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INTERAÇÕES AGONÍSTICAS ENTRE ABELHAS VISITANTES DA FLOR DE *Solanum lycocarpum* (SOLANACEAE)

AGONISTIC INTERACTIONS AMONG BEES VISITORS OF *Solanum lycocarpum* (SOLANACEAE) FLOWER

INTERACCIONES AGONÍSTICAS ENTRE ABEJAS VISITANTES DE LA FLOR DE *Solanum lycocarpum* (SOLANACEAE)

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Resumo

A demanda por recursos florais, o alto gasto energético durante o forrageamento e o número limitado de flores podem resultar em diferentes níveis de competição inter e intraespecífica entre abelhas. Este trabalho teve como objetivo estabelecer as categorias de interações intra e interespecíficas envolvendo espécies de abelhas durante o forrageamento nas flores de *Solanum lycocarpum*. A atividade de forrageamento das abelhas foi registrada por 12 dias, não necessariamente consecutivos, ao longo de todo o período de floração, entre 6h00 e 17h15, nos primeiros 15 minutos de cada hora, totalizando 132 horas de observação. Foram registrados o número de flores visitadas e as interações agonísticas intra e interespecíficas. Foi realizada análise faunística para definir as classes, abundância, frequência, constância e dominância das espécies. Das 10 espécies de abelhas registradas, foram classificadas

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como constantes: *Centris scopipes*; *Augochlora* sp.; *Augocloropsis* sp.; *Exomalopsis fulvofasciata*; *Bombus* sp.; *Oxaea flavescens*. Foram registrados 401 encontros agressivos, contemplando diferentes interações agonísticas. Essas interações foram observadas apenas entre as espécies *O. flavescens*, *E. fulvofasciata*, *Augochlora* sp. e *Augochloropsis* sp. As espécies *O. flavescens* e *E. fulvofasciata* estiveram mais frequentemente envolvidas em combates nos quais saíram vencedoras, exercendo, assim, dominância em relação à área de forrageamento, sendo o "confronto na flor" a ação mais constante, tanto nas interações intra quanto interespecíficas. Esses padrões são discutidos como dominância comportamental na escala da flor, e a alteração do habitat é tratada como uma hipótese contextual plausível, porém ainda não testada.
Palavras-chave: Competição; recursos florais; visitantes florais; sobreposição de nicho.

Abstract

The demand for floral resources, the high energetic cost of foraging, and a limited number of flowers can generate different levels of intra- and interspecific competition among bees. We quantified foraging activity and agonistic interactions among bee visitors of *Solanum lycocarpum* (Solanaceae), a buzz-pollinated plant with poricidal anthers. Bee activity was recorded on 12 non-consecutive days across the flowering period, from 06h00 to 17h15, during the first 15 minutes of each hour (132 h of observations). We recorded flower visits and agonistic encounters and performed a faunistic analysis (abundance, frequency, constancy, and dominance). Ten bee species visited *S. lycocarpum*; six were classified as constant (*Centris scopipes*, Augochlora sp., *Augochloropsis* sp., *Exomalopsis fulvofasciata*, *Bombus* sp., and *Oxaea flavescens*). We recorded 401 agonistic encounters, restricted to *O. flavescens*, *E. fulvofasciata*, *Augochlora* sp., and *Augochloropsis* sp. The composition of behavioral acts differed among species (chi-square test, $p < 0.001$), and when standardized by visitation effort, *E. fulvofasciata* and *O. flavescens* showed the highest interaction rates. In interspecific encounters with a recorded outcome, *O. flavescens* and *E. fulvofasciata* displaced opponents in all cases observed. These patterns are discussed as behavioral dominance at the flower scale, and habitat alteration is treated as a plausible, but untested, contextual hypothesis.
Keywords: Competition; floral resources; floral visitors; niche overlap.

