Influence of surrounding vegetation on the diversity of social wasps on coffee culture

Gabriel de Castro Jacques[1]

Bruna Síntia Silva de Araújo[2]

Abstract

Every year, coffee crops are affected by pests and diseases that hamper productivity and grain quality. Chemicals used to tackle these issues not only increase production cost, but may also lead to serious problems in the long term. The use of biological control for the management of pest aims to reduce the use of such products and preserve the environment. For being natural predators of these pest insects, social wasps are an effective alternative for biological control. Attractive traps were installed in two areas of coffee culture: one with predominant orchard vegetation, called Orchard-coffee; and the other with an Atlantic forest fragment as predominant surrounding vegetation, called Forest-coffee. The aim was to compare the diversity and abundance of social wasp species that visited the two areas. Bray-Curtis (dis-)similarity between the two areas was low, 0.45, showing surroundings influence in both areas. In total, 208 individuals of 11 species and 4 different genera were collected, with a total Shannon-Wiener (H') diversity index of 1.591. Orchard-coffee showed a higher number of social wasps, whereas Forest-coffee showed a higher diversity index. The most abundant species in both areas was *Polistes versicolor*, which can reduce damage caused by coffee pests and has a great potential use in biological control programs.

Keywords: Polistinae. Biological control. Atlantic Forest. Orchard.

Introduction

Coffee culture plays a pivotal role in Brazilian agribusiness due to its booming market that generates income for small and large producers. As coffee is the economic basis of various properties, pests and diseases that may compromise crop success pose an increasing concern (REIS et al., 2002). Leaf miner, *Leucoptera coffella* (Guérin-Mèneville, 1842) (Lepidoptera: Lyonetiidae) and coffee berry borer, *Hypothenemus hampei* (Ferrari, 1867) (Coleoptera: Curculionidae, Scolytinae) are two of the main indexed pests, as they cause serious and often irreversible damage (REIS et al., 2002).

Brazil is one of the greatest pesticide consumers in the world. The incorrect and excessive use of these chemicals directly affects a wide ecological chain, granting resistance to pests and diseases, reducing pollinating insect population, and harming human health (CASSAL et al., 2014). The search for alternative practices and biological products aims to reduce the impact of these chemicals.

The coffee culture environment directly influences the diversity of natural enemies that may be housed within it (FERNANDES, 2013). Agroecosystem diversity increases natural enemy diversity (TOMAZELLA et al., 2018). For providing different habitats and food resources, the overall vegetation

1 Instituto Federal de Educação, Ciência e Tecnologia de Minas Gerais (IFMG) – *Campus* Bambuí. Professor. gabriel.jacques@ifmg.edu.br. Rodovia Bambuí/Medeiros, Km 5, Fazenda Varginha, Bambuí/MG, 38900-000.

2 Instituto Federal de Educação, Ciência e Tecnologia de Minas Gerais (IFMG) – *Campus* Bambuí. Discente. brunaagro8@yahoo.com.br.

and ecosystem directly influence social wasp communities due to variations in temperature, relative humidity, and amount of shade of the environment (SANTOS et al., 2009).

Wasps belong to the order Hymenoptera and family Vespidae (CARPENTER, 1993). Over 4,600 species of these insects are described worldwide, with solitary and social behavior. Whereas the subfamilies Euminae, Massarinae, and Euparaginae present solitary behavior, Polistinae, Vespinae, and Stenogastrinae present social behavior (CARPENTER; MARQUES, 2001). In Brazil, the only social wasps are those of the subfamily Polistiane, which occur in 21 genus and 344 species HERMES et al., 2019).

