



# Faunistic composition and seasonal occurrence of parasitoid and predatory wasps in maize intercropped with beans

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**Background:** Lepidopteran caterpillars attack maize plants, and the main control methods involve the application of phytosanitary products, which is disadvantageous from an ecological point of view. With a view to finding alternative control mechanisms, the present study surveys parasitoid and predatory wasp species in maize (AG1051) intercropped with beans in southwestern Bahia, Brazil. The survey of parasitoids involved the use of Moe-ericke traps. Relevant families (Braconidae, Ichneumonidae, Scelionidae, and Eulophidae) for the biological control of maize and bean pests were identified to subfamily, genus, or species level. For predatory wasps, the survey involved the use of trap nests and, once nesting, emerging wasps were identified to genus level. The following were determined: faunistic indices, relative frequency, constancy, Shannon diversity ( $H'$ ) and evenness ( $J'$ ) indices.

**Results:** The results highlighted parasitoids of the genera *Telenomus* and *Gryon* (Scelionidae), *Opius* and *Chelonus* (Braconidae), *Aprostocetus* and *Horismenus* (Eulophidae), *Anomalon* (Ichneumonidae), and the subfamily Cryptinae (Ichneumonidae), as well as predatory wasps of the genera *Isodontia*, *Monobia*, and *Pachodynerus*.

**Conclusions:** Parasitoids occurring in maize intercropped with beans in Vitória da Conquista, Brazil, are relevant for the biological control of maize and bean pests.

**Keywords:** Braconidae, Eulophidae, Ichneumonidae, Scelionidae

## Introduction

The maize crop (*Zea mays* L.) stands out worldwide due to its economic and social importance. In addition to being cultivated in different regions of the planet, this cereal has countless applications, being the basis of human and animal food, in addition to being used as a source of energy as biofuel.

Maize intercropping, especially with beans, is a common practice in Brazil. This system is mostly used by small farmers that aim to make better use of the area and workforce, reduce the occurrence of weeds (Concenço et al. 2013) and increase nutrient cycling (Ceccon et al. 2014). Among the advantages of intercropping, the most cited and documented is the reduction of pest attacks in polycultures. This is because herbivorous insects generally reach higher population densities in monocultures than in multi-specific stands of host plants, which provide resources for natural enemies (Saunders et al. 2016). However, intercropping faces many challenges, especially from a phytosanitary

point of view, with recurring attacks by pests and diseases.

Lepidopteran caterpillars, such as *Elasmopalpus lignosellus* and *Spodoptera frugiperda*, attack corn plants during their development and growth, from sowing to harvest. This leads to yield losses, as reported in recent studies (Santos et al. 2020). The most adopted practice to control these pests is the use of phytosanitary products. Thus, a large number of insecticides is registered, at first because they indirectly increase yield. Notwithstanding, these products have some disadvantages, mainly from an ecological point of view. Examples are the potential elimination of beneficial insects to the crop - such as predators, parasitoids, and pollinators (Thancharoen et al. 2018) and the contamination of soil and water systems, which can harm health and alter ecosystems (Lopes et al. 2016).

Considering the possibility of applying other phytosanitary control practices, such as the use of parasitoids and predators of the order Hymenoptera, the present study surveys parasitoid and predatory wasp species in maize (AG1051) intercropped with beans in southwestern Bahia, Brazil.



The aim is to identify families/species with potential for biological control in integrated pest management programs.

## Material and Methods

The experiment was conducted on a property in Planalto da Conquista, Brazil, whose geographic coordinates are 14°55'11.5" S and 40°47'29.4" W. The experiment occurred from April 2013 to October 2014 and covered five maize plantations intercropped with beans.

The areas were divided into plots of one hectare each, prepared in a conventional way, with plowing and harrowing. In these areas, maize (*Zea mays* L.) of the double hybrid cultivar AG1051 was intercropped with common bean (*Phaseolus vulgaris* L.). After completing the maize cycle, another one-hectare plot was pre-prepared and submitted to the new intercropping. The distance between plots was 2 m, with 200 m between the cultivation area and the native vegetation, a deciduous montane seasonal forest popularly known as 'mata de cipó' (Fig. 1).

