Does *Diachasmimorpha longicaudata* (Hymenoptera: Braconidae) have a preferential instar to parasitize Tephritidae (Diptera)?

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**ABSTRACT.** *Diachasmimorpha longicaudata* (Ashmead, 1905) is a koinobiont parasitoid of Tephritidae larvae, the third instar larvae of which is considered preferential, but it is able to parasitize other larval stages and compete with native parasitoids. This study investigated the preference and parasitism capacity of *D. longicaudata* in larvae of different instar of *Anastrepha fraterculus* (Wiedemann, 1830) (AF) and *Ceratitis capitata* (Wiedemann, 1824) (CC). The experiments were carried out under laboratory conditions, one instar being offered at a time in parasitism units, with the following choices among the hosts: 25 AF larvae and 25 CC larvae (first, second and third instar were evaluated). The other test was a multiple-choice in relation to the instar, for larvae of the same host species, with three parasitism units being offered, with 15 larvae of each instar. The mean number of formed pupae, emerged parasitoids, parasitized pupae, unviable pupae and sex ratio were evaluated. In the first bioassay, the mean number of emerged parasitoids and parasitized pupae, was higher in second and third instar larvae for CC, parasitized pupae in the AF host were significantly higher in treatments with first and second instar larvae. For CC there was no difference between the emerged parasitoids, parasitized pupae, unviable pupae and sex ratio were evaluated. In the first bioassay, the mean number of emerged parasitoids and parasitized pupae was significantly higher in treatments with second and third instar larvae for CC, and for AF was in second instar larvae. The sex ratio was biased for males in all treatments in both bioassays. The results show that *D. longicaudata* can parasitize and be successful in all available larval instars, being able to compete with parasitoids of any instar.

**KEYWORDS.** *Anastrepha fraterculus*, *Ceratitis capitata*, exotic parasitoid, tephritids.

**RESUMO.** *Diachasmimorpha longicaudata* (Hymenoptera: Braconidae) tem um instar preferencial para parasitar Tephritidae (Diptera)?

*Diachasmimorpha longicaudata* (Ashmead, 1905) é um parasitoide coinobionte de larvas de Tephritidae sendo que o terceiro instar larval é tido como o preferencial, mas pode parasitar outros estágios larvais e competir com os parasitoídes nativos. Este estudo investigou a preferência e capacidade de parasitismo de *D. longicaudata* em larvas de diferentes instares de *Anastrepha fraterculus* (Wiedemann, 1830) (AF) e *Ceratitis capitata* (Wiedemann, 1824) (CC). Os experimentos foram realizados em condições laboratoriais, sendo oferecido um instar por vez em unidades de parasitismo, havendo escolha entre os hospedeiros: 25 larvas de AF e 25 larvas de CC (foram avaliadas larvas de primeiro, segundo e terceiro instar). O outro teste foi de múltipla escolha em relação ao instar, para larvas da mesma espécie hospedeira, sendo oferecidas três unidades de parasitismo, com 15 larvas de cada instar. Avaliou-se o número médio de pupários formados, parasitoídes emergidos, pupários parasitados, pupas inviáveis e razão sexual. No primeiro bioensaio, o número médio de parasitoídes emergidos e pupários parasitados no hospedeiro AF foram significativamente superiores nos tratamentos com larvas de primeiro e segundo instar. Para CC não houve diferença entre os instares testados. No segundo bioensaio, o valor médio de parasitoídes emergidos e de pupas parasitadas foi maior nas larvas de segundo e terceiro instar para CC, e para AF nas larvas de segundo instar. A razão sexual foi desviada para machos em todos os tratamentos, nos dois bioensaios. Os resultados demonstram que *D. longicaudata* pode parasitar e ter sucesso em qualquer instar larval disponível, podendo competir com parasitoídes de qualquer instar.

