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VISITING BEES OF *Cucurbita* FLOWERS (CUCURBITACEAE) WITH EMPHASIS ON THE PRESENCE OF *Peponapis fervens* SMITH (EUCERINI – APIDAE) - SANTA CATARINA, SOUTHERN BRAZIL

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ABSTRACT

Cucurbita flowers are monoecious, the male and female flowers requiring a pollinator to transfer pollen. Bees were systematically collected as they visited flowers of three cultivated *Cucurbita* species grown at seven separate localities of Santa Catarina state in southern Brazil. Additionally, pantraps were used to estimate the general bee diversity at three of these locations. In total, 3.270 bees were sampled representing 50 species, with 3.153 bees (24 species) counted during censuses on the flowers and 117 individuals of 30 species in the pantraps. The most abundant bee species was *Apis mellifera* (32%) followed by the squash specialist, *Peponapis fervens* (25%). This latter species was present at five of the seven study localities. It was the most abundant bee at *Cucurbita* in three of these places. Nests of *P. fervens* were found in two localities. Each vertical nest was excavated in clay soil and occupied by a single female. Pollen analyses of the larval provision revealed that the females collect pollen only on squash flowers (100% *Cucurbita* pollen grains) confirming its specialization. The presence of this bee species in the study area seems to be related to the good environmental condition and stewardship by the farmers, especially their careful use of insecticides.

Key words: Bee fauna, community, crop, pollination, solitary bee.

RESUMO

ABELHAS VISITANTES DE FLORES DE *Cucurbita* (CUCURBITACEAE), COM ÊNFASE SOBRE A PRESENÇA DE *Peponapis fervens* SMITH (EUCERINI – APIDAE) - SANTA CATARINA, SUL DO BRASIL. Flores de *Cucurbita* são monóicas, as flores masculinas e femininas necessitam de polinizador para transferir pólen. Abelhas foram sistematicamente amostradas enquanto visitavam flores de três espécies de *Cucurbita* cultivadas em sete localidades do estado de Santa Catarina no sul do Brasil. Adicionalmente, pratos-armadilhas foram utilizados para estimar a diversidade geral de abelhas destes locais. No total, 3.270 abelhas foram registradas representando 50 espécies, sendo 3.153 abelhas (de 24 espécies) amostradas durante os censos em flores e 117 indivíduos (de 30 espécies) nos pratos-armadilhas. A espécie de abelha mais abundante foi *Apis mellifera* (32%) seguida pela especialista em abóbora, *Peponapis fervens* (25%). Esta espécie esteve presente em cinco das sete localidades estudadas. Foi a abelha mais abundante em *Cucurbita* em três destes locais. Ninhos de *P. fervens* foram encontrados em duas localidades. Cada ninho vertical foi escavado em solo argiloso e ocupado por uma única fêmea. A análise de pólen da provisão da larva revelou que as fêmeas coletam pólen somente em flores de abóbora (100% grãos pólen de *Cucurbita*) confirmando sua especialização. A presença desta espécie de abelha nas áreas estudadas parece estar associada às boas condições ambientais e

ao manejo dos agricultores, especialmente seu cuidado com o uso de inseticidas químicos.
Palavras chave: Fauna de abelhas, comunidade, plantação, polinização, abelha solitária.

RESUMEN

ABEJAS VISITANTES DE FLORES DE Cucurbita (CUCURBITACEAE), CON ENFASIS SOBRE LA PRESCENCIA DE Peponapis fervens SMITH (EUCERINI – APIDAE) - SANTA CATARINA, SUR DE BRASIL. Las flores de Cucurbita son monoicas, las flores masculinas y femeninas necesitan de un polinizador para transferir el polen. Las abejas fueron sistemáticamente colectadas cuando visitaban las flores de tres especies de Cucurbita cultivadas en siete localidades del estado de Santa Catalina, al sur de Brasil. Adicionalmente, se utilizaron trampas hechas con platos de color (pantraps) para estimar la diversidad general de abejas de estas localidades. En total, 3.270 abejas fueron registradas representando 50 especies, siendo 3.153 abejas (de 24 especies) colectadas durante los censos en flores y 117 individuos (de 30 especies) en las trampas. La especie de abeja más abundante fue Apis mellifera (32%) seguida por la especialista en flores de zapallo, Peponapis fervens (25%). Esta última especie estuvo presente en 5 de las siete localidades estudiadas y fue la abeja más abundante en Cucurbita en tres de estas localidades. Nidos de P. fervens fueron encontrados en dos localidades. Cada nido vertical fue escavado en suelo arcilloso y ocupado por una única hembra. El análisis del polen provisto a las larvas reveló que las hembras colectan polen solamente en flores de zapallo (100% granos de polen de Cucurbita) confirmando su especialización. La presencia de esta especie de abeja en las áreas estudiadas parece estar asociada a las condiciones ambientales favorables y al manejo de los agricultores, especialmente por su uso cuidadoso de insecticidas.
Palabras-clave: Fauna de abejas, comunidad, cultivo, polinización, abeja solitaria.