Pest and weed control were performed manually with the aid of a hoe, without application of phytosanitary products. The property had no history of use of phytosanitary products in the previous ten years.

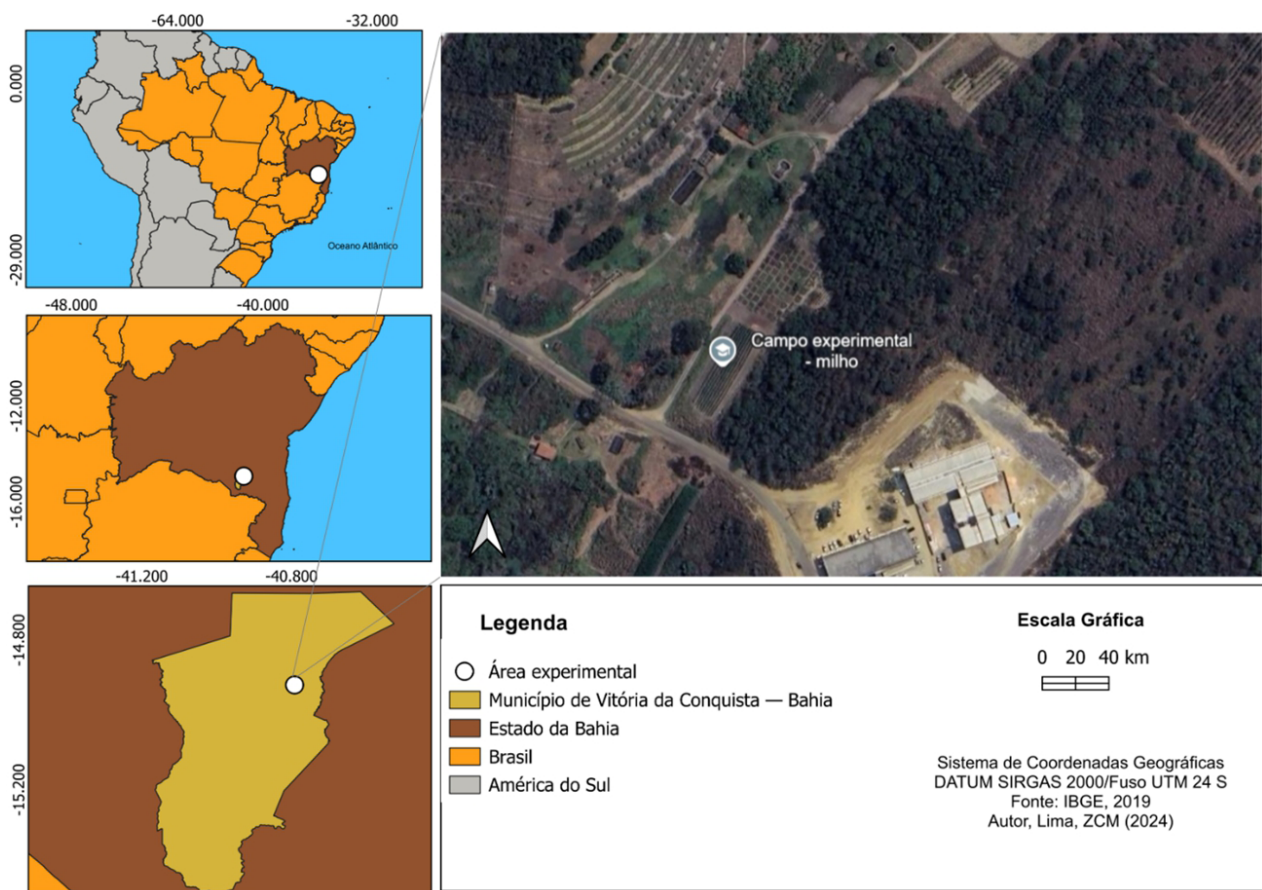
The rainfall index was around 400 mm in 2013, with high rainfall concentration in December (232.7 mm). In 2014 the index was around 600 mm, with most rainfall concentrated in November (207 mm). The temperature in the period ranged from 17 to 22°C. These data were obtained from the meteorological station of the State University of Southwestern Bahia, which was approximately 12 km away from the cultivation area. Due to the low rainfall, the crops received complementary sprinkler irrigation during the experimental period.