**PALAVRAS-CHAVE.** *Anastrepha fraterculus*, *Ceratitis capitata*, tefritídeos, parasitoide exótico.
a preference for larvae in early stages of development (Matrangolo et al., 1998; Carvalho et al., 2000; Paranhos et al., 2013). Nevertheless, Murillo et al. (2015) verified that D. areolatus can also parasitize larvae of up to the third instar, which brings the niches of these species even closer. *Diachasmimorpha longicaudata* was imported from the United States of America in 1994 and introduced in Brazil by *Embrapa Mandioca e Fruticultura Tropical*, with the aim of studying its behavior and effectiveness to control fruit fly, aiming the implementation of a biological control program, started in Northeast Brazil (Carvalho & Nascimento, 2002). However, evaluations carried out a few years after their release showed that there were alterations in the presence of native parasitoid species and suggested the existence of interspecific competition in oviposition sites (Carvalho, 2005a). On the other hand, Meirelles et al. (2016), after release *D. longicaudata* in Rio Grande do Sul field, did not detect a negative impact on native parasitoid populations. Despite parasitizing preferentially third instar larvae (Montoya et al., 2018), we affirm that *D. longicaudata* is able of parasitizing and succeeding in any instar, differing from that generally described. The interaction between multiple species of parasitoids in the environment is not fully understood, and the release of *D. longicaudata* may be controversial. Thus, this work aimed to investigate the preference and parasitism capacity of *D. longicaudata* in larvae of native *Anastrepha fraterculus* (Wiedemann, 1830) and exotic *C. capitata* from different instars.

**MATERIAL AND METHODS**

**Study site.** The study was conducted at the Laboratory of Biology, Ecology and Biological Control of Insects (Bioecolab), at the Universidade Federal do Rio Grande do Sul, under controlled conditions of 26 ± 1 °C, 60 ± 10% RH, with 14 hours of photophase.

**Host rearing.** The adults of *A. fraterculus* and *C. capitata* were kept in wooden cages (45 x 30 x 30 cm), covered on the sides with voile fabric, receiving distilled water and a solid diet on an *ad libitum* basis, which consisted of crystal sugar, hydrolyzed protein, soybean extract (3:1:1) and vitamin complex (Lavitan – A-Z®), in the ratio of two macerated tablets per 250 g of diet (adapted from Jaldo et al., 2001). As an oviposition substrate for *C. capitata*, a 250 ml yellow plastic tube with small perforations (FAO/IAEA/USDA, 2003) was used. For *A. fraterculus*, the substrate used was a blue tissue bag covered with silicone, as described in Meirelles et al. (2016). The eggs were collected daily and placed on polystyrene trays (23.5 x 18 x 1 cm), with an artificial diet based on organic carrot, beer yeast, corn flour, sugar, distilled water, sodium benzoate (Dinâmica®), nipagin (Synth®) and citric acid (Synth®) (modified from Teran, 1977). After seven days, these were placed inside larger plastic trays (51 x 30 x 9.5 cm), with sterile sand and covered by organza, where they remained for approximately seven days for the pupation. Subsequently, the sand was sifted and the pupae obtained were placed in plastic containers (6.6 x 6.6 x 6 cm) until emergence.

**Parasitoids rearing.** The rearing has started from the parasitized pupae of *A. fraterculus*, from *Embrapa Clima Temperado*, Pelotas, RS, Brazil. The adults were kept in wooden cages (19.5 x 16.5 x 25.5 cm), covered with organza material and fed with honey dissolved in water (7:3), offered in Petri dishes (5 x 5 x 1.5 cm) with cotton, water was provide by capillarity through a strip of Spontex Resist® fabric. Third instar *C. capitata* larvae were placed in parasitism units, which consisted of a circular plastic plate (4 cm in diameter), with a 0.3 cm border, formed by a small layer of silicone, wrapped with white organza fabric stuck with a rubber band. After one hour of exposure, the larvae were returned to the artificial diet in polystyrene trays (15.5 x 15.5 x 1 cm) and stored in plastic trays (41 x 28 x 7 cm) on a layer of sand sterilized until the pupae formation. After five days, the sand was sifted, and the pupae were packaged in the same manner as for fly breeding, waiting for parasitoids emergence that were reintroduced to the breeding in new cages.

Parasitism in different instars between two host species. The females preference was evaluated by concomitantly offering 25 larvae of *A. fraterculus* (AF) and 25 larvae of *C. capitata* (CC) to five couples of parasitoids (eight days old). First, second and third instar larvae of the two host species were evaluated. The larvae were offered daily for five days, completing 60 replicates and totaling 1,500 larvae evaluated by treatment. The couples were kept in wooden cages (15 x 15.5 x 20 cm), covered with organza, offered water and food. The larvae were offered in parasitism units, consisting of a circular plastic plate (2.7 cm in diameter), with a border of 0.2 cm, formed by a small layer of silicone and encased in white voile, trapped with an elastic band, disposed on pots with 3.8 cm in height as support. The units were exposed for eight hours, and the larvae were then returned to the artificial diet in polystyrene trays and placed in plastic containers (35 x 17.5 x 10 cm) on a layer of sand until pupa formation.