Resumen

La demanda de recursos florales, el alto gasto energético durante el forrajeo y el número limitado de flores pueden resultar en diferentes niveles de competencia inter e intraespecífica entre las abejas. Este trabajo tuvo como objetivo establecer las categorías de interacciones intra e interespecíficas que involucran especies de abejas durante el forrajeo en las flores de *Solanum lycocarpum*. La actividad de forrajeo de las abejas se registró durante 12 días, no necesariamente consecutivos, a lo largo de todo el proceso de floración, entre las 6:00 h y las 17:15 h, en los primeros 15 minutos de cada hora, totalizando 132 horas de observación. Se registraron el número de flores visitadas y las interacciones agonísticas intra e interespecíficas. Se realizó un análisis faunístico para definir las clases, abundancia, frecuencia, constancia y dominancia de las especies. De las 10 especies de abejas registradas, se clasificaron como constantes: *Centris scopipes*; *Augochlora* sp.; *Augocloropsis* sp.; *Exomalopsis fulvofasciata*; *Bombus* sp.; *Oxaea flavescens*. Se registraron 401 encuentros agresivos, que incluyeron diferentes interacciones agonísticas. Estas interacciones se observaron únicamente entre las especies *O. flavescens*, *E. fulvofasciata*, *Augochlora* sp. y *Augochloropsis* sp. Las especies *O. flavescens* y *E. fulvofasciata* participaron con mayor frecuencia en combates en los que resultaron ganadoras, ejerciendo así dominancia en relación con el área de forrajeo, siendo la "confrontación en la flor" la acción más constante, tanto en las interacciones intra como interespecíficas. Estos patrones se discuten como dominancia conductual a escala de la flor, y la alteración del hábitat se considera una hipótesis contextual plausible, aunque no comprobada.
Palabras clave: Competência; recursos florales; visitantes florales; solapamiento de nicho.

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1. Introduction

Bees visit plants to collect floral resources, especially nectar and pollen, which may be limited within a community, causing competition among individuals (Johnson & Hubbell, 1974; Inouye, 1978; Roubik, 1982). The high energetic expenditure involved in the search for food, combined with the potentially limited number of flowers, can result in different scales of interspecific and intraspecific competition for resources (Antunes, 2003). Competition can occur either indirectly, through simple exploitation of resources, or directly, with interference in the behavior or intensity of foraging during resource exploration (Duijns & Piersma, 2014). Thus, when resources are abundant, competitive interactions tend to be less intense. However, when the number of flowers is limited and resource availability is lower, interactions tend to increase in intensity (Ricklefs, 2003; Ye et al., 2025; Walters et al., 2024).

Interspecific competition, due to the niche overlap, may present intense variations, but competition during foraging tends to be more intense intra intraspecifically, since individuals of the same species share similar resources (Ferreira & Absy, 2015; Ye et al., 2025).

The presence of bees exploring a floral resource may suggest the profitability of this resource for other bees (Leadbeater & Chittka, 2005; Kawaguchi et al., 2006). In response to interference from other interspecific or intraspecific individuals, bees can alter their patterns of flower visitation spatially, as a function of their distribution on the plant (Goulson et al., 2001; Reader et al., 2005; Goulson et al., 2008; Ishii et al., 2008) or temporarily, by altering foraging times during the exploitation of a particular floral resource (Morse, 1981; Nagamitsu & Inoue, 1997).

However, there is little understanding of how intraspecific and interspecific encounters among bees on flowers can affect subsequent foraging behavior and, in turn, shape the foraging community associated with a particular resource (Rogers et al., 2013; Miner & Wilson Rankin, 2025).

There are few reports of aggressiveness in bees related to the defense of resources within foraging areas, a behavior that allows greater access to the exploited

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resource (Johnson & Hubbell, 1975; Nagamitsu & Inoue, 1997; Nieh et al., 2005), illustrating dominance among individuals and/or species during disputes over these areas (Gass, 1979; Ewald & Rohwer, 1980; Miner & Wilson Rankin, 2025).

There is still a lack of studies addressing competition for floral resources among solitary bees during foraging activities, especially in plant species that require specialized pollinators, such as those with poricidal anthers. Species of the genus *Solanum* present flowers with poricidal anthers (Souza & Lorenzi, 2005), which makes them dependent on specialized bees for pollination. Thus, this study aimed to establish the types of intraspecific and interspecific interactions involving bee species during foraging on the flowers of *Solanum lycocarpum*, in order to address the following questions: How do interactions occur within the bee visitor guild of *Solanum lycocarpum*? Do these interactions influence the foraging activity of these bees? (Delgado et al., 2023; Russell et al., 2024; Woodrow et al., 2024)

2. Materials and Methods

Characterization of the area

The study was conducted in a secondary fragment of Seasonal Semideciduous Forest (22º16’43” S, 53º48’47” W), located in a rural area of the municipality of Ivinhema, state of Mato Grosso do Sul. The area is composed of vegetation resulting from a regeneration process, as the primary vegetation was replaced by eucalyptus cultivation and later recolonized by native species after the end of silvicultural activities. According to Alvares (2013), the climate of the region is classified as tropical (Aw), with dry winters, under the influence of a humid subtropical climate (Cfa) characterized by hot summers.

