Social Wasp Predators of *Tuta absoluta*

by

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ABSTRACT

The social Vespidae are important agents for biological control in agro-ecosystems and natural ecosystems. *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is the most important tomato pest in South America. This insect was introduced into Europe and the Mediterranean region of Africa, where it has caused great damage. Despite the importance of Vespidae, little is known about their activity as predators of pest insects. Thus, this study aimed to determine the importance of social Vespidae as predators of *T. absoluta*, to study the influence of climatic elements on their foraging activity, to establish techniques for sampling, and to study their predation behavior. The main predators of *T. absoluta* larvae were the social Vespidae, which preyed mainly caterpillars of the third and fourth instars. The social Vespidae predators of *T. absoluta* larvae were: *Brachygastra lecheguana*, *Protopolybia exigua*, *Polybia ignobilis*, *Polybia scutellaris*, *Protonectarina sylveirae*, *Polybia fastidiosuscula* and *Synoeca cyanea*. *P. scutellaris* and *P. sylveirae* were the most abundant ones. The social Vespidae showed predation activity from 2 to 11 hours after sunrise. Predation of *T. absolute* by Vespidae involved the behavior of locating the plant, locating of mines in the leaves, identification of mines with caterpillars, opening the mines, catching the caterpillars, transporting of caterpillars and body cleansing.

Keywords: Social insects, Vespidae, tomato pinworm, predation behavior, foraging wasps.

INTRODUCTION

Insects of the Vespidae family are divided into six subfamilies: three formed by social species (Stenogastrinae, Polistinae and Vespinae) and three consist of

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solitary species (Euparigiinae, Masarinae and Eumeninae). The social Vespidae may have colonies with few or thousands of individuals. Their colonies consist of workers, males and queens. Usually there are no morphological differences between queens and workers, and the number of queens varies depending on the size of the colony. Their nests are made on the ground or vessels, especially on trees. These structures are made of a mixture of cellulose and water (Ross & Matthews 1991). The diet of the social Vespidae consists of food rich in carbohydrates (nectar, pollen, fruits and sap of plants) and proteins. The protein is obtained by predation on insects, spiders (Sugden & McAllen 1994) and animal carcasses (Gomes *et al.* 2007). Their main prey are insects of the orders Diptera, Lepidoptera, Hymenoptera and Hemiptera (Gobbi & Machado 1986).

The social wasps are voracious generalist predators. They are important agents for natural biological control in agroecosystems and natural ecosystems (Ross & Matthews 1991; Miranda *et al.* 1998, Gonring *et al.* 2003a 2003b, Pereira *et al.* 2007a and 2007b). Picanço *et al.* (2010) observed that the social wasp *Polybia ignobolis* (Haliday) is the main predator of *Ascia monuste* (Godart) (Lepidoptera: Pieridae) caterpillars on kale, and this wasp controls more than 70% of the population of this pest. Koide & Suganuma (2001) found that a nest of the social wasp *Vespula shidai* L. consumes 1300 caterpillars per day of *Mamestra brassicae* (L.) (Noctuidae), *Pieris rapae* (L.) (Pieridae), *Prodenia litura* (Fabr.) (Noctuidae) and *Trichoplusia ni* (Hübner) (Noctuidae) on cabbage. Harris (1991) noted that 15.58 nests of the social wasp *Vespula vulgaris* (L.) prey on 4.8 million insects/ ha in forests.

The tomato pinworm *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is native to South America, originating from Ecuador, the Andes, northern Chile and the Pacific coast, including the Galapagos archipelago. This insect is the most important tomato pest in South America (Picanço *et al.* 1998 2007). In 2006, it was introduced into Europe through Spain, where it distributed quickly for almost all of Europe and subsequently reached the Mediterranean region of Africa where it has caused great damage in tomato culture (Desneux *et al.* 2010, Garcia-Marí & Vercher 2010).