Wasps forage and return to the nest with macerated prey, which are divided among other wasps in the colony and later with immature larvae of the same species (ELISEI et al., 2010). The prey most captured by social wasps (around 90.0 %) are insects of the order Lepidoptera (PREZOTO et al., 2006; BICHARA-FILHO et al., 2009). Several social wasp species have been reported as efficient coffee pest predators, responsible for nearly 70.0 % of biological control in coffee plantations, such as *Agelaia pallipes* (Olivier, 1972), *Brachygastra lecheguana* (Latreille, 1824), *Polistes* sp., *Polybia ignobilis* (Haliday, 1836)*, Polybia occidentalis* (Olivier*,* 1791), *Polybia scutellaris* (White, 1841), *Polybia sericea* (Olivier, 1971), *Protonectarina sylveirae* (De Saussure, 1854), and *Synoeca surinama cyanea* (Fabricius, 1775)(PARRA et al., 1977; PERIOTO et al., 2011; REIS et al., 2002). (PARRA et al., 1977; PERIOTO et al., 2011; REIS et al., 2002) (REIS et al., 2002).

To identify the ideal wasp species to perform biological control, insects in predominantly agricultural environments must be identified and inventoried, as well as factors that may contribute to their effectiveness in pest control (PREZOTO et al., 2006). Given that, the present study aims to investigate the diversity and abundance of social wasps that visit coffee culture, comparing different surrounding vegetations.

Materials and methods

This research was conducted in the coffee sector of the Instituto Federal de Educação, Ciência e Tecnologia de Minas Gerais (IFMG), at *Campus* Bambuí. The sector is composed of two areas where coffee cultures are established. The first area (FIGURE 1), "Orchard-coffee", pertains to the cultivar Rubi. It is 8 years old, covers 5,263.41 m^2, and vegetation surrounding coffee tree is predominantly composed of fruit trees, such as: Orange (*Citrus sinensis*), Guava (*Psidium guajava*), Acerola (*Malpighia emarginata*), Lemon (*Citrus limonum*), Passion Fruit (*Passiflora edulis f. flavicarpa*), Peach (*Prunus persica*), among others.

Figure 1 – "Orchard-coffee" area, which surrounding vegetation are different fruit trees. Six attractive traps for social wasps were randomly distributed in each study area.

Source: Google Earth (2020).

The second area (FIGURE 2), "Forest-coffee," belongs to the cultivar Acaiá cerrado. It is also 8 years old, covers 2,508.44 m², and its surrounding vegetation is a fragment of the Atlantic Forest, with large trees that provide shading to part of the coffee trees. The same management system is employed in both areas, with little chemical use.

Figure 2 – "Forest-coffee" area, which surrounding vegetation is predominantly closed forest. Six attractive traps for social wasps were randomly distributed in each study area.

Source: Google Earth (2020).

Social wasps were collected using six attractive traps randomly distributed per area. From September 2018 to April 2019, 11 collections were performed. Traps were made from two-liter plastic bottles with three triangular openings (2.0 x 2.0 x 2.0 cm) to allow wasps to enter (JACQUES

et al., 2012). An attractive solution of water and honey, in ratio 1:1, was inserted within the traps (SOUZA; PREZOTO, 2006), which were then hung on stakes approximately 1.0 m from the ground between coffee tree lines.

Traps were exposed in the field for a week and then collected to avoid the deterioration of insects. Wasps captured by the attractive traps were placed in plastic containers with 70% alcohol, pinned, and later identified by Prof. Gabriel C. Jacques (IFMG – *Campus* Bambuí) and Prof. Marcos Magalhães de Souza (Instituto Federal de Educação, Ciência e Tecnologia do Sul de Minas Gerais – *Campus* Inconfidentes).

Species diversity and dominance for total and each area were calculated by the Shannon-Wiener diversity index (H') and Berger-Parker dominance index (Dpb), using the PAST software (HAMMER et al., 2005). Each species relative collection frequency was also calculated. Individuals abundance and species richness within each area underwent variance analysis; means were compared by the T-test at 5% significance level, using the PAST statistical program (HAMMER et al., 2005). A cluster analysis between social wasp faunas collected in the two studied areas was performed, using the Bray-Curtis (dis-)similarity index by the *PAST* software (HAMMER et al., 2005), which considers species occurrence and abundance in each area.