Experimental Design

Bee visitation rates were estimated following Polatto & Alves Jr. (2008). Observations were conducted on 12 non-consecutive days throughout the flowering period, from 06:00 to 17:15. During each hour, bee visits were recorded in the first 15

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minutes, totaling 132 hours of standardized sampling. The remaining 45 minutes of each hour were used for quantitative and qualitative observations of behavioral interactions among bees, distinguishing between intraspecific and interspecific encounters during foraging.

The sampling effort (12 days spanning the full flowering period and hourly stratification throughout the day) was chosen to capture within-day and among-day variation in bee activity typical of field studies of floral visitation, while maintaining a standardized observation window (Polatto & Alves Jr., 2008). Because agonistic behavior can be episodic, distributing observations across the entire flowering period reduces the risk of drawing conclusions from short-term peaks in activity.

The number of flowers visited, and the intraspecific and interspecific agonistic interactions were recorded. The faunistic analysis to define species abundance, frequency, constancy, and dominance classes was conducted according to the methods of Silveira Neto et al. (1976). A confidence interval (CI) of 95% to 99% was determined, and from this interval the following abundance classes were established: VA= very abundant (number of individuals greater than the upper limit of the CI to 99%); A= abundant (number of individuals between the upper limit of 95% CI and 99% CI); C= common (number of individuals within the 95% CI); D= dispersed (number of individuals between the lower limits of the 95% CI and 99% CI) and R= rare (number of individuals lower than the lower limit of the 99% CI).

Still according to Silveira Neto et al. (1976), the frequency of individuals of a species relative to the total collected, the confidence interval (CI) for the mean frequency with 95% probability is determined by adopting the following classification: VF= very frequent (frequency greater than upper limit of 95% CI); F= frequent (frequency located within the 95% CI) and LF= less frequent (frequency lower than the lower limit of the 95% CI).

Using the frequency of observations throughout the day of a certain species, the constancy was calculated (Silveira Neto et al., 1976) as follows: C= (number of collections of the species “X”/total number of collections) x 100, being classified as: W= constant (C ≥ 50%); Y= accessory (C ≥ 25 and >50%) and Z= accidental (C< 25%). Finally, dominant species were those whose frequency values exceeded the limit

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calculated by the formula: D = 1/total number of species x 100. The BioEstat 5.0 program was used to determine the confidence intervals and to calculate the correlation tests of Pearson (Ayres et al., 2007).

To verify the differences in the number of visits between the two observation periods (morning and afternoon), the Mann-Whitney test was also applied using the BioEstat 5.0 software.

Agonistic interactions were summarized as (i) the number of encounters and (ii) the distribution of encounters among behavioral categories (Table 1). To compare the composition of interactions among species, we built a species-by-behavior contingency table (Table 4) and applied a chi-square test of independence. To reduce bias due to differences in visitation effort, we computed interaction rates as the number of agonistic encounters per 100 flower visits for each species involved in agonistic interactions (Table 6).

For behavioral interactions, the term “dominance” was used strictly at the flower/encounter scale: the dominant individual (or species) was defined as the one that displaces the opponent from the flower and retained access to the resource at the end of the encounter. This operational definition does not imply population-level or landscape-level competitive dominance.

The different agonistic interactions between bees visiting flowers of *S. lycocarpum* are defined in Table 1.

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Table 1. Classification of different agonistic interactions exhibited by bees visiting flowers of *Solanum lycocarpum*.