Despite the importance of Vespidae, little is known of their activity as a biological control agent of insects, their predation behavior, techniques to be used in their sampling and the factors that influence their foraging. Thus, this study investigated the natural biological control of *T. absoluta* caterpillars by social Vespidae. We evaluated: I) the importance of these social insects as predators of *T. absoluta*, II) the influence of climatic elements on their foraging activity, III) techniques for their sampling, and IV) their predation behavior.

MATERIALS AND METHODS

This research was carried out on tomato crops in Viçosa (20°48'45"S, 42°56'15"W and altitude of 660m) and Guidoval (21°09'07"S, 42°47'49"W and altitude of 302m), Minas Gerais, Brazil, in 2004. The crops covered about 0.4 ha. We used the Santa Clara variety in spacing of 1 x 0.5 m. The plants were treated with normal cultivation practices according to Picanço *et al.* (1998) and Picanço *et al.* (2007).

Major Predators of *T. absoluta*

To assess the relative importance of predators in natural control of *T. absoluta*, 10 plants attacked by this insect were marked. The mortality of *T. absoluta* caterpillars by predators was monitored in these plants. The number and causes of caterpillar mortality for each instar were recorded. Predators were collected and stored in a 200 mL glass container containing 70% ethanol. These arthropods were identified to family using taxonomic keys. We calculated the percentage of mean mortality of *T. absoluta* larvae caused by each group of predators. We also calculated the confidence interval of this characteristic at 95% probability. The same procedure was used in the analysis of mortality caused by social Vespidae in each larval instar of *T. absoluta*.

Sampling Techniques

For the observation of social Vespidae, an area of 20 m^2 (2 x 10m) was used with the tomato crop. The sampling techniques used were direct counting, insect net and the pointer hit of the plants on a plastic tray. We used 32 replicates for each sampling technique.

In the direct counting technique, the number of Vespidae in the observation area was written down for 15 minutes. In the technique with the use of insect net (40 cm diameter, 60 cm deep and 10 mesh), Vespidae were collected using this instrument. for 15 minutes in the observation area The net was opened to count the Vespidae present. In the tray sampling, a plastic tray of 35 cm x 30 cm x 5 cm was used. This tray was placed under the shoot apex of the plant and through slight and firm movements, the plants were shaken and the insects present in the plant that fell on the tray were counted (Moura *et al.* 2007).

The average density of Vespidae and confidence interval at 95% probability of this variable were estimated for each sampling technique in terms of number of wasps*20m^{-2}*hour^{-1}. The same procedure was used to evaluate the most abundant species of Vespidae using the most efficient technique for sampling.

Effect of Climatic Elements

The intensity of visits of the five most abundant species of wasps to plants (wasps*20m^{-2}*hour^{-1}) depending on air temperature, time elapsed after sunrise, occurrence of rainfall and winds throughout the day was monitored. Regression analysis of the intensity of wasp visits to plants in terms of climatic elements at the time of foraging at $p < 0.05$ were performed.

Predation behavior

In the experimental area, the predation behavior of *T. absoluta* caterpillars by the four most abundant wasps was monitored. For each of these species, four observations of prey searching behavior, identification of mines by the wasps and predation of caterpillars were performed. The wasp acts in each behavior were written down. It was not possible to assess the number of wasps engaged in each behavior due to the speed of their execution. From the observations of the predation behavior of these wasps, an ethogram of general predation behavior on *T. absoluta* larvae was made, following Picanço *et al.* (2010).

RESULTS AND DISCUSSION

The main predators of *T. absoluta* larvae were the social Vespidae, followed by generalist arthropods, bedbugs and predatory Neuroptera: Chrysopidae (Fig. 1A). Therefore, social wasps are important natural enemies of *T. absoluta*, and the use of conservation practices for such predators becomes very important for pest management. Among these practices, we can mention: the non-destruction of social wasp nests, the planting of flowering plants around crops (Paula *et al.* 1998), the preservation of forests, where their nests are located, and the use of pest control methods not harmful to the wasps.

The wasps preyed preferentially on third and fourth instar larvae of *T. absoluta* (Fig. 1B). Therefore, these predators had a preference for caterpillars with larger body size. This occurred possibly because they are more easily located and represent a major food resource due to their larger size (Picanço *et al.* 2010).