For sampling of parasitoid and solitary predatory wasps, five random points were used, distancing on average 20 m from each other.

### Sampling of parasitoid wasps

Two Moerick traps were used at each point, totaling 10 traps ha<sup>-1</sup>. Once a month the traps were randomly distributed. After 48 hours in the field, the material was collected, stored in 70% alcohol, and taken to the laboratory for screening.

Screening was performed at the Hymenoptera family level with the help of identification keys by Goulet and Huber (1993). The main families of agricultural importance in the control of key pests of the crop were conducted to reference researchers.



**Fig. 1** Experiment location map.

## Sampling of solitary predatory wasps

Five sets of trap nests made with bamboo or sugarcane (*Arundo donax* L.) segments were used, which were cut to 10 cm in length, with one end closed by its own node. Bamboo segments were cut in half, lengthwise, and the halves were joined with adhesive tape, to facilitate further observations. The internal diameters of the nests were 3, 5, 8, and 10 mm. Sixteen trap nests were housed in a PVC pipe of 6 cm in diameter and 15 cm in length, with one side of the pipe covered with styrofoam and hanging from a wooden stake 1.5 m from the ground. The monitoring of nests was fortnightly, and every founded nest was collected and replaced by another of the same diameter.

Founded nests were opened and described in terms of construction material, nest diameter, prey for feeding the offspring, and gender of the individual born. The species were identified by Dra. Raquel Perez-Maluf in terms of gender and morphotypes, using identification keys.

## Faunistic analysis

Parasitoid and solitary predator wasps underwent the following faunistic analyses:

### 1) Relative frequency (RF):

$RF = N_i/N$ , where:

$N_i$  = number of individuals in the family (i);

$N$  = total number of individuals collected.

### 2) Constancy (C), according to Bodenheimer's methodology as presented by (Silveira Neto et al. 1976):

$C = P_i \times 100/N$ , where:

$P_i$  = number of collections containing family "i";

$N$  = total number of collections performed.

Based on the results obtained, the families were classified as: Constant (W present in more than 50% of the collections), Accessory (Y present between 25%–50% of the collections), and Accidental (Z present in less than 25% of the collections).

Shannon diversity ( $H'$ ) and evenness ( $J'$ ) indices were estimated for the parasitoids using the statistical program PAST version 3.11 (Hammer et al. 2016).

The  $\chi^2$  test was performed at a significance level of 5% to determine the preference of solitary predatory wasp species for different diameters, using the statistical program PAST version 3.11 (Hammer et al. 2016).

## Results

### Parasitoid wasps

In the intercropping of corn cultivar AG1051 with beans, 1,179 specimens of Hymenoptera were collected, distributed in twenty-one families. Among them, four stand out (Scelionidae, Ichneumonidae, Braconidae and Eulophidae) (Table 1), which were chosen for analysis due to their high frequency in the Planalto da Conquista region and their

relevance in the intercropping of crops. Although the families Bethyridae and Chalcididae also include parasitic wasps of *S. frugiperda*, the decision to emphasize the four mentioned was based on their predominance and importance in the biological control of the main pests of corn and beans in the studied area.

The diversity estimated by the Shannon index ( $H'$ ) was 2.31 and the evenness index was 0.76, indicating the absence of a dominant group in the sample. Family Encyrtidae makes up approximately 30% of the total, and the other families have relative frequencies below 15%. This survey indicated a monthly population fluctuation of the families Scelionidae, Ichneumonidae, Braconidae, and Eulophidae (Fig. 2).

Parasitoids of the families Scelionidae and Eulophidae occurred more frequently in June 2014. Scelionidae is one of the most diversified families of the superfamily Chalcidoidea. In turn, Eulophidae are common in several habitats, predominating in the collections in all environments.