Behavior /acronym	Definition
Frontal confrontation – Fc	Bees crash head-on in flight
Lateral confrontation – Lc	Bees crash laterally in flight
Air confrontation – Ac	Bees grab and fly in turns
Confrontation in the flower – Cf	Bee expelled the other one of the flower when it bumps against the opponent
To bite – Bi	The bee bites the opponent to expel it from the flower
Chasing – Ch	Bee chase the opponent (the opponent, in this case, keeps fleeing)
Chasing in circles – Chc	A bee flies behind the other one in circles
Sentinel – St	Bee hovers over the flower for a few seconds, preventing the foraging of other bees
Indentation – Id	Bee diverts from flower in which another bee is foraging

Some specimens of each bee species visiting *S. lycocarpum* flowers were collected, filmed and photographed. The collected specimens were sacrificed in a lethal chamber containing ethyl acetate and stored in 50 ml vials. Subsequently, they were identified using specialized literature (Silveira et al., 2002; Michener, 2007) or by comparison with other specimens from the Laboratório de Apicultura (LAP) of the Faculdade de Ciências Biológicas e Ambientais (FCBA), Federal University of Grande Dourados. All identifications followed standard taxonomic procedures to ensure consistency and accuracy.

3. Results

The species of bees recorded in order of abundance that visited the flowers of *S. lycocarpum* were: *Oxaea flavescens* Klug, 1807; *Exomalopis fulvofasciata* Smith, 1879*; Centris scopipes* Friese, 1899*; Augochlora* sp.; *Augochloropsis* sp.; *Bombus* sp.*; Apis mellifera* Linnaeus, 1758*; Epicharis maculata* Smith, 1874*; Xylocopa frontalis* Oliver, 1789; and *Epicharis flava* Friese, 1900 (Figure 1).

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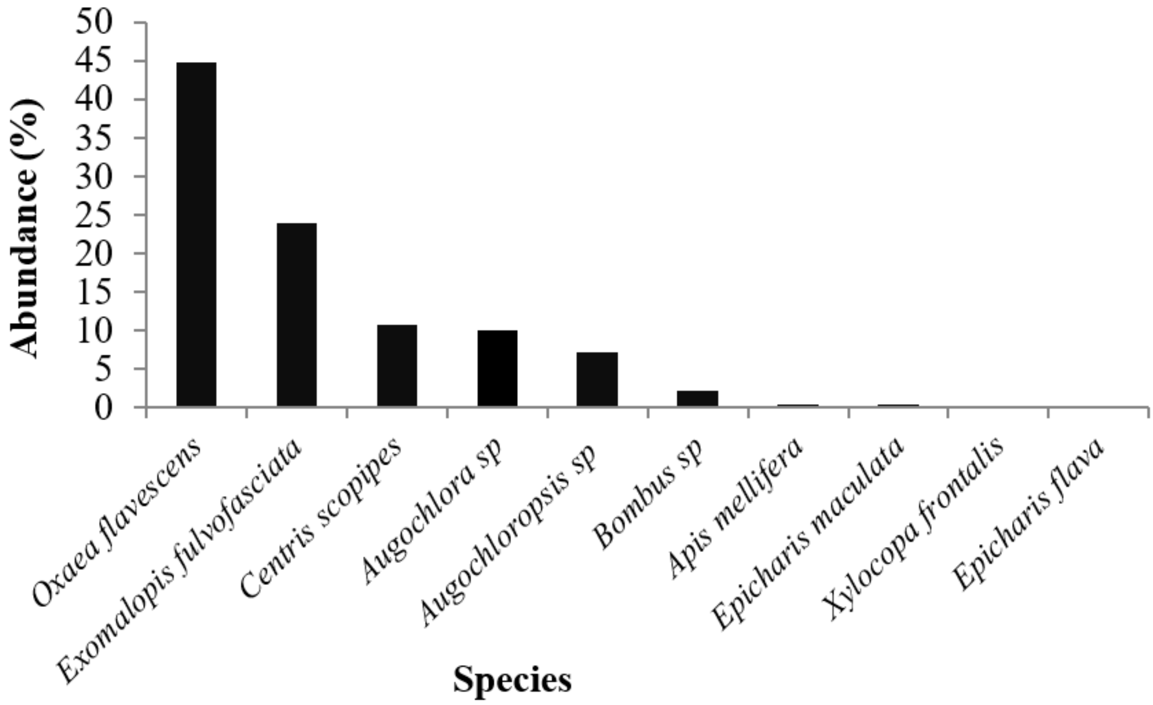

Figure 1. Abundance of bee species visiting *Solanum lycocarpum* flowers in a forest fragment in the municipality of Ivinhema, MS, Brazil.