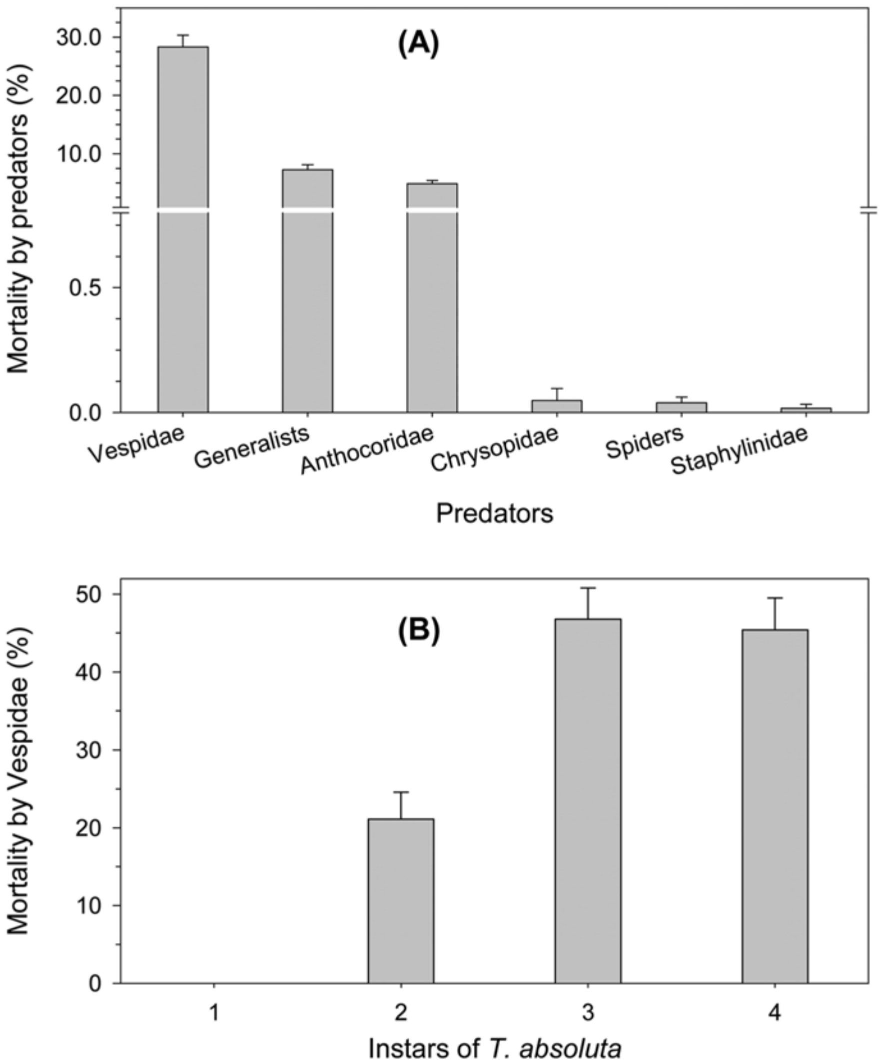

Fig. 1. (A) Larval mortality of *Tuta absoluta* by predators and (B) mortality in instars of *T. absoluta* by Vespidae.

The sampling technique that allowed assessment of the highest number of social wasps was direct counting followed by the use of an insect net. Tray sampling was ineffective (Fig. 2A). The direct count was the most efficient technique for enabling the evaluation of Vespidae during flight and when they were resting on the plants (either on the outside or inside of them). The use of insect net was less effective than direct counting because with this technique it was only possible to capture the Vespidae that were in flight or on leaves that were outside the plant. In the capture of Vespidae that were sitting in the plant, there was damage to the insect net due to contact with the plant. Tray sampling produced no result because wasps flew when the plants were agitated during sampling.