INTRODUCTION

Insects are often viewed as the scourge of agriculture, yet many food crops require insects, particularly bees, for pollination to set fruit (Klein *et al*. 2007). This is true for all of the cultivated species of the genus *Cucurbita* (Cucurbitaceae), the squashes, gourds and pumpkins.

Cucurbita is a well-defined New World plant genus that is characterized massive, campanulate yellow-orange (rare pale yellow) flowers and by hard, spherical, indehiscent fruits (Nee 1990). The center of diversity and perhaps distribution of the genus are the tropical and semitropical regions from south of Mexico City south to Guatemala (Whitaker & Bemis 1964, Smith 1997).

The genus *Cucurbita* includes between 20 and 26 species, divided into two groups: (1) the arid zone perennials species with storage roots and (2) the more mesophytic annuals or short-lived perennial species without storage roots. There are wild and cultivated species in the genus (Whitaker & Bemis 1964). The five domesticated species of *Cucurbita* have arisen from the mesophytic group (Whitaker & Bemis 1964, Nee 1990).

Solitary bees of the genera *Peponapis* and *Xenoglossa* (Eucerini) have an intimate relationship with the flowers of the genus *Cucurbita*. These bees are commonly known as squash and gourd bees, and they present behavioral and morphological adaptations for foraging at *Cucurbita* flowers (Hurd *et al.* 1971). We can assume that the survival of these bees depends on the resources collected at *Cucurbita* flowers, particularly pollen.

Hurd *et al.* (1974) suggested that *Peponapis* followed the different domestication centers of *Cucurbita* at different times through history, with the extensive cultivation of *Cucurbita* in the Americas contributing to expansion of the bees' geographical distribution. Cane (2004) and colleagues in the Squash Pollinators of the Americas Survey (SPAS) in North American found *Peponapis pruinosa* in almost all North American squash fields. Our contribution to this project was the study of some places in Santa Catarina State, southern Brazil, following the protocols for the SPAS project as described below.

This study is part of the project financed by FAO to analyze the pollinators' status of cucurbit crops in different parts of the world.

MATERIAL AND METHODS

STUDY SITES

The censuses were performed in seven sites at six localities in the State of Santa Catarina in the far south of Brazil (Figure 1). In nearby Uruguay, *Cucurbita* phytoliths are reported from human archaeological sites dated to at least 4000 years BP (Iriarte *et al.* 2004). The climate in region is subtropical humid (Atlas 2002). Some data of the study sites are summarized on Table I. A total of 27 censuses were performed from May 2005 to May 2006, summing about 38 hours of sampling.

In the district of Joinville we used two sites for this study (Figure 2A). In the first, called Quiriri, the squash field is surrounding by forest vegetation due to a protected area called APA Quiriri. In this place the farmers (with small proproperties) are not allowed to use insecticides. Around the cucurbit plantation they cultivate banana, manioc and potato. The second place, Mildau, is about 20km distant from Quiriri, and has no protected area. Its vegetation is very impacted and the growers used pesticides (including insecticides).

At the two localities in the south of the State, Criciúma and Turvo, the squash fields were surrounding by disturbed vegetation and the farmers use conventional tillage, insecticides and fungicides. In Concórdia the surrounding vegetation is recovering and the grower did not use pesticides on the pumpkins (Figure 2B). In Porto União, the cultivated