Of the 10 bee species recorded, the following were classified as constant: *C. scopipes; Augochlora* sp.; *Augochloropsis* sp.; *E. fulvofasciata; Bombus* sp.; and *O. flavescens.* The species classified as accidental were *E. flava; E. maculata;* and *X. frontalis,* while *A. mellifera* was classified as an accessory species (Table 2).

Most of the collected bees (60%) were classified as non-dominant due to their low visitation rates and together accounted for only 3.4% of the specimens foraging on *S. lycocarpum* flowers.

Four species were dominant in flower visits, as follows: *C. scopipes; Augochlora* sp.*; E. fulvofasciata;* and *O. flavescens*, accounting for 96.6% of the individuals sampled.

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Table 2. Foraging intensity of bees on *Solanum lycocarpum* flowers in a secondary forest fragment in Ivinhema, MS, Brazil, in 2015.

Species	%	Abundance	Frequency	Constancy	Dominance
Apidae					
A. mellifera	0,5	D	Lf	Y	Nd
E. flava	0,1	R	Lf	Z	Nd
C. scopipes	10,7	Va	F	W	D
E. maculate	0,3	R	Lf	Z	Nd
Augochlora sp	*10,1*	*Va*	*F*	*W*	*D*
Augochloropsis sp	*7,2*	*Va*	*F*	*W*	*Nd*
E. fulvofasciata	*24*	*Va*	*F*	*W*	*D*
Bombus sp	2,2	C	Lf	W	Nd
X. frontalis	0,2	R	Lf	Z	Nd
Andrenidae					
O. flavescens	44,7	Va	Vf	W	D

Va = very abundant; R= rare; C=common; Vf = very frequent; F = frequente; Lf = less frequent, W = constant; Y = accessory; Z = accidental, D = dominant; Nd = not dominant.

Flower visitation on *S. lycocarpum* flowers was more intense and involved higher species richness during the morning than during the afternoon (Table 3; Mann-Whitney U = 0.2418; p = 0.0250). *Centris scopipes* and *O. flavescens* were the only species active at 06:00 h. *Augochlora* sp. and *E. fulvofasciata* began activity at 07:00 h, and most species concentrated their visits between 07:00 and 11:00 h (Table 3).

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Table 3. Abundance of different bee species on *Solanum lycocarpum* flowers throughout the day.

Bee species	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	Total
Apidae													
A. mellifera	0	0	3	1	0	0	0	0	0	0	1	0	4
E. flava	0	0	0	1	0	0	0	0	0	0	0	0	1
C. scopipes	13	8	11	11	7	1	5	3	10	16	3	3	91
E. maculata	0	1	1	0	0	0	0	0	0	1	0	0	3
Augochlora sp	0	10	16	25	18	11	3	2	1	0	0	0	86
Augochloropsis sp	0	0	13	15	6	23	1	3	0	0	0	0	61
E. fulvofasciata	0	32	39	47	34	22	10	9	4	7	0	0	204
Bombus sp	0	3	0	0	0	2	1	0	2	0	10	1	19
X. frontalis	0	0	0	0	2	0	0	0	0	0	0	0	2
Andrenidae													
O. flavescens	18	72	60	68	47	43	23	17	16	15	2	0	381
Total	31	126	150	157	114	102	43	34	33	39	15	4	852

A total of 401 agonistic encounters were recorded (Table 1), occurring predominantly during the morning.

Agonistic interactions were recorded only among *O. flavescens*, *E. fulvofasciata*, *Augochlora* sp., and *Augochloropsis* sp., which were the most frequent visitor species. The number of aggressive encounters decreased in the afternoon, concomitantly with reduced visitation rates (Table 3).

Across all encounters, 401 agonistic interactions were classified into behavioral categories (Table 1). “Confrontation in the flower” (Cf) was the most frequent interaction (n = 235, 58.6%). The distribution of interaction types differed among species (chi-square test: $\chi^2 = 189.15$, df = 21, $p < 0.001$). When standardized by visitation effort (Table 3), *E. fulvofasciata* and *O. flavescens* exhibited the highest interaction rates (Table 6).