Seven species of social Vespidae were observed preying on *T. absoluta larvae.* These species were: *Polybia scutellaris* (White), *Protonectarina sylveirae* (Saussure), *Brachygastra lecheguana* (Latr.), *Polybia ignobilis* (Haliday), *Polybia fastidiosuscula* Saussure*, Protopolybia exigua* (Saussure) e *Synoeca cyanea* (Fabr.). The most abundant social Vespidae were *P. scutellaris* and *P. sylveirae*, followed by *B. lecheguana*, *P. ignobilis* and *P. fastidiosuscula*. *P. exigua* and *S. cyanea* were the less abundant species (Fig. 2B). This is the first report of these Vespidae preying on *T. absoluta* larvae.

The predation activity of the five most abundant social Vespidae species varied throughout the day depending on the time after sunrise (Fig. 3A). The social wasps began to visit the plants two hours after sunrise (8:00 am) and this activity ended 11 hours after sunrise (5:00 pm). The maximum intensity of visits to plants by *P. ignobilis* and *P. fastidiosuscula* occurred five hours after sunrise (11:00 am). The maximum activity observed of *P. scutellaris* and *P. sylveirae* to plants occurred six hours after sunrise (noon). As for *B. lecheguana*, the maximum intensity of visits to plants occurred seven hours after sunrise (1:00 pm) (Fig. 3A). The foraging variation of Vespidae throughout the day helps to plan conservation practices of these predators. For example, if it is necessary to use chemical control methods for *T. absoluta,* spraying of insecticides should be performed at least 11 hours after sunrise (5:00 pm), since social wasps are not foraging at this time.

No foraging of social Vespidae was noticed when rain or high winds occurred. The wasps foraged at temperatures between 23.5 to 31°C. The foraging of *B. lecheguana*, *P. fastidiosuscula* and *P. ignobilis* was higher with increasing