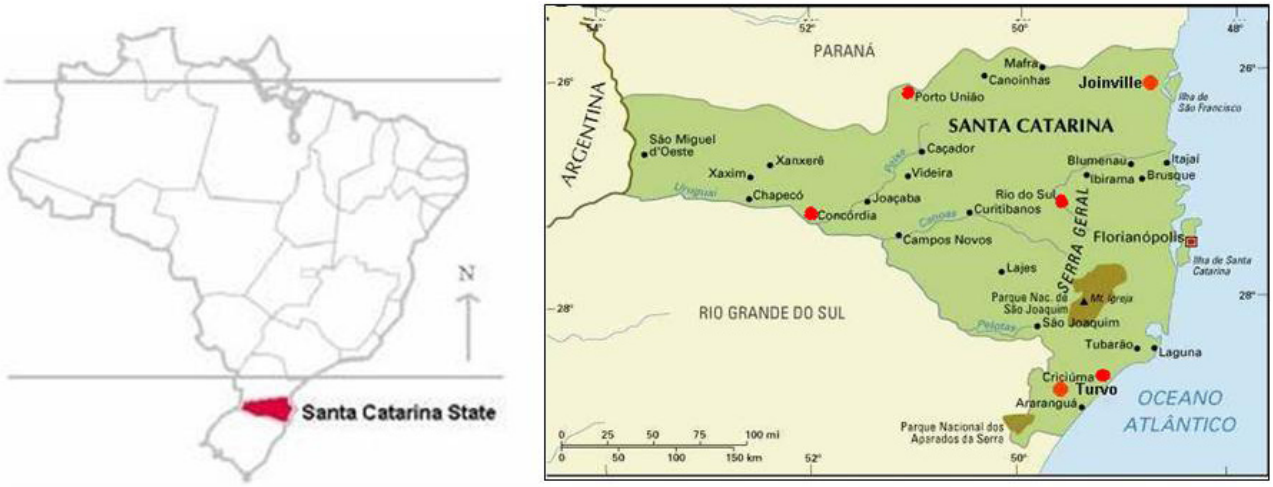

Figure 1. Studied sites: Location of Santa Catarina State in southern Brazil and the studied areas (red dots): Joinville, Turvo, Concórdia, Porto União, Rio do Sul and Criciúma.

Table I. Characteristics of each study site and cucurbit farm with the number of censuses performed in each place. Vegetation surrounding: D= disturbed, P= preserved, R= recovering; period of the census (month/year), number of censuses performed (Nº), duration of the censuses (hours and minutes).

Locality	Geographic Position Coordinators – S/W	Altitude (m)	Cultivated area (m^2)	Use of pesticides	Vegetation surrounding	Month year	Nº census	Time
Joinville - Mildau	26°18'05"/48°50'38"	3	1000	Yes	D	XI/05	3	4h30"
Joinville - Quiriri	26°18'05"/48°50'38"	3	900	No	P	V/05	9	13h10"
Porto União	26°14′16″/51°04′40″	752	2000	Yes (few)	P	II/06	4	5h05'
Rio do Sul	27°12′50″/49°38′34″	341	1500	No	D	III/06	4	5h45'
Concórdia	27º13'55"/52º00'26"	569	1000	No	R	XII/05	4	4h55'
Criciúma	28°40'39"/49°22'11"	46	3000	Yes	D	V/06	2	2h45'
Turvo	28°55′33″/49°40′44″	28	10000	Yes	D	V/05	1	1h10'

area (Figure 2C) was associated with corn (maize), surrounding by well-preserved vegetation. There the farmer used limited amounts of pesticides; while in Rio do Sul (Figure 2D) no pesticides were used the year of sampling (2006). The oldest *Cucurbita* fields are from Criciúma (10-15 years old) and Rio do Sul (10 years).

CENSUS

Bees were censused at squash flowers in the morning. The protocol used characterizes both diversity of floral visitors and each species' abundance at squash flowers. During each survey, the observer walked slowly along the rows counting the number of open flowers and the numbers of bees of each species encountered on the flowers. At the farms with small cultivated fields (Concordia, Joinville and Porto União) all the open flowers were surveyed; at larger farms (Criciúma, Rio do Sul and Turvo) fields were divided and subsampled. Due to their easy recognition, three species were just counted: *Apis mellifera*, *Bombus morio* and *B. atratus*. All the others bees were collected, pinned, labeled and identified using

Figure 2. A) Studied place in Joinville (Santa Catarina - SC, Brazil) a small farm in Mildau Street. **B)** Studied place in Concórdia/SC. **C)** Studied site in Porto União associated with maize. **D)** Studied site of the cultivated area in Rio do Sul. **E)** Entrance of a nest of *Peponapis fervens* **F) and G).** Tunnels of *P. fervens* nests. **H)** Cell founded in the end of the tunnel on nest of *P. fervens* in Porto União.

the available literature, keys and consultation with regional bee taxonomists. The classification is based on Michener (2000) and Silveira *et al*. (2002). All the bees were deposited in the entomological collection of the Universidade do Extremo Sul Catarinense (Unesc) in Criciúma, SC.