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Table 4. Quantitative and qualitative aspects of agonistic interactions among bee species visiting *Solanum lycocarpum flowers* in a rural area of Ivinhema, MS, Brazil*.*

Species of bees	*C. scopipes*	*Augochlora* sp	*Augochloropsis* sp	*E. fulvofasciata*	*O. flavescens*
Augochlora sp		Cf=8 Bi=3	Bi=1	Cf=3	Id=8
Augochloropsis sp		Cf= 5 Bi=1	Cf= 11		Id=4
E. fulvofasciata		Cf=18 Bi=6	Cf=32 Bi=16	Cf=26 Bi=18	Id= 21
O. flavescens	Cf=3	Cf=6	Cf=11	Cf= 16	Cf=68 Cf=28 Lc=12 Ch=30 Ac=13 Chc=15 Fc=18

Fc = Frontal confrontation; Lc = Lateral confrontation; Ac = Air confrontation; Cf = Confrontation in the flower; Ch = Chasing; Chc = Chasing in circles; St = Sentinel; Id = Indentation; Bi = Bite.

Table 6. Agonistic encounters recorded for each species, standardized by visitation effort.

Species	Flower visits (n)	Agonistic encounters (n)	Encounters per 100 visits
Augochlora sp	86	23	26.7
Augochloropsis sp	61	21	34.4
E. fulvofasciata	204	137	67.2
O. flavescens	381	220	57.7

4. Discussion

Except for *A. mellifera*, which does not exhibit anther vibration behavior, the other species observed visiting *S. lycocarpum* flowers follow the general behavioral pattern known for flowers with poricidal anthers, as described by Buchmann (1983). In this pattern, the bees land and, on that occasion, perform anther vibrations to remove pollen, as described for *S. lycocarpum* by Tavares et al. (2014) and more recently by Russell et al. (2024), Woodrow et al. (2024), Xu et al. (2025).

During the few visits to *S. lycocarpum* flowers, *A. mellifera* (Figure 1) collected

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only residual pollen from the corolla, without directly interacting with other species during foraging.

Oxaea flavescens was the species most involved in agonistic encounters, with interactions prevailing among individuals of the same species. Behavioral observations indicated *O. flavescens* as the dominant species, most often exhibiting "flower confrontation" in interspecific interactions and frontal confrontations in intraspecific interactions. During foraging, *O. flavescens* chased other bees that were already collecting pollen, often asserting dominance over the contested flower. In each frontal encounter, they collided with the opponent an average of 3.66 ± 1.86 times.

Oxaea flavescens and *E. fulvofasciata*, when interacting with other species, were successful in 100% of the conflicts.

Table 5. Quantitative summary of agonistic encounters among bee species visiting *Solanum lycocarpum* flowers, indicating the aggressor, the attacked species and the respective winner of each conflict, in a forest fragment in Ivinhema, MS, Brazil.

Species attacked	Winners: O. flavescens	Winners: E. fulvofasciata
C. scopipes	3	0
Augochloropsis sp.	11	48
Augochlora sp.	6	24

Exomalopsis fulvofasciata, when disputing flowers, proved to be highly aggressive and attacked conspecific bees flying towards them, colliding with the opponent and, on many occasions, expelling other individuals by vigorously biting their wings. Individuals of *E. fulvofasciata* avoided foraging near flowers occupied by conspecifics.

As a larger and more aggressive species, *O. flavescens* may influence the activity of other bees. Balfour et al. (2015) evaluated the exclusion of large and medium-sized bees competing in the environment and found that large bees limit and interfere with the activity of smaller bee species. They concluded that competition for foraging resources exerts a strong influence on the formation and maintenance of the bee community studied.

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In a naturally stable environment, interactions among bee species tend to remain in equilibrium; in other words, they use flower resources equitably (Wilms et al., 1996).

However, changes due to fragmentation and habitat loss can reduce vegetation density and diversity, thereby decreasing the amount of floral resources available to maintain the population of their visitors and, consequently, of pollinators (Rathcke & Jules, 1993; Murcia, 1996). This reduction increases competition among them for the limited resources, both for their own maintenance and for offspring development (Librán-Embid et al., 2024; Olhnuud et al., 2025).

