-4 in relation to stratum-3 could be influenced by the greater practical difficulties in manual collection, due to the height of the canopy. In general, it can be said that the abundance and richness of species varies according to the type of stratum, this confirms what was said by SAMU *et al.* (1999), SAMU & SZINETÁR (2002), YSNEL & CANARD (2000) and MALONEY *et al.* (2003), about the structural complexity and density of the foliage being directly related to the density and diversity of spider species.

According to the vertical stratification of the lemon tree, the spiders were distributed according to their stage of development, as the height of the stratum increases, the size of the spiders increases (BENAMÚ 2004), as well as the dimension of their webs, coinciding with VIERA (1995). In this way, the coexistence of the different stages of spiders would decrease intra-specific competition (VIERA 2003). In the species of weaver spiders (Araneidae and Theridiidae), a certain stratification of the webs in the vertical plane of the lemon tree was observed which, according to VIERA (1995), may be a mechanism that allows the coexistence of individuals that exploit the same type of appeal in a similar way, minimizing competition.

The nodes of similarity between strata-4, stratum-3 and stratum-2 in both lemon crop, would be related to the species richness that they shared, highlighting mainly: *Araneus lathyrinus* (Araneidae), *Aysha prospera* (Anyphaenidae), *Metaltella* sp. 1 (Amphinectidae), *Clubiona* sp. 1 (Clubionidae) and *Theridion calcynatum* (Theridiidae). While the stratum-0 that presented spiders in common with the rest of the strata, they were able to migrate from the weeds to the trees and vice versa, in search of new prey, better refuges or evading predators. The low abundance of spiders in stratum-1 suggests that it is more a temporary bridge or corridor than a stable habitat.

The stratum-0 was the one with the highest representation of the nine spider guilds in lemon crop, the ground hunter runners being the most abundant, mainly represented by Lycosidae and Corinnidae, coinciding with MAQSOOD *et al.* (2016), who also reported as dominant families in citrus crops. According to NYFFELER & SUNDERLAND (2003), the abundance of this guild would be related to the extensive diet observed in these spiders. The wandering irregular sheet web weavers (Linyphiidae), sheet web weavers (mainly Hahniidae) were also abundant in this stratum, coinciding with BENAMÚ & AGUILAR (2001), SCHMIDT & TSCHARNTKE (2005), BENAMÚ (2004, 2010), ARMENDANO (2008), RIVERA (2013), MEMAH *et al.* (2014), present in pitfall traps. According to DEAN *et al.* (1982), AGNEW *et al.* (1985) and COSTELLO & DAANE (1998), the species of these families are commonly registered in vegetation cover the soil or near it. According to VASCONCELLOS-NETO *et al.* (2017), there are spider guilds that are frequent and associated with them, which is why they are almost always present. For BISHOP & RIECHERT (1990) and MINERVINO (1996), these families are considered the first colonizers of cultivated fields. Cursorial spiders would colonize at short distances, while at long distances they would be caused by ballooning, typical of juvenile spiders (LILJESTHRÖM *et al.* 2002; PEARCE *et al.* 2004; ÖBERG *et al.* 2007).

The vertical strata of the lemon crop tree were characterized by the presence of the orb web weavers spider guilds, mainly in the stratum-3 and stratum-4 represented by *Araneus lathyrinus (*Araneidae), ranking in the first place of importance, compared to the rest of the guilds present in AC and CC, being the one with the greatest dominance, followed by the foliage hunter runners (mainly Anyphaenidae). According to YOUNG & EDWARDS (1990), most of these families are found mainly in the middle and upper strata of the plant, coinciding with this study. For AVALOS *et al.* (2013), the eating habits of these spiders foraging mainly insects, would be the most abundant predators found in citrus crop. According to OTT *et al.* (2007), the low frequency of ambush hunters and stalker hunter in citrus, could be due to their preference for the herbaceous vegetation environment or the direct dispute with foliage hunter runners (Anyphaenidae), abundant in citrus crop.

The analysis of the results of this study shows how the spider community is distributed in the different strata of the lemon tree, showing a certain correlation between the structural complexity of the habitat, the abundance and species richness, the spiders taking advantage of the structural physiognomy of the plant. Also demonstrating, how agricultural management practices can influence the spider community.

This type of study would represent the first contribution to the knowledge of spiders at the level of vertical strata in lemon crop trees and soil, considering them as part of the native fauna of predators in lemon crops and the importance of conserving them.

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