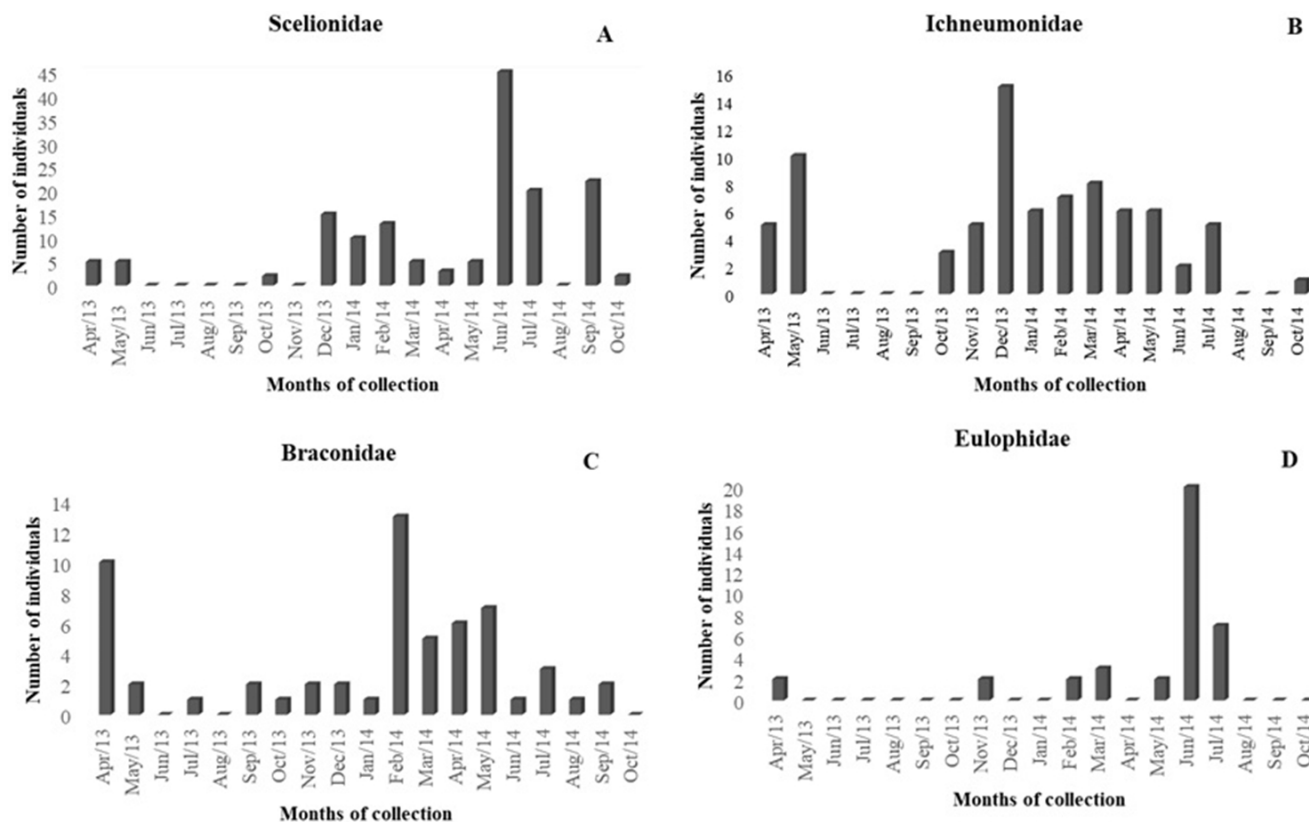
The present study identified ten species of the family Scelionidae (*Calliscelio* sp., *Gryon* sp., *Idris* sp., *Leptacis* sp., *Macroteleia* sp., *Platigaster* sp., *Probaryconnus* sp., *Telenomus* sp., *Trissolcus* sp., *Triteleia* sp.) and one genus (*Cremastobacus*). Among these species, *Gryon* sp. and *Telenomus* sp. stood out with greater occurrence in June,

**Table 1** Families, abundance (N), relative frequency (RF), and constancy (C) of Hymenoptera in maize (*Zea mays* L.) cultivar AG1051 intercropped with beans (*Phaseolus vulgaris* L.) in Vitória da Conquista - BA from April 2013 to October 2014