In addition to changes in environmental conditions, an increase in competitive pressure can be expected following the introduction of new competitors or an increase in the abundance of a competitor that is highly dominant (Steffan-Dewenter & Tscharntke, 2000), as observed for *O. flavescens* on *S. lycocarpum* flowers (Beaurepaire et al., 2025).

Intense competition among bee species for the same resource can result in more restricted foraging, displacement or aggressive interactions. For example, agonistic interactions caused by interference (physical obstruction or aggressive behavior) and exploratory competition (reduction of available resources), or both, may contribute to explaining why bees are more likely to leave a plant when they encounter another bee there (Rogers et al., 2013). These mechanisms may account for the behaviors observed in this study (Walters et al., 2024; Ye et al., 2025).

Bees, such as some species of *Bombus* spp., have altered their foraging area and diet breadth in the presence of conspecific bees (Makino & Sakai, 2005; Fontaine et al., 2008). Interspecific contact among bees often results in the displacement of some species (Pinkus-Rendon, 2005), which helps explain why certain species are more sensitive to interference competition than others (Rogers et al., 2013).

The observed patterns are interpreted primarily as resulting from differences in visitation, behavioral strategies, and flower-level interference among the most frequent species. While habitat alteration and reduced floral resource availability could plausibly intensify competition, this study did not quantify environmental metrics (e.g., vegetation cover, floral density, or pollen availability) nor include control sites.

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Therefore, any reference to habitat alteration should be considered a contextual hypothesis rather than a demonstrated causal explanation.

Pollinators such as solitary bees (Michener, 2007) collected in this study are more vulnerable to habitat fragmentation, as they often occur in small populations with a clustered distribution (Quesada et al. 2004). Likewise, plants with a specialized pollinator system, such as *S. lycocarpum*, in which flowers are pollinated by bees capable of vibrating their anthers (poricidal), become most vulnerable because they rely on a limited number of pollinators species (Bond, 1994) (Delgado et al., 2023).

There was a marked overlap between species in their exploration of *S. lycocarpum* flowers with respect to pollen foraging schedules (Table 3), as well as similarities in their pollen-collecting behavior, which intensified interspecific competition. No separation of species in niches (habitat, resources, or time) was observed, which according to Jones et al. (2001), would reduce overlap in resource use and competition, thereby promoting coexistence among species.

Exomalopsis fulvofasciata, for example, the smallest bee among those recorded, persisted in foraging even after being attacked, particularly by *O. flavescens*, which attacked more frequently, quickly returning to the flowers after being expelled. This behavior is likely related to the availability, quantity, and quality of the collected resource (pollen), with these factors exerting a strong influence on the bees' decision to continue foraging, even at the risk of aggressive attacks by larger species.

Studies performed by Silva et al. (2013), Polatto et al. (2014), and Tavares et al. (2015) report that the availability of floral resources greatly influences the intensity of bee foraging on flowers, corroborating observations made on the flowers of *S. lycocarpum*.

Although intense competition for foraging areas may be disadvantageous for the bees due to the energy expenditure and time involved, resulting in varied forms and intensities of agonistic behaviors, activity overlap among bees may, however, be advantageous for reproduction of *S. lycocarpum.* As foraging intensity increases, the amount of pollen grains deposited on the stigmas of its flowers is likely to increase,

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favoring the pollen transfer between individuals and thus promoting cross-pollination.

6. Conclusion

Intense intraspecific and interspecific interaction involving bee species were observed during foraging on the flowers of *S. lycocarpum.*

The species *O. flavescens* and *E. fulvofasciata* were more frequently involved in combats, in which they were victorious, thus exerting dominance over the foraging area, with “flower confrontation” being the most frequent action, both in intraspecific and interspecific interactions.

Habitat alteration and changes in resource availability may influence the intensity of competition; however, such effects were not directly measured in this study and should be treated as hypotheses to be tested in future comparative studies.

Although intense competition for the foraging area may be disadvantageous to the bees because it entails different forms and intensities of agonistic behavior, it can be advantageous for *S. lycocarpum* reproduction, since increased foraging contributes to more pollen grains being deposited on the stigmas of its flowers, thereby increasing reproductive success.

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