The pumpkin and squash species used in this work were: *Cucurbita pepo* in Joinville; *C. moschata* in Porto União, Concórdia and Rio do Sul, and a hybrid of *C. moschata* and *C. maxima*, variety 'Tetsukabuto' in Turvo and Criciúma.

PANTRAPS

Concomitantly with the census of the floral visitors, we sampled the local bee fauna using pantraps at four localities: Joinville, Porto União, Criciúma and Concórdia. In Rio do Sul, one strong rain flooded the pan traps; and for the occasion of the census in Turvo we still did not have the traps.

The pantrap technique used colored plastic pans, 5cm high by 15cm across. They were filled with 200ml water and several drops of detergent to break the surface tension. We used 15 bowls per site: five blue, five yellow and five white. They were placed on the ground surface two or more meters apart. The pantraps were left out for 48 consecutive hours along the border of the cucurbit fields. Except for Lepidoptera, captured insects were labeled, preserved in 70% ethanol, and later identified and deposited in the Unesc collection.

PEPONAPIS FERVENS OBSERVATIONS

Peponapis fervens occurred in four of the seven studied localities: Joinville, Concórdia, Porto União and Rio do Sul. In the places where we found *P. fervens* (PU and RS), we found and excavated nests. Six nests were excavated to describe the architecture, to sample the brood cells, their contents and immatures. Pollen masses from three cells were preserved in 70% alcohol and later used to make slide mounts of the pollen. Pollen slides of each cell's pollen provision were prepared in triplicate and 300 pollen grains were counted and identified on each slide. The eggs and larvae of the bees were preserved in ethanol 70%.

STATISTICAL ANALYSIS

Only bees were analyzed in this study. The bee fauna was characterized qualitatively and quantitatively by the number of families, species and individuals represented in surveys of visitors to squash flowers at each locality. The diversity indexes of Shannon-Wiener (H') and Simpson (D) were calculated for the three places with the same *Cucurbita* species and same number of censuses performed. We used the PAST program (Paleontological Statistics 1,32, Hammer *et al.* 2001). Morisita's measure of similarity was used to compare sites for the numbers of individuals per species censused at *Cucurbita* flowers (Krebs 1989).

The diversity of floral visitors at *Cucurbita* in Santa Catarina was interpreted with regard to the quality of the surrounding vegetation at each locality.

RESULTS

The 27 censuses of bees at flowers of *Cucurbita* plus the insects captured in the pantraps together yielded 3.270 bees representing 50 bee species (Table II). Nearly all (96%) of the individuals belonged to just eight species of the bee family Apidae. The most abundant species was *Apis mellifera* (32%), followed by *P. fervens* with 25% of the individuals. The remains 3% (106 individuals) belong to the family Halictidae, with 35 species, some represented by just one exemplar; while bees of the families Andrenidae (5 species), Colletidae and Megachilidae (one species each) represent less than 1% in the bee richness.

Twenty-four bee species were counted during the 16h spent censusing bees at cucurbit flowers (Table II). The specialist bee *P. fervens* occurred in four of the seven studied sites. It was the predominant bee species visiting *Cucurbita* flowers at three of these places: Concórdia, Porto União and Rio do Sul. *Apis mellifera* occurred at all the studied sites, being dominant at two locations, Criciúma and Turvo. The third species in abundance at *Cucurbita* flowers, *Trigona spinipes*, occurred at all the sites except in Turvo.

In the pantraps, 30 bees species (117 individuals) were sampled surrounding the cucurbit crops. Most of these species (19) belong the Halictidae family, for which *Dialictus* was the most abundant and diverse genus.

Table II. Bee species recorded at *Cucurbita* flowers and captured in pantraps at Concordia (Con), Criciúma (Cri), Joinville/Mildau (J/Mil), Joinville/Quiriri (J/Qui), Porto União (P.U), Rio do Sul (Rio) and Turvo (Tur). Method of collection: Cen (censuses) and Pan (pantraps). In bold: individual bees from floral censuses, italic: bees from pantraps.