Results and discussion

We captured 208 social wasps, of 11 species and 4 different genera, with a total diversity index of 1.591 (TABLE 1). The study site is a very diverse environment; it comprises habitats that offer wasps greater protection against predatory insects and a high amount of food resources and components for such vespids survival, allowing different species to survive (JACQUES et al., 2015)

For the first time on *Campus* Bambuí, it was founded the specie *Polybia punctata* du Buysson, 1907. It was present in a significant number of individuals within the two studied coffee areas, corroborating studies on diversity previously conducted in this place (JACQUES et al., 2015; JACQUES et al., 2018).

We captured 150 individuals in the "Orchard-coffee," with an average of 13.63 ± 3.98 individuals per collection, and only 58 in "Forest-coffee", with an average of 5.27 ± 3.31 (Table 1). The greater abundance of social wasps in Orchard-coffee ($p = 4.88 \times 10^{-6}$) may be associated with the high diversity of fruit trees in its surroundings, as wasps are attracted to places wealthier in resources for their survival. Thus, these vespids have an opportunistic habit, being present in environments with a greater number of herbivorous insects (SANTOS et al., 2009). Fruits and pests that attack orchards are themselves food to these insects, whereas trees function as a nesting site.

The large trees that partially shade coffee trees in the Forest-coffee may have influenced the presence of wasps in the area, as shading may create a physical barrier that hinders predatory wasps to locate their prey, causing them to forage (AMARAL et al., 2010).

Polistes versicolor (Oliver, 1917) was the most collected species in the two studied areas, with 101 individuals in the Orchard-coffee (67.33% frequency) and 26 in the Forest-coffee (44.83% frequency). This high representativeness corroborates studies conducted by Jacques et al. (2015), who found this same species to be dominant when gathering the diversity of social wasp species in the *Campus* Bambuí – as it is a highly sinanthropic species that nests well in agricultural and urban environments.

P. versicolor are excellent predators, specially of insects of the Lepidoptera order, which corresponds to 95% of its captured prey used in feeding (PREZOTO et al., 2006). Some studies found

significant results in this wasp predation over the leaf miner, *L. coffeella*, which belongs to the order Lepidoptera (ELISEI et al., 2010).

Among the 11 species collected, *P. versicolor*, *Polybia ignobilis* (Haliday, 1836), *Polybia occidentalis* (Olivier, 1791), *Polybia sericea* (Olivier, 1791), and *Synoeca cyanea* (Fabricius, 1775) were reported as efficient predators of coffee pests (ELISEI et al., 2010; PARRA et al., 1977; PERIOTO et al., 2011; REIS et al., 2002).

These predators contribute to reducing the number of pests even at low population levels, consequently reducing infestation peaks (DEBACH, 1951). *Polistes simillimus* Zikán, 1951, *Polistes ferreri* (Saussure, 1853), *Polybia jurinei* de Saussure, 1854, and *Polybia punctata* du Buysson, 1907, were reported foraging over coffee culture (FREITAS et al., 2015; TOMAZELLA et al. 2018). However, further studies are necessary to indicate the efficacy of these species as predators of this crop pests.

The average species richness per collection was similar in Orchard and Forest-coffee ($p = 0.0261$), but diversity index was higher in the Forest-coffee. This is explained by the use of species number and dominance to calculate the Shannon-Wiener diversity index. As a result of the very high dominance index in Orchard-coffee, diversity index decreases (TABLE 1). The forest surrounding coffee trees has favorable edaphoclimatic factors so that the species diversity is at greater balance. Elements such as temperature, luminosity, and humidity provided by this environment influence the biodiversity and adaptation of various insects and animals, directly reflecting in the diversity of social wasps within it (MACHADO et al., 1998; RICHARDS, 1978).

Table 1 – Richness, diversity, and dominance of social wasps collected in Forest- and Orchard-coffee areas.