Family	N	RF	C
Encyrtidae	355	0.3011	W
Scelionidae <sup>a</sup>	142	0.1204	W
Diapriidae	96	0.0814	Y
Figitidae	92	0.0780	Y
Platygastridae	88	0.0746	Y
Ichneumonidae <sup>a</sup>	83	0.0704	W
Braconidae <sup>a</sup>	76	0.0645	W
Ceraphronidae	73	0.0619	W
Eulophidae <sup>b</sup>	49	0.0416	Y
Eupelmidae	38	0.0322	W
Bethylidae	30	0.0254	W
Mymaridae	28	0.0237	Y
Evaniidae	10	0.0085	Y
Chalcididae	7	0.0059	Z
Tanaostigmatidae	3	0.0025	Z
Pteromalidae	3	0.0025	Z
Crysididae	2	0.0017	Z
Perilampidae	1	0.0008	Z
Megaspilidae	1	0.0008	Z
Eurytomidae	1	0.0008	Z
Driinidae	1	0.0008	Z
Total	1,179		

W: constant; Y: accessory; Z: accidental.

<sup>a</sup>Family of interest for the biological control of maize pests; <sup>b</sup>Family of interest for the biological control of bean pests.



**Fig. 2** Fluctuation of parasitoid families: (A) Scelionidae; (B) Ichneumonidae; (C) Braconidae; and (D) Eulophidae in maize (AG1051) intercropped with beans, from April 2013 to October 2014, in Vitória da Conquista – BA.

period in which they presented 10 and 24 individuals, respectively.

The subfamily Cryptinae, belonging to the family Ichneumonidae, was the first most frequent (14 individuals), followed by species *Anomalon* sp. (12), and finally subfamily Ichneumoninae (6).

In the autumn/winter of 2014, subfamily Cryptinae presented three individuals, but in 2013 there was a peak in the month of December, with seven individuals identified. Species *Anomalon* sp. occurred in greater numbers in April 2013, with four individuals, being also present in the first quarter of 2014, with one to two individuals per month. In late summer and early autumn of 2014, from March to May, subfamily Ichneumoninae had an average of one individual per month.

The genus *Opius* from the family Braconidae predominated in the cultivation, with thirty-eight individuals. This genus was abundant in February and July 2014, with ten and sixteen individuals, respectively.

**Solitary predatory wasps**

In intercropping, 101 nests were collected, which were distributed in four genera. Of these, *Isodontia*, used to control crickets and grasshoppers, and *Pachodynerus* and *Monobia*, used to control *Spodoptera* caterpillars, are the most relevant (Table 2). The genus *Trypoxylon*, despite being the most frequent, is not important for the biological

**Table 2** Quantity, frequency, and constancy of nests founded by the genera *Trypoxylon*, *Isodontia*, *Pachodynerus*, and *Monobia* in maize (AG1051) intercropped with beans, from April 2013 to October 2014, in Vitória da Conquista, BA

Genus	Quantity	Frequency	Constancy
<i>Trypoxylon</i>	42	0.41	W
<i>Isodontia</i>	32	0.31	W
<i>Pachodynerus</i>	22	0.21	Y
<i>Monobia</i>	5	0.04	Z
Total	101		

W: constant; Y: accessory; Z: accidental.

control of maize and bean pests, as its species mainly prey on spiders.

The genus *Isodontia* was constant during the period of the experiment. This allows to increase practices for successful integrated management of orthopterans. The genus *Pachodynerus* was accessory, with a frequency of 22% in the cultivation. New techniques in crop management can be improved to make the presence of this genus constant in maize cultivation. The genus *Monobia* was accidental.

The fluctuation in the nesting of species that use trap nests may be due to abiotic factors, environmental conditions such as extreme climatic factors, and genetic patterns of the species.

The nesting activity of the genera *Pachodynerus*, *Monobia*, and *Isodontia* varied over the months (Fig. 3).

The genus *Pachodynerus* was present in nine months of collection. In January 2014 it founded 6 nests; in July 2014 it founded four nests. The genus *Monobia* occurred more frequently in January 2014, with 6 nests founded.

The genus *Isodontia* was present in ten months, presenting greater nesting in February 2014 and May 2013, with eleven and eight nests, respectively. The presence of wasps of the genus *Isodontia* in the integrated management of pests can be a viable alternative for the control of orthopterans. One example is their predation on locust nymphs to feed the offspring, preventing consumption of the plant and consequently reducing damage due to the lower population rate of the pest.

Regarding the use of trap nests offered, the largest number of foundations occurred in diameters of five mm for *Pachodynerus* sp., and ten mm for *Isodontia* sp. (Table 3), evidencing a preference of these species for these diameters.