Family	Species	Study sites							Method		Total
		Con	Cri	J/Mil	J/Qui	P.U	Rio	Tur	Cen	Pan	
Colletidae	*Protodiscelis* sp.			*1*						*1*	1
Andrenidae	*Callonychium petuniae* Cure & Wittm. 1990	*5*				*2*				*7*	7
	Anthrenoides meridionalis (Schrottky, 1906)			*2*		*12*				*14*	14
	Psaenythia bergi Holmberg, 1884					*5*				*5*	5
	Rhophitulus flavitarsis (Schlindwein & Moure, 1998)					*1*				*1*	1
	Rhophitulus sp.3					*1*				*1*	1
Halictidae	*Augochlora* aff. *semiramis* (Schrottky 1910)		1			*3*				*4*	4
	Augochlora foxiana Cockerell, 1900	**1**							**1**		1
	Augochlora sp.5				**1**				**1**		1
	Augochlora sp.6				**6**				**6**		6
	Augochlora cydippe (Schrottky, 1910)	*1*								*1*	1
	Augochlora sp.9			*1*					***1***		1
	Augochlora sp.10				**1**				**1**		1
	Augochlora sp.11				**4**				**4**		4
	Augochlora sp.12			**1**	**2**		**1**	**1**	**5**		5
	Augochlora sp.14	*1*				*1*	**1**	**2**	**3**	*2*	5
	Augochlora amphitrite (Schrottky, 1910)	**3**+*1*				**3**			**6**	*1*	7
	Augochlora sp.17					**1**			**1**		1
	Augochlora sp.20				**1**				**1**		1
	*Augochloropsis cupreola (*Cockerell, 1900)				**1**			**1**	**2**		2
	Augochloropsis sp. 2					*1*				*1*	1
	Augochlorella ephyra (Schrottky, 1910)					*1*				*1*	1
	Ceratalictus sp.1				**2**				**2**		2
	Rhectomia sp.1					*1*				*1*	1
	Pseudaugochlora sp.1				**3**				**3**		3
	Temnossoma sp.1							**1**	**1**		1
	Temnossoma sp.2		*1*							*1*	1
	Agapostemon (N.) semimelleus Cockerell, 1900				**1**				**1**		1
	Dialictus sp.1					*1*				*1*	1
	Dialictus sp.2	*1*	*1*			*1*				*3*	3
	Dialictus sp.3	*3*	*1*							*4*	4
	Dialictus sp.6	*1*								*1*	1
	Dialictus sp.7	*1*	*3*							*4*	4
	Dialictus sp.10	*1*	*1*							*2*	2
	Dialictus sp.11	*13*	*1*			*11*				*25*	25
	Dialictus sp.12					*6*				*6*	6
	Dialictus sp.17	*3*								*3*	3
	Dialictus sp.23					*1*				*1*	1

Continuation of Table II.

	Neocorynura sp.3				**3**				**3**		3
	Pseudagapostemon (N.) cyanomelas Moure, 1958					*1*				*1*	1
	Pseudagapostemon sp.2				**1**				**1**		1
Megachilidae	*Coelioxys (G.) chacoensis* Holmberg, 1904					*1*				*1*	1
Apidae	*Apis mellifera* Linnaeus, 1758	**131**+*2*	**229**+*13*	**41**+*3*	**334**	**81**	**1**	**223**	**1040**	*18*	1058
	Bombus atratus Franklin, 1913				**4**	**2**	**25**		**31**		31
	Bombus morio Swederus, 1787		**3**	**9**	**423**		**36**	**2**	**473**		473
	Trigona spinipes Fabricius, 1804	**5**	**2**	**456**	**57**	**29**	**175**		**724**		724
	Melissoptila cnecomala (Moure, 1944)					*2*				*2*	2
	Peponapis fervens (Smith, 1879)	**144**	*1*		**2**	**216**+*2*	**477**		**839**	*3*	842
	Exomalopsis (E.) analis Spinola, 1853				**3**				**3**		3
	Exomalopsis (E.) tomentosa Friese, 1899		*1*							*1*	1
Total		317	258	514	849	386	716	230	**3153**	*117*	3270

The morpho-species number follows the numeration adopted by the Bees collection of the UNESC.

Just 4 species were common to both methods: *Augochlora* sp.14, *Augochlora amphitrite*, *A. mellifera* and *P. fervens*. Twenty-three species of bees were recorded only once in the two methodologies. Bees of the families Colletidae and Megachilidae were represented by only one individual.