Species	Orchard-coffee		Forest-coffee		Total	
	Number of individuals	Frequency	Number of individuals	Frequency	Number of individuals	Frequency
Myschocittarus rotundicollis (Cameron,1912)	2	1.33%	0	0.00%	2	0.96%
Polistes ferreri Saussure, 1853	3	2.00%	0	0.00%	3	1.44%
Polistes simillimus Zikán, 1951	11	7.33%	4	6.90%	15	7.21%
Polistes versicolor (Olivier, 1791)	101	67.33%	26	44.83%	127	61.06%
Polybia erythrothorax (Richards, 1978)	0	0.00%	1	1.72%	1	0.48%
Polybia ignobilis (Haliday, 1836)	4	2.67%	5	8.62%	9	4.33%
Polybia jurinei Saussure, 1854	8	5.33%	6	10.34%	14	6.73%
Polybia occidentalis (Olivier, 1791)	8	5.33%	2	3.45%	10	4.81%
Polybia punctata du Buysson, 1907	3	2.00%	6	10.34%	9	4.33%
Polybia sericea (Olivier, 1791)	10	6.67%	2	3.45%	12	5.77%

(continue...)

Table 1 – Continuation

Species	Orchard-coffee		Forest-coffee		Total	
	Number of individuals	Frequency	Number of individuals	Frequency	Number of individuals	Frequency
Synoeca cynea (Fabricius, 1775)	0	0.00%	6	10.34%	6	2.88%
Total individuals	150		58		208	
Mean number of individuals per collection	13.63 ± 3.98a		5.27 ± 3.31b			
Species richness (S')	9		9		11	
Mean species per collection	3.72 ± 0.90a		2.45 ± 1.50a			
Shannon-Wiener diversity index (H')	1.262		1.762		1.57	
Berger-Paker dominance index (Dpb)	0.6645		0.4286		0.5805	

*Lines with different letters differ from each other by the t test at 5% significance

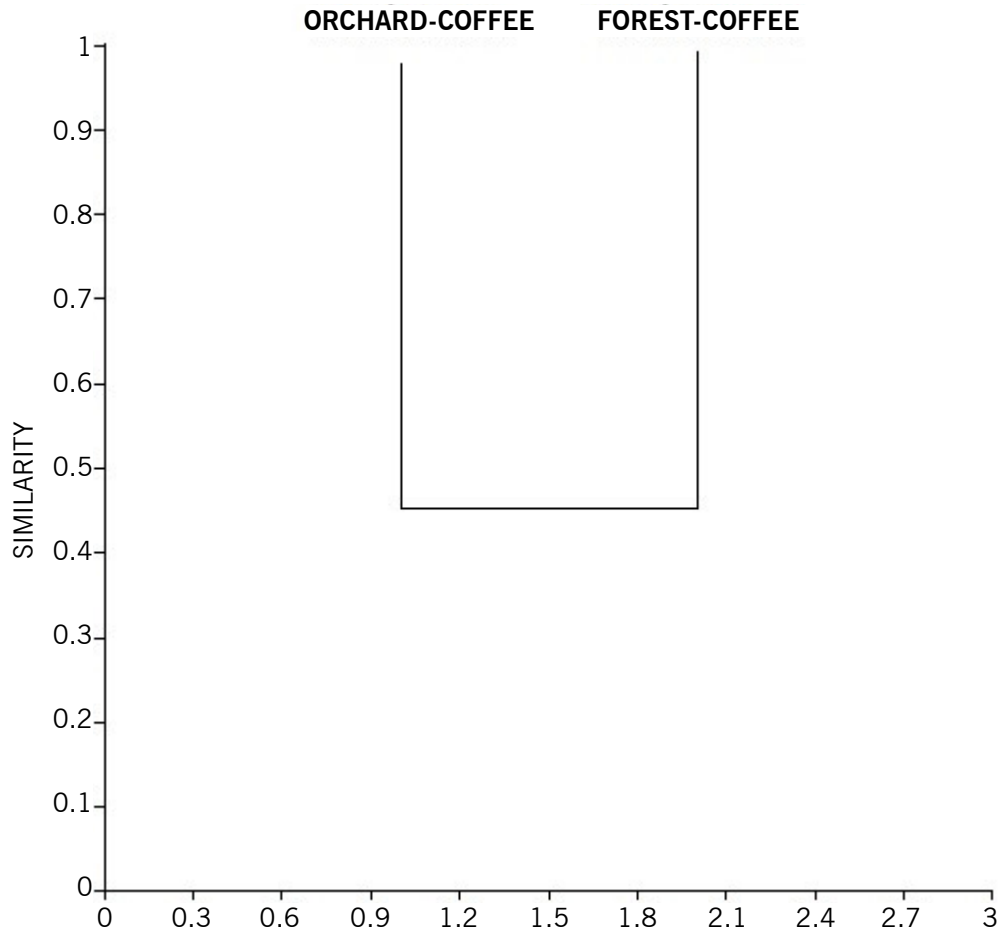
Source: Prepared by the authors (2020).