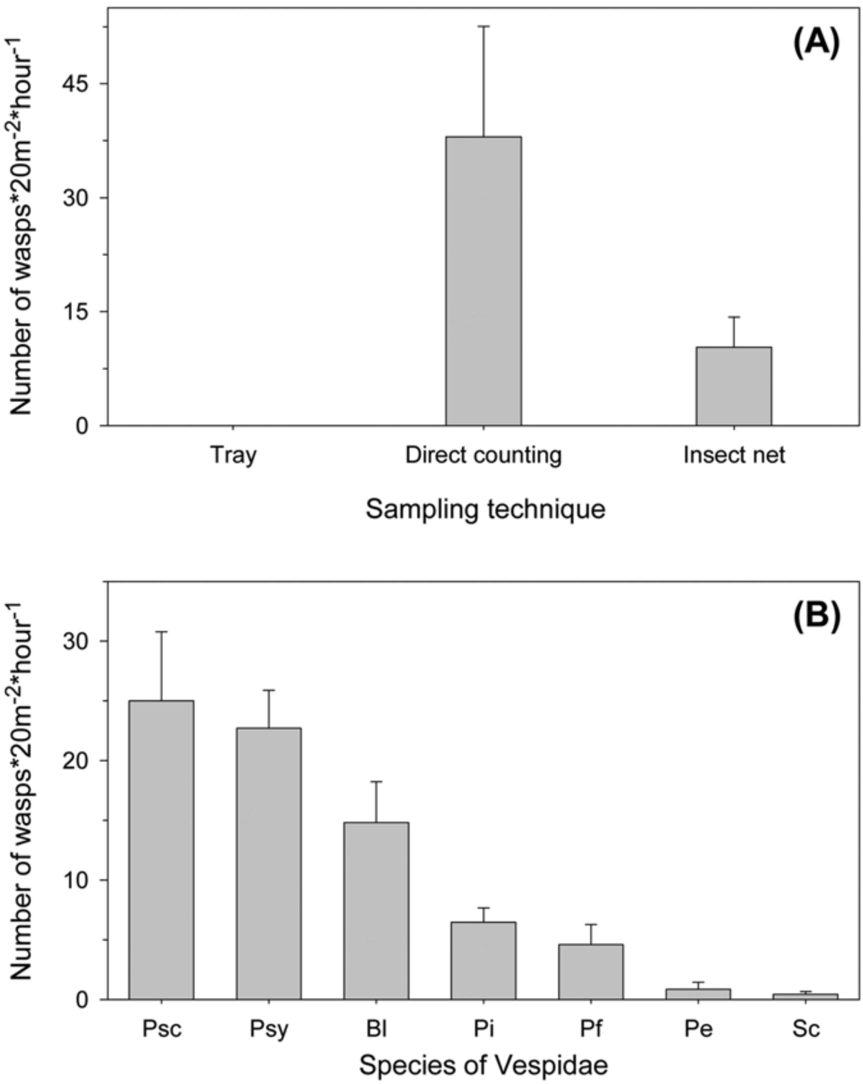

Fig. 2. (A) Densities of assessed wasps by sampling techniques of Vespidae and (B) densities of species of Vespidae in tomato crops. Psc = *Polybia scutellaris*, Psy = *Protonectarina sylveirae*, Bl = *Brachygastra lecheguana*, Pi = *Polybia ignobilis*, Pf = *Polybia fastidiosuscula*, Pe = *Protopolybia exígua* and Sc = *Synoeca cyanea*.

temperature. For *P. scutellaris* and *P. sylveirae*, foraging was higher with increasing temperature up to 29°C. From 29 to 31°C there was a foraging decrease of these two wasps with increasing temperature (Fig. 3B). At low temperatures, the flight activity of Vespidae is lower due to the low thermoregulatory ability