The two most abundant bee species, *A. mellifera* and *P. fervens,* together accounted for 2/3 of the bees seen at *Cucurbita* flowers. Curiously, in one area where *P. fervens* dominated, *A. mellifera* was very sparse (Rio do Sul); conversely, in the three areas where honeybees abounded, *P. fervens* was sparse or absent. At three localities, Porto União, Rio do Sul and Concórdia, there were hives of honeybees on the properties, but in these places *A. mellifera* was not particularly abundant at cucurbit flowers. The general high abundance of apids in part reflects presence of four social species, whose colonies supply large populations of foragers.

The two sites with the most similar bee faunas at *Cucurbita* flowers (Table III) were Criciúma and Turvo. At both site, honey bees predominated and natives were rare to absent at squash flowers. Both had large squash fields surrounded by disturbed vegetation where the farmers used conventional tillage, insecticides and fungicides.

In the pantraps, besides the Hymenoptera, we captured Coleoptera, Diptera, Hemiptera and Orthoptera. Most insects were caught in the yellow pantraps (56%), followed by the white (24%) and blue (20%) pans. The bees in particular also showed preference to yellow pans (45%), followed by the blue (36%) and white (20%).

The Shannon index for the flower censuses (Table IV), which attributes higher values to the rare species, was slightly higher in Porto União, followed by Rio do Sul and Concórdia. From pan traps at Porto União, twelve species were considered rare (*Rhophitulus flavitarsis, Rhophitulus* sp.3, *Augochlora* sp.14 and sp.17, *Augochloropsis* sp.2, *Augochlorella ephyra*, *Rhectomia* sp.1*, Dialictus* sp.1, sp.2 and sp.23, *Pseudagapostemon (N.) cyanomelas* and *Coelioxys (G.) chacoensis*), while Rio do Sul and Concordia three and eight species respectively were rare. The Simpson index from the censuses (Table IV) tends to attribute higher value to the common species (more abundant). In this case Concórdia had slightly higher diversity, followed by Porto União and Rio do Sul, in the censuses. The most abundant common species were *P. fervens* and *A. mellifera*. The majority of the bees species captured in pantraps in general did not visit *Cucurbita* flowers.

PEPONAPIS FERVENS OBSERVATIONS

Small nesting aggregations of *P. fervens* were found adjacent to *Cucurbita* fields. In Rio do Sul, eight nests were found in the cultivated area, while in Porto União, three aggregations were found along the border of the *Cucurbita* plants and in a partly

Table III. Morisita similarity coefficients comparing the sample sites for their bee faunas censused at *Cucurbita* flowers.

	Con	Cri	J/Mil	J/Qui	P.U	Rio	Tur
Con	1.00						
Cri	0.64	1.00					
J/Mil	0.09	0.10	1.00				
J/Qui	0.42	0.58	0.17	1.00			
P.U.	0.92	0.33	0.15	0.23	1.00		
Rio	0.70	0.01	0.33	0.10	0.92	1.00	
Tur	0.64	1.00	0.10	0.57	0.33	0.00	1.00

Table IV. Diversity index of Shannon-Wiener and Simpson obtained for the censuses of the bees on *Cucurbita* flowers in three studied localities and for the bees captured on pantraps in two localities.

Location	Census		Pantraps	
	Shannon	**Simpson**	**Shannon**	**Simpson**
Concórdia	0.84	0.52	2	0.80
Porto União	0.92	0.50	2.5	0.88
Rio do Sul	0.91	0.49		

cleared areas (free of vegetation). In these localities the farmers used no pesticides.

One aggregation in Porto União occupied an area of 30m x 4.5m, located 500m from the *Cucurbita* field. There we found 230 nest entrances. A second aggregation of 122 nest entrances was in an area of about 10m x 3.5m. It also was distant from the squash field (100m). A third aggregation (2.7m x 2.6m) was in a soil bank and had about 25 nest entrances.