In order to evaluate larval mortality without action of parasitoids (control treatment) 25 larvae of *A. fraterculus* and *C. capitata* (total of 50 larvae per cage) were placed in parasitism units and these remained in cages for eight hours without parasitoids presence. Following that, the larvae were kept in the same manner as described for breeding.

Multiple-choice parasitism test with different larval instars of the same host. The preference of *D. longicaudata* females was evaluated in cages as described previously with three parasitism units containing 15 larvae of first, second and third instar (total of 45 larvae per replicate) of one host species – AF or CC – to five couples of parasitoids (eight days old). The larvae were offered daily for five days, totaling 30 replicates and 1,350 larvae evaluated. The units remained exposed for eight hours, and the larvae were then conditioned as described previously.

To evaluate larval mortality, without action of the parasitoids (control treatment), 15 instar larvae each, totaling 45 larvae per cage, or *A. fraterculus* or *C. capitata* were placed in parasitism units and kept in the cages for the
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For both bioassays, after five days, the sand was sifted and the pupae packed in plastic pots until the emergence of flies or parasitoids. The pupae of which there was no emergence were dissected for check the presence of parasitoids or flies. The mean numbers of formed pupae were recorded, as well as parasitized pupae (emerged parasitoids + pupae dissected with parasitoids), emerged parasitoids, unviable pupae [number of offered larvae - (number of flies emerged + emerged parasitoids)], sex ratio of parasitoids, and parasitism rate.

Statistical analysis. The mean values were analyzed for normality by the Shapiro-Wilk test and submitted to analysis of variance, the means being compared by ANOVA, followed by the Tukey test, with a significance level of 5%.

The sex ratio (Rs) was estimated using the formula: Rs = number of females / number of females + number of males. The Chi-square ($\chi^2$) of heterogeneity was used to compare Rs between treatments. The parasitism index was calculated using the formula: IP = number of emerged parasitoids / number of pupae formed × 100. The tests were performed using the BioEstat 5.0 software (Ayres et al., 2007).

RESULTS

Multiple-choice parasitism in different instars between two host species

Anastrepha fraterculus. The mean number of parasitized pupae and emerged parasitoids was significantly higher ($F = 30.5686; df = 2; p < 0.0001$, $F = 35.4343; df = 2; p < 0.0001$, respectively) in larvae of first and second instar when compared to third instar larvae (Fig. 1) (Tab. I). The parasitism rate was 73.8, 74 and 34% in first, second and third instar larvae, respectively.

The mean value (± SE) of pupae formed in control treatment (without presence of parasitoids) was 21.0 ±

Tab. I. Mean number (± SE) of formed pupae, parasitized pupae, unviable pupae and sex ratio of hosts Anastrepha fraterculus (Wiedemann, 1830) and Ceratitis capitata (Wiedemann, 1824), exposed to parasitism by Diachasmimorpha longicaudata (Ashmead, 1905) on first, second and third-instar larvae. The bars correspond to the standard error. Bars with asterisk presented significant difference (ANOVA test, followed by the Tukey test, p < 0.05) of the other instars for the same host species.

<table>
<thead>
<tr>
<th>Variables evaluated</th>
<th>Instar</th>
<th>AF</th>
<th>CC</th>
<th>AF</th>
<th>CC</th>
<th>AF</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formed pupae</td>
<td>First</td>
<td>17.9 ± 0.80 bA</td>
<td>18.2 ± 0.65 bA</td>
<td>19.6 ± 0.44 abA</td>
<td>18.5 ± 0.56 bA</td>
<td>21.4 ± 0.78 aA</td>
<td>21.7 ± 0.63 aA</td>
</tr>
<tr>
<td>Parasitized pupae (1)</td>
<td>First</td>
<td>13.3 ± 0.68 aA</td>
<td>13.2 ± 0.70 aA</td>
<td>14.6 ± 0.60 aA</td>
<td>13.3 ± 0.61 aA</td>
<td>7.9 ± 0.65 bB</td>
<td>13.4 ± 0.71 aA</td>
</tr>
<tr>
<td>Unviable pupae (2)</td>
<td>First</td>
<td>10.4 ± 0.72 bA</td>
<td>9.2 ± 0.66 aA</td>
<td>9.6 ± 0.62 bA</td>
<td>10.5 ± 0.58 aA</td>
<td>17.1 ± 0.71 aA</td>
<td>9.4 ± 0.70 aB</td>
</tr>
<tr>
<td>Sex ratio</td>
<td>First</td>
<td>0.24 bA</td>
<td>0.10 bB</td>
<td>0.31 aA</td>
<td>0.21 aB</td>
<td>0.27 bA</td>
<td>0.10 bB</td>
</tr>
</tbody>
</table>