Similarity analysis between the two studied coffee areas showed a Bray-Curtis similarity of 0.45 (FIGURE 3). As Bray-Curtis index range from one to zero, this is a relatively low value. Considering that, the studied areas are different from each other, despite the short distance between them (354.0 m). It also shows that the surrounding vegetation directly influences the diversity of wasps in coffee culture.

We found *Mischocyttarus rotundicollis* (Cameron, 1912) and *P. ferreri* species only in the Orchard-coffee. *P. ferreri* was previously recorded foraging on cabbage culture, which verifies this species interaction with the agricultural environment (JACQUES et al., 2018). *Polybia erythrothorax* Richards, 1978 *and* S. *cynea* were present in Forest-coffee only. *S. cynea* nests in larger tree trunks (ELISEI et al., 2005), found closer to Forest-coffee. Social wasps may build their nests in one place and forage in others (SANTOS et al., 2009).

Further studies are necessary to better understand the function of different surrounding vegetation on the diversity of social wasps in agricultural areas. However, it is evident that different surroundings of a same culture influence the biodiversity of social wasps within it and may interfere in agricultural pest control.

Figure 3 – Analysis of similarity (Cluster analysis) between faunas of social wasps collected in Orchard- and Forest-coffee areas, considering species occurrence and abundance in each area.



Source: Prepared by the authors (2020).

Conclusion

The predominant surrounding vegetation of the studied coffee areas influenced the diversity of social wasp species found, with higher abundance in coffee cultivation near the orchard and higher diversity index in coffee cultivation near the forest. The most abundant species in both areas was *Polistes versicolor*, which is capable of reducing damage caused by coffee pests and has a great potential use in biological control programs.

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Influência da vegetação de entorno na diversidade de vespas sociais na cultura do café

Resumo

A cada ano, lavouras de café são tomadas por pragas e doenças que afetam a produtividade e a qualidade final dos grãos. Para tentar contornar esses problemas são utilizados produtos químicos que além de aumentar o custo de produção podem acarretar sérios problemas em longo prazo. O uso do controle biológico de pragas visa diminuir a utilização desses produtos, bem como a preservação do meio ambiente. Vespas sociais são predadoras desses insetos considerados pragas, portanto funcionam como uma alternativa eficaz no controle biológico. As armadilhas atrativas foram instaladas em duas áreas de cultura de café, uma com pomares como vegetação de entorno predominante, nomeado de Café-Pomar; a outra, com um fragmento de mata atlântica como vegetação de entorno predominante, nomeada de Café-Mata. O objetivo foi comparar a diversidade e a abundância de espécies de vespas sociais que visitaram as duas diferentes áreas. A análise de similaridade de Bray-Curtis entre as duas áreas foi de 0,45, valor baixo, mostrando a influência do entorno nas duas áreas. 208 indivíduos foram coletados, sendo 11 espécies e 4 gêneros diferentes, com índice total de diversidade de Shannon-Wiener (H') de 1,591. O Café-Pomar apresentou maior número de indivíduos de vespas sociais, em contrapartida, o Café-Mata apresentou maior índice de diversidade. *Polistes versicolor* foi a espécie encontrada com maior abundância nas duas áreas, espécie essa capaz de reduzir os danos causados por pragas cafeeiras e com grande potencial de ser utilizada em programas de controle biológico.

Palavras-chave: Polistinae. Controle Biológico. Mata Atlântica. Pomar.

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