### Discussion

The four parasitoid families, Scelionidae, Ichneumonidae, Braconidae, and Eulophidae stand out in the control of fall armyworm (*S. frugiperda*), a key pest of maize and

bean crops. The constant presence of these families in the crop strengthens the proposal of alternative management. The occasional occurrence of Eulophidae has an impact on pest control practices in the secondary bean crop, especially regarding leaf miner flies (*Liriomyza* sp.).

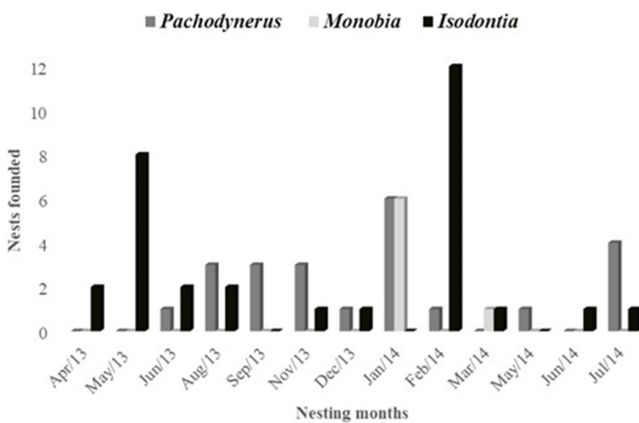
These families can parasitize several other orders, increasing the range of host options (Noyes 2012). This June period is likely to present a greater supply of flowers, which may have provided caterpillars with an additional option in food supply (pollen and nectar).

Species of the family Scelionidae are parasitoids of bed bugs and lepidopterans. These species have already been reported parasitizing eggs of some agricultural pests (Golin et al. 2011). From a biological point of view, this type of parasitism, classified as idiobiont, is the most effective form of control, as the parasitoid kills its host early in development and feeds on it, thus preventing the host from causing further damage to the plant (Bueno et al. 2012) Many of the hosts of these species are agricultural pests, which makes them major biological control agents (Van 2019). Some authors have highlighted their frequency in different agroecosystems (Comério et al. 2013; Pacheco and Corrêa-Ferreira 2000; Riffel et al. 2010).

The biological characteristics and parasitism capacity of *Telenomus remus* in eggs of *S. frugiperda*, *Spodoptera albula*, *Spodoptera eridania*, and *Spodoptera cosmioides* indicate satisfactory development and parasitism (around 80%). A female of that species is capable of parasitizing 140 eggs from any of these three hosts throughout her life (Pomari-Fernandes et al. 2014).

Parasitoids of the genus *Gryon* are host to Heteroptera eggs. Reports on the maize crop mention *Gryon gallardoii* parasitizing eggs of the bug *Leptoglossus zonatus*, considered a secondary pest of maize (Marchiori et al. 2001).

Cryptinae occur in the northern, northeastern, midwestern, southeastern, and southern states of Brazil (Fernandes et al. 2019). Gauld (2006) stated that Cryptinae is probably the most species-rich group of Ichneumonidae in the Neotropical region, most consisting of Cryptini, and that Costa Rica alone may be home to more than 1,000 of these species. Also, according to the author, hosts of this subfamily are greatly diversified: most of its species are associated



**Fig. 3** Total number of *Pachodynerus*, *Monobia*, and *Isodontia* nests in maize (AG4051) intercropped with beans, from March 2013 to October 2014, in Vitória da Conquista - BA.

**Table 3** Number of nests founded by wasp species and diameter, and  $\chi^2$  value for preference of the use of diameters in maize (AG1051) intercropped with beans in Vitória da Conquista - BA from April 2013 to October 2014

Family/Species	Diameter (mm)				Total	$\chi^2$
	3	5	8	10		
Sphecidae						
<i>Isodontia</i> sp.	3	0	10	19	32	26.75**
Vespidae						
<i>Monobia</i> sp.	0	1	2	3	06	5.8*
<i>Pachodynerus</i> sp.	2	10	9	3	24	8.25*
Total	5	11	21	25	62	

\* $p < 0.05$  and \*\* $p < 0.001$ .

with lepidopterans, but reports of hosts belonging to the orders Coleoptera, Diptera, Hymenoptera, and Araneae are common. Its species can be ectoparasitoid or endoparasitoid; some are insect and spider egg predators (van Lenteren et al. 2018).