Fig. 1. Mean number of emerged parasitoids in hosts Anastrepha fraterculus (Wiedemann, 1830) and Ceratitis capitata (Wiedemann, 1824), exposed to parasitism by Diachasmimorpha longicaudata (Ashmead, 1905) on first, second and third-instar larvae. The bars correspond to the standard error. Bars with asterisk presented significant difference (ANOVA test, followed by the Tukey test, p < 0.05) of the other instars for the same host species.
Does Diachasmimorpha longicaudata (Hymenoptera: Braconidae) parasitize Anastrepha fraterculus (Diptera: Tephritidae) to produce sex ratio differences in the offspring, compared to Ceratitis capitata (Diptera: Tephritidae) as host species?

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Sex ratio, tested by $\chi^2$ for heterogeneity. (1) emerged parasitoids + pupae dissected with parasitoids; (2) number of larvae offered – (number of emerged flies + emerged parasitoids).

<table>
<thead>
<tr>
<th>Variables evaluated</th>
<th>Anastrepha fraterculus</th>
<th>Ceratitis capitata</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First</td>
<td>Second</td>
</tr>
<tr>
<td>Formed pupae</td>
<td>$11.4 \pm 0.46$ a</td>
<td>$12.2 \pm 0.57$ a</td>
</tr>
<tr>
<td>Parasitized pupae</td>
<td>$7.6 \pm 0.64$ b</td>
<td>$10.6 \pm 0.55$ a</td>
</tr>
<tr>
<td>Emerged pupae</td>
<td>$7.6 \pm 0.64$ b</td>
<td>$10.6 \pm 0.55$ a</td>
</tr>
<tr>
<td>Unviable pupae</td>
<td>$5.2 \pm 0.58$ b</td>
<td>$4.3 \pm 0.54$ b</td>
</tr>
<tr>
<td>Sex ratio</td>
<td>$0.27$ b</td>
<td>$0.32$ b</td>
</tr>
</tbody>
</table>

Tab. II. Mean number (± SE) of formed pupae, parasitized pupae, emerged parasitoids, unviable pupae and sex ratio of hosts *Anastrepha fraterculus* (Wiedemann, 1830) and *Ceratitis capitata* (Wiedemann, 1824) exposed to parasitism by *Diachasmimorpha longicaudata* (Ashmead, 1905) on first, second and third-instar larvae. Lowercase letters compare the different treatments with the same host species. ANOVA test, followed by Tukey ($p < 0.05$). Sex ratio, tested by $\chi^2$ for heterogeneity. (1) emerged parasitoids + pupae dissected with parasitoids; (2) number of larvae offered – (number of emerged flies + emerged parasitoids).
with the presence of parasitoids (p > 0.05) (Tab. II). In the treatments with parasitoids, the mean number of univiable pupae was higher in those exposed in the third instar (F = 9.4386; df = 2; p = 0.0004) (Tab. II). In the control, the mean value (± SE) were of 2.6 ± 0.67; 2.0 ± 0.83 and 8.6 ± 0.4 for the first, second and third instars, respectively, being lower than treatments with parasitoids only in the third instar (F = 23.2425; df = 1; p = 0.0001).

The sex ratio of offspring generated was higher in third instar larvae, with more females emerged (χ^2 = 47.9; df = 5; α = 0.05) (Tab. II).

**Ceratitis capitata.** The mean number of parasitized pupae and emerged parasitoids (F = 16.6636; df = 2; p < 0.0001; F = 16.36337; df = 2; p < 0.0001, respectively) was higher in the second and third instars (Tab. II). The parasitism rate was 78.2% for first instar larvae and 85.9% and 79.9% for second and third instar larvae, respectively.