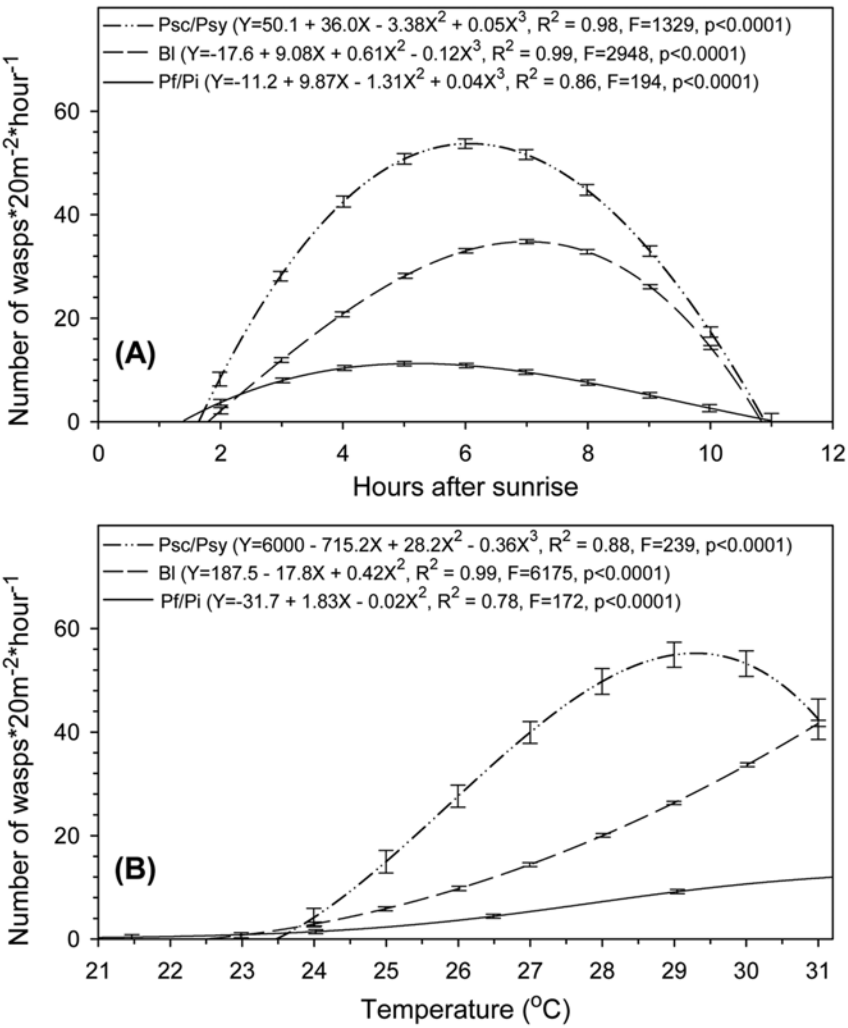

Fig. 3. Foraging intensity of five species of Vespidae preying on *Tuta absoluta* caterpillars in tomato crops according to (A) hours after sunrise and (B) air temperature. Bl = *Brachygastra lecheguana*, Pf = *Polybia fastidiosuscula*, Pi = *Polybia ignobilis*, Psc = *Polybia scutellaris*, Psy = *Protonectarina sylveirae*.

of these insects. Furthermore, in warm periods, there is greater availability of prey and resources such as pollen, nectar and water (Picanço *et al.* 2010).

The social Vespidae performed a series of predation behaviors on *T. absoluta* caterpillars. In the general pattern of predation on *T. absoluta* caterpillars by Vespidae, initially the wasp flew up the tomato plants to then land on a plant leaf. After landing, the wasp examined the leaf to see if it had a mine of *T. absoluta.* After finding a mine in the leaf, the wasp touched the mine with their antennae and mouthparts. If the mine had a caterpillar, the wasp would open the mine using its mouthparts and captured the caterpillar with its forelegs and mouthparts. Then, the wasp would ingest the caterpillar. If the mine had more than one caterpillar, the others would also be consumed by the wasp. After the predation, the wasp cleaned its mouthparts, legs and antennae, and finally flew back to its nest. However, if the leaf did not have a mine, or if the mine did not have a caterpillar, the wasp would go to another leaf or another plant (Fig. 4).

The identification of caterpillar presence in mines by Vespidae was possibly tactile, and wasps touched the mines with antennae and mandibles. *B. lecheguana* and *P. ignobilis* took about 25 s. in this process, while other Vespidae took over 60 s. to identify whether or not the mine had a caterpillar. *P. ignobilis* and *P. scutellaris* eventually performed this identification during flight, touching the mines with their mandibles and antennae without landing on the plant.

P. sylveirae had the lowest efficiency in locating mines of *T. absoluta*. This wasp made slow and prolonged flights (about 60 s.) around the plant and when landing, it walked around the plant looking for mines. When finding the mine, even if empty, it spent about 120 s. touching the mine in search for caterpillars. On some occasions, it returned to a mine several times, repeating the search process for larvae in the mine.

In the process of checking whether the mine had caterpillars *P. ignobilis, P. scutellaris* and *P. sylveirae* touched the mines without tearing them. *B. lecheguana* pierced the mine with the jaws looking for caterpillars. Although *B. lecheguana* was the wasp with the largest body size, it was expelled by *P. scutellaris* when both landed on the plant.

In the consumption of caterpillars, some behaviors were different among the species of wasps. *P. ignobilis, P. scutellaris* and *P. sylveirae* tore mines by