Species of the genus *Opius* are larvae-pupae endoparasitoid koinobionts that have a range of hosts belonging to the order Diptera, more specifically to the family Agromyzidae. The genus *Liriomyza* is an important host for these species (Pereira et al. 2002). In recent decades, research with the aim of evaluating natural parasitism on species of the genus *Liriomyza* has been carried out in different crops of economic importance and regions of the world. These studies highlight the occurrence and parasitism of species of the families Braconidae and Eulophidae on larvae of this pest (Li et al. 2012). In southern Minas Gerais, the rate of parasitism of *Liriomyza huidobrensis* larvae by *Opius* sp. in common bean reached 100% (Pereira et al. 2002).

Eulophids are important controllers of leaf miner flies in common bean. Intercropping maize with beans can reduce the costs of controlling this pest, having beans as a compensatory crop. For the Eulophidae, the genus *Aprostocetus* stands out with greater participation in the cultivation (sixteen individuals identified), followed by species *Horismenus* sp. (three individuals). Species *Aprostocetus* sp. occurred in greater numbers in June 2014, at the beginning of winter (eight individuals). Molina-Ochoa et al. (2004) observed the relationship of three species of Eulophidae (*Aprostocetus* sp., *Euplectus platypenae*, and *Horismenus* sp.) parasitizing *S. frugiperda* larvae.

It is possible that wasps of these genera prefer this spring-summer period, as mild temperatures, photoperiod, and rainfall occurrence favor the physiological processes of plants, triggering flowering. Reports mention the solitary wasp genera *Pachodynerus* and *Monobia* as important agents in the control of *S. frugiperda* (Pires et al. 2012).

When studying the contribution of forest fragments in the biological control of pests in maize, Sousa et al. (2011) negatively correlated the population density of caterpillars (*S. frugiperda*) with that of predatory wasps (*Pachodynerus guadulpensis*). The authors thus considered the latter as important agents of biological control, which were favored by the proximity of the forest fragment.

Guerra et al. (2012) observed that unlike natural environments, in environments with human intervention such as crops, both the simplified composition of vegetation and the high rate of disturbance reduce the number of locust species and increase the density of populations, which can become important agricultural pests.

In an agroecosystem of coffee intercropped with maize, Nascimento et al. (2020) found *Isodontia* nests preferably in diameters between 7, 8, and 9 mm. The preference of wasps for different diameters is probably related to their size. Thus, more robust wasps that need better comfort for

nesting and feeding their offspring prefer a 10 mm hole, while thinner wasps need smaller holes so as not to waste energy heating the nests. The trap nest is a valuable method for managing wasp nesting (Martins et al. 2012). It also serves to provide biological information (Pires et al. 2012), essential in the management of these natural enemies in the field.

These results allow a better exploration of trap nests in maize intercropping, enabling their use in the field as a supplementary pest control technique. For that, one must consider the diameters of preference for the genera of interest in a way that facilitates the internal construction of nests as well as food supply for the offspring.

## Conclusions

The parasitoids found in maize intercropped with beans in Vitória da Conquista are relevant for the biological control of maize and bean pests. The identified parasitoids belong to the genera *Telenemus* and *Gryon* (Scelionidae), *Opius* and *Chelonus* (Braconidae), *Aprostocetus* and *Horismenus* (Eulophidae), *Anomalon* (Ichneumonidae), and the subfamily Cryptinae (Ichneumonidae). In the intercropping system, solitary wasps such as *Isodontia*, *Monobia*, and *Pachodynerus* were mostly occurred in the spring/summer season.

### Abbreviations

C: Constancy

RF: Relative frequency

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### Authors' contributions

TGB and RPM conceived the idea designed in the study. PSM, TGB, ZCML, and RPM contributed to the preparation, quantification of samples and conduction of field experiments. RPM, AAM and SAL reviewed the manuscript. All authors wrote the article and approved the final version of the manuscript.

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### Availability of data and materials

The datasets generated and/or analyzed during the present study are available from the corresponding author upon reasonable request.

**Ethical approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that they have no competing interests.

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