The mean values (± SE) of pupae formed in the control was 12.6 ± 0.74; 14.8 ± 0.20 and 14.6 ± 0.24 for first, second and third instar larvae, respectively. There was no difference between control and treatments parasitoids presence (p > 0.05). In the treatments with parasitoids, the second and third instars were the ones with the highest mean number of pupae formed (F = 41.3569; df = 2; p < 0.0001) (Tab. II). The mean number of univiable pupae in tests with parasitoids presence was higher in first instar larva (F = 8.8180; df = 2; p = 0.0008) (Tab. II). The control had the mean values (± SE) of 2.4 ± 0.74; 0.2 ± 0.2 and 0.4 ± 0.24 for the first, second and third instars, respectively. All treatments that had the presence of parasitoids had a higher mean number of univiable pupae, when compared to their controls (F = 6.7424; df = 1; p = 0.0134 for first, F = 5.6186; df = 1; p = 0.0224 for second, and F = 5.0216; df = 1; p = 0.0301 for third instar).

The sex ratio of offspring generated was higher in larvae exposed in the third instar, with more females emerged (χ^2 = 64.4; df = 5; α = 0.05) (Tab. II).

**DISCUSSION**

The lack of difference in pupae number formed between treatments, even with the presence of parasitoids, is expected, considering that *D. longicaudata* is a koinobiont parasitoid (OVRUSKI et al., 2000), that does not kill the larvae of its hosts immediately, allowing them to finish their development and pupate before causing death. This is known for Braconidae fruit fly parasitoids that emerge only at the pupal stage (OVRUSKI et al., 2000; 2003). The higher mortality in some treatments, when compared to the control in this experiment, may be due to the stress caused to the larvae by parasitism, test punctures or even by superparasitism (OVRUSKI et al., 2011; HARBI et al., 2018). In our study, when only one instar was offered, *D. longicaudata* efficiently parasitized larvae of both the first and second instars of *A. fraterculus*, showing that their response may be conditioned to the environment, differing from other studies that registered their preference for the late larval stages (OVRUSKI et al., 2011; VAN NIEUWENHOVE & OVRUSKI, 2011; MONTOYA et al., 2017). In addition, *D. longicaudata* showed no instar preference in *C. capitata* larvae when exposed only one at a time. On the other hand, when the three instars were offered concomitantly, the highest parasitism was in the second and third instar. In general, parasitoids usually to have a preferential or single instar to parasitize, as seek to specialize in relation to the species they use as hosts and can be specialize in certain stages thereof (MATTIACCI & DIKE, 1995; MONTOYA et al., 2018). In the case of *D. longicaudata*, there are records that it is able to parasitize the second and third instars (SIVINSKI et al., 2001; SIME et al., 2006). Additionally, this species has been shown a broad plasticity, adapting easily to environmental conditions (CARVALHO & NASCIMENTO, 2002).

When the three larval instars of *A. fraterculus* were exposed simultaneously, the second instar was preferred, differing from the studies that suggested the third as preferential (OVRUSKI et al., 2011; VAN NIEUWENHOVE & OVRUSKI, 2011; MONTOYA et al., 2017). The interaction between *D. longicaudata* and *A. fraterculus* can be considered as a “new association”, as they do not share an intense history of coevolution, a factor that may influence the parasitoid-host relationship (HOKKANEN & PIMENTEL, 1989), and even change the parasitoid’s preferences for the parasite. The fact that *A. fraterculus* larvae are larger than *C. capitata* (MEIRELLES et al., 2013; OLIVEIRA et al., 2014; SÁ et al., 2018) or those of many *Bactrocera* species (MAU & KESSING, 1992; THOMAS et al., 2001; SINGH et al., 2010), their original hosts, may cause the *D. longicaudata* to parasitize also the first instars of the South American fruit fly, recognizing the youngest larvae as appropriate for their development, with sufficient nutritional quality and quantity to meet their needs, opposing previous studies (LÓPEZ et al., 2009; HARVEY et al., 2012).

In the environment, hosts can be found at different stages and densities inside the fruits, which may reflect parasitoid choices (NÚÑEZ-CAMPERO et al., 2016). Thus, there is no ensure that *D. longicaudata* will not compete for the same oviposition niche of the native parasitoids. For parasitoids, a single host comprises its entire source of larval food and can have great influence on the adult’s fitness. In general, larger hosts have more qualitative resources to supply parasitoid fitness (MATTIACCI & DICE, 1995; OVRUSKI et al., 2011; HARVEY et al., 2012). This apparently did not influence in *D. longicaudata* choice in our study, being effective even in first and second instar larvae. In this case, possibly even smaller larva can guarantee the quantity and nutritional quality for *D. longicaudata* development, as their hosts were originally species of *Bactrocera* (WHARTON & GILSTRAP, 1983), smaller than those tested in this study (SINGH & RAMAMURTHY, 2010).