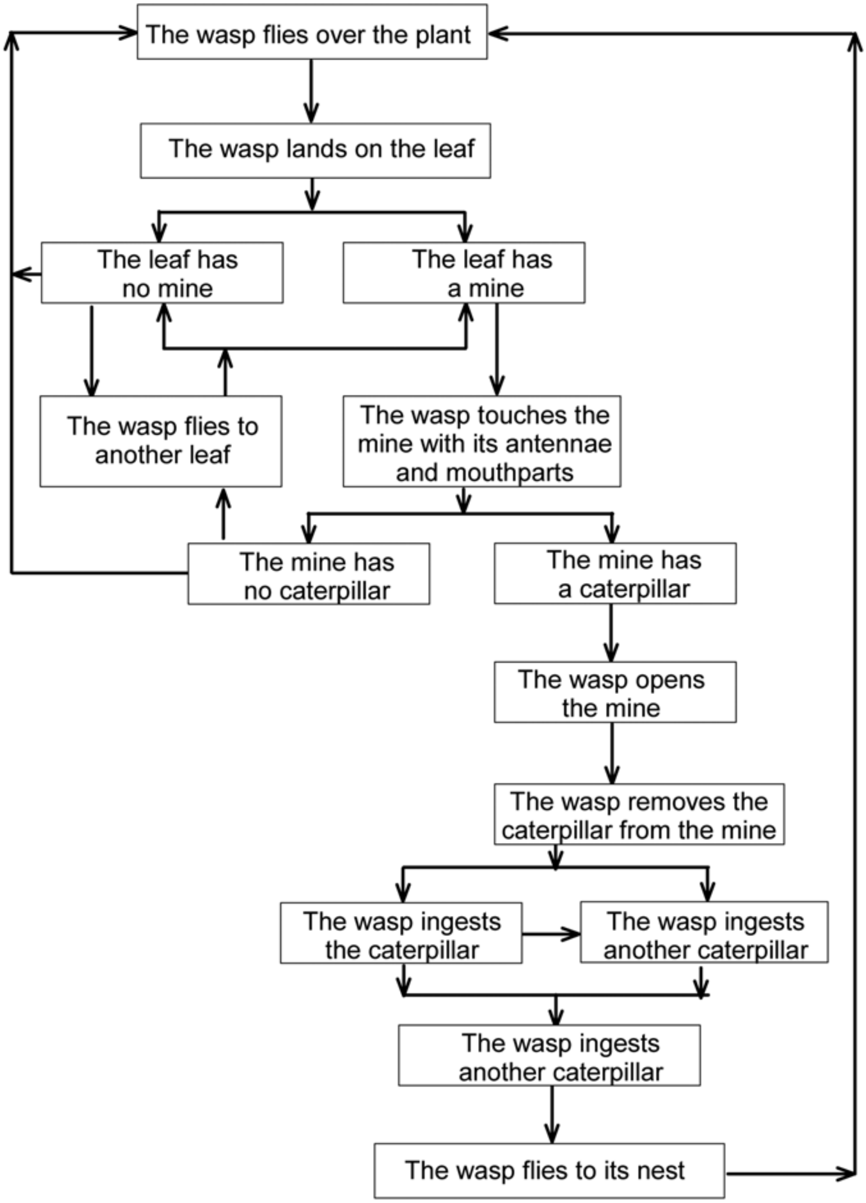

Fig. 4. Predation ethogram of *Tuta absoluta* caterpillars by Vespidae in tomato crops.

pulling the epidermis of the leaf with their mandibles and forelegs. *B. lecheguana* cut the mine using only jaws. The opening of the mine and capture of the caterpillar by *B. lecheguana* took 15 to 20 s., while the other wasp species took 50 to 60 s.

Larvae were removed from the mine and ingested whole, or transported to the nest without being totally ingested. When the caterpillars were ingested, three behavior patterns were seen: I *P. scutellaris* manipulated the caterpillar, forming a cluster before eating it; II) *P. sylveirae* and *P. ignobilis* gradually ingested the caterpillars without manipulating them; III) *B. lecheguana* cut the caterpillar into small pieces to then swallowed it. The ingestion of caterpillars for all species of Vespidae lasted from 25 to 30 s. When the caterpillars were transported without total ingestion, two behavior patterns were seen: I) the wasps transported whole caterpillars to the nest if they were smaller; II) when the caterpillars were larger, the wasps ingested part of it and transported the rest to the nest.

After predation, all species of wasps cleaned parts of their body that were exposed to the prey, i.e., antennae, legs and mouthparts. This cleaning process lasted from 30 to 90 s.

In addition to the predation of *T. absoluta* caterpillars, visits by wasps to tomato plants to collect material for the construction of their nest were also seen. For such, the wasps collected skin from dried fruits and dried leaves. Wasps also visited the tomato flowers to collect pollen and nectar.

To conclude, our results demonstrate the importance of social wasps as *T. absoluta* predators and elucidate the factors affecting their performance. This knowledge should be considered when planning strategies and tactics for pest management in order to preserve these predators and maximize their performance in biological pest control.

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