The entrance of each nest was surrounded by a small tumulus of excavated loose grains of soil (Figure 2E). The main tunnels were 6-8mm in diameter and, in the most cases, they were vertical and straight except where obstacles like stones or roots caused them to deviate (Figures 2F and 2G). In two of the six excavated nests, the tunnels were incomplete. In three nests, the long axis of the cells were oriented vertically at the far end of the tunnel. The single cells were found 23 to 45 cm deep. The cells were ovals in vertical longisection and radially symmetric in cross-section. The provision of pollen and nectar occupies the bottom third of the cell (Figure 2H). The egg is placed above the provision. The pollen mass is yellow and composed of uniform large pollen grains. The analyses of the provision of three different cells revealed 100% pollen from *Cucurbita.*

Females of *P. fervens* collect nectar and pollen from the *Cucurbita* flowers early in the morning, from 6:30 AM to 13:30 PM, or until the flowers close. Males also drink nectar and patrol among the *Cucurbita* flowers for potential mates. Males of *P. fervens* were observed to use the staminate flowers to spend the night, as a sleeping place. Sometimes more then one male was seen in the same flower in the evening.

The size of the *P. fervens* population (females and males) was not estimated in each locality. But in both places where we found its nests (Rio do Sul and Porto União), the proportion of this specialist bee to the number of *Cucurbita* flowers was higher (Table V). This table also shows that even in the areas where we sampled a lot of flowers, *P. fervens* was absent (Joinville and Criciúma) or has very low representatives.

DISCUSSION

Analyzing the local bee faunas and pollinators of in Santa Catarina, we found among the flower visitors (24 bee species) the specialist squash bee, *P. fervens*, in 4 localities. Bees of this genus have attributes for a good pollinator, like body size, species fidelity and frequent contact with the floral sexual organs (Hurd *et al.* 1971). At *C. pepo*, 2-3 visits by females (Tepedino 1981, Cane *et al*. submitted) or seven floral visits by male *P. pruinosa* (Cane *et al.* submitted) maximized fruit set and growth. We expect that cultivated *Cucurbita* should be well-pollinated at least in three of the study sites, in Santa Catarina: Rio do Sul, Porto

Table V. Number of flowers, number of *Peponapis fervens* observed (males and females), and number of *P. fervens* per 100 squash flowers, in each locality.

Locality	Flowers	*P. fervens*	*P. fervens/flowers* X 100 flowers
Joinville - Mildau	1638	0	-
Joinville - Quiriri	3042	2	0.006
Turvo	123	0	-
Concórdia	982	144	14.66
Porto União	1071	216	20.16
Rio do Sul	1338	477	35.6
Criciúma	618	0	-

União and Concórdia. In this locations *P. fervens* were abundantly sampled, and they were easily numerous enough at flowers to provide all of the pollination.

At two of the study sites, *P. fervens* even outnumbered the honeybee at *Cucurbita* flowers: Porto União and Rio do Sul. At these two farms, squash bees had established their nests alongside the cultivated patches, providing many individuals to pollinate the cucurbits. The analyses of the provision of the brood cells from these nests revealed 100% pollen from *Cucurbita*, further evidence that *P. fervens* depends on *Cucurbita* for pollen to feed their larvae. In provisioning their nest cells, it would seem that female squash bees will visit many flowers in the cultivated area during the flowering season.

The association of *Peponapis* bees and its *Cucurbita* hosts is mutualistic. The dependence of *Peponapis* bees on *Cucurbita* flowers was demonstrated in other works (Hurd & Linsley 1967, Hurd *et al*. 1971), which corroborate the results of this study. Canto-Aguilar & Parra-Tabla (2000) showed the pollination benefits of *Peponapis limitaris* for cultivated *Cucurbita moschata*, which was four times more efficient in the pollen transference then the honeybee.

In Criciúma, a single *P. fervens* was caught in the pantraps, but none seen in nearly three hours of observing flowers. The absence or sparsity of *P. fervens* at some sites may reflect several factors. Too few years of squash cultivation in the locale may have provided inadequate time for colonization, as could spatial isolation from the nearest farm growing squashes and populated with *Peponapis*. This attribute alone is not predictive of the presence of *Peponapis*, however, as squashes had long been cultivated at the Criciúma site but *Peponapis* remained absent. Furthermore, regular cultivation of squashes each year is needed to increase populations of *Peponapis*. Poor use, timing or choice of pesticides in the fields, especially broad-spectrum insecticides, could have killed resident bee populations. Lastly, no adequate sites for nesting may have existed nearby, although this seems doubtful from our observations and nest excavations.