The sex ratio of *D. longicaudata* offspring grown in both *A. fraterculus* and *C. capitata* was biased for males, indicating that host or environmental conditions may not have been proper for the parasitoid (GODFRAY, 1994). When different instars of the same host species were offered simultaneously, a larger number of females emerged in second and third instar larvae, respectively. The data found in our study corroborate the records that Tephritidae parasitoids...
that parasitize larvae in later stages tend to produce a larger number of females (Eben et al., 2000; Ovurski et al., 2011; Van Nieuwenhove & Ovurski, 2011). On the other hand, Montoya et al. (2011, 2012) argue that larval size influences superparasitism, which, in turn, influences the sexual ratio of D. longicaudata. When moderate superparasitism occurs (2-6 scars per pupa), there is a trend of female emergence, with no detrimental effects on the demographic parameter to offspring, including longevity and fecundity (González et al., 2007; Montoya et al., 2011; 2012). It is possible that this occurred in our study on the second bioassay, although we did not record the number of scars left on the larvae, given that it could help to evaluate superparasitism and corroborate this hypothesis.

When the hosts A. fraterculus and C. capitata were exposed simultaneously, we observed that in A. fraterculus there was a higher proportion of females. In relation to the emergence of parasitoids and mortality, however, both had similar means, except for third instar larvae of A. fraterculus, with a higher mean number of unviable pupae and lower number of emerged parasitoids. Although C. capitata has been used for a long time in rearing of D. longicaudata in several places of the world, A. fraterculus has already been used, showing a good performance as a host (Messing et al., 1993; Van Nieuwenhove & Ovurski, 2011; Meirelles et al., 2016; Harrh et al., 2018), and our study confirms this data. This aspect is important in mass rearing since studies such as those by Segura et al. (2007) and Tognon et al. (2013) have demonstrated that parasitoids that are reared in a given host are easier to recognize through chemical tracks, obtained by memory or learning, which would provide greater efficiency in the control of the target pest (Mattiacci & Dicke, 1995; Eben et al., 2000).

Our study demonstrates the plasticity of D. longicaudata at the moment of host selection, and that it can be considered a good competitor. It is important that D. longicaudata coexist with other parasitoids, not leading their populations to decline. Therefore, before releasing exotic wasps species, it is important to know how they respond (behavior) in the field. Other factors such as biotic and abiotic conditions (Sivinski et al., 2000), chemical tracks of plants (Eitam et al., 2003; Silva et al., 2007; Segura et al., 2016) and patch isolation (Eitam et al., 2004) may also interfere in search and parasitism. Considering that not all environments have abiotic and biotic barriers, which may help in the niches division, and that D. longicaudata is a competitive species, easily parasitizing any instar, its introduction into new environments should be well evaluated, so as not to cause suppression of other species and a subsequent imbalance in the environment.

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Does Diachasmimorpha longicaudata (Hymenoptera: Braconidae) parasitize Ovatus fraterculus (Diptera: Tephritidae)?

Ovatus fraterculus (Diptera: Tephritidae) is a major pest of tropical fruits, particularly mangoes. Its management often involves the release of its natural enemies, such as Diachasmimorpha longicaudata (Hymenoptera: Braconidae), a parasitoid of the larva and pupa of Ovatus fraterculus. The parasitoid’s host selection is influenced by several factors, including host density and the availability of alternative hosts.

This study aimed to understand how the parasitoid Diachasmimorpha longicaudata selects its hosts, particularly in the context of augmentative biological control programs. The research focused on the behavioral and ecological aspects of the parasitoid’s interactions with its host and potential competitors.

Key findings include:
- Host size affects the interaction between pupal parasitoid Coptera haywardi (Hymenoptera: Diapriidae) and larval–pupal parasitoid Diachasmimorpha longicaudata (Hymenoptera: Braconidae).
- Quality control parameters of mass-reared Opine parasitoids used in augmentative biological control of Tephritid fruit flies in Hawai'i.

The study’s results contribute to the understanding of parasitoid-host interactions and their implications for the effective management of pest species in tropical regions.