Besides the squash bee, some other flower visitors recorded in the study sites are potential pollinators, as proposed by Meléndez-Ramirez *et al.* (2002). For instance, Tepedino (1981) reported that another halictid bee, *Agapostemon coloradinus*, was an abundant visitor and promising pollinator of cultivated squashes. This was also the case for several species sampled during this study, including the two species of bumble bees, the larger-bodied *Augochlora* species (like *Augochlora amphitrite* and *Augochlora* sp.6), *Trigona spinipes* and the exotic *Apis mellifera*. All were often abundant and appeared to frequently contact anthers and stigmas of squash flowers. The honeybee, which was recorded in all the study sites observed here, was also a primary pollinator of *Cucurbita mixta* in São Paulo, southeastern Brazil (Lattaro & Malerbo-Souza 2006).

Meléndez-Ramirez *et al.* (2002) recorded 58 bee species at *Cucurbita* flowers in Yucatán, Mexico. But they show that among them, 7 species were dominant, including two species of *Peponapis*. To these authors, other visitors like *Augochlora*, *Partamona* and *Ceratina* warrant study attention as regional pollinators of *Cucurbita* due to their abundance and observed contact with sexual flower structures. Lenzi et al. 2005 found *Bombus morio* and one species of *Augochlora* as potential pollinator of *Momordica charantia* L. (Cucurbitaceae) in Florianópolis, an island off the coast of Santa Catarina.

The generalist status of cucurbit flowers with respect to pollinator guild was argued by Ashworth & Galetto (2001) while studying wild populations of *C. maxima* ssp. *andreana* in Argentina. Besides one *Peponapis* species, they found two coleopteran

species with appropriate behavior for the efficient in pollen transference.

BEE DIVERSITY IN THE PANTRAPS

In Brazil, pantraps are being used recently to maximize sampling results in some places (e.g. Krug & Alves-dos-Santos 2008) or to evaluate composition of the insect faunas associated with particular agricultural practices (Souza 2006). According to Droege *et al.* (2010), pan traps are suitable tools for the sampling of bees, as they are inexpensive, don't need special entomological training to use, and presumably capture most of the species present in a community. The last assertion was not true in this study, where the pan trap samples of bees among flowering squashes were uninformative regarding the guild of bees that visit flowering squashes, even though hundreds of individual bees were active at the flowers. The majority of the bees species captured in pantraps did not visit the cucurbit flowers. That is to say, pan-sampling in this case was did not represent a populous pollinator guild, even at a dominant flowering species. Therefore, pan trapping was no substitute for net collecting at the squash flowers. Pantraps at Porto União did have higher diversity in terms of bee fauna, which we believe to be related to the well preserved surrounding habitat at this site.

PEPONAPIS FERVENS *OBSERVATIONS*

Other species of the genus *Peponapis* demonstrate similar nesting habits to *P. fervens*, building the nests associates to squash or pumpkin plants (Hurd *et al.* 1974, Mathewson 1968, Rozen & Ayala 1987). Although Michener & Lange (1958) had evidences that more than one cell was constructed in the same tunnel, most of our observations on the nest structure of *P. fervens* otherwise agree with the results presented in that study performed in Paraná state, as well as the results for *P. utahensis* found by Rozen & Ayala (1987) in Chamela, Mexico.

FINAL REMARKS

The importance of native bee pollination for commercial crops of southern Brazil has been shown occasionally, such as for passion fruit (*Passiflora*), where the plant depends completely on the carpenter bees to be pollinated (Camillo 2003, Siqueira *et al*. 2009). Another study showed that the native bee *Trigona spinipes* is as efficient as *Apis mellifera* for strawberry pollination (Malagodi-Braga & Kleinert, 2007). Other cases may await discovery. Thus, demonstrating the importance of native bees as pollinators and motivate their rational use.

Our results show that at all 6 study sites we found some native bees visiting *Cucurbita* flowers with some attributes for a good pollinator, such as larger body size, and frequency and contact with the floral sexual organs. *Peponapis fervens* additionally shows fidelity to the plant, as evidenced by their larval provisions of pure *Cucurbita* pollen. This species seems to be quite common in southern Brazil, and therefore represents an available, dedicated and free alternative regional pollinator for squash and pumpkin crops.

According to Shuler *et al.* (2005), squash bee population density was influenced by tillage practice but not by pesticide use. Therefore, we believe that even for the sites where the surround was disturbed and the farmers used pesticides (Criciúma, Joinville-Mildau and Turvo), the native fauna of squash pollinators could multiply following farming practices favorable to the bees because some of the bees are present there already.

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