BIOLOGICAL CHARACTERISTICS OF *Trichogramma maxacalii* (HYMENOPTERA: TRICHOGRAMMATIDAE) ON EGGS OF *Anagasta kuehniella* (LEPIDOPTERA: PYRALIDAE)

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ABSTRACT

Individuals of two populations of *Trichogramma maxacalii* (Hymenoptera: Trichogrammatidae) were collected from eggs of *Euselasia apisaon* (Lepidoptera: Riodinidae), a lepidopteran defoliator of *Eucalyptus*, in plantations in the states of São Paulo and Minas Gerais, Brazil. This study investigated the sex ratio, number of parasitoids per egg, and longevity of individuals of these two populations of *T. maxacalii*, when this parasitoid was reared receiving eggs of the factitious host *Anagasta kuehniella* (Lepidoptera: Pyralidae) in different periods after emergence, and with or without honey. Sex ratio of *T. maxacalii* varied from 0.44 to 0.60, and was affected by the interaction between populations, availability of food (honey), and length of time in which the parasitoid stayed without host eggs after their emergence. The population of *T. maxacalii* collected in São Paulo produced a larger number of individuals per egg of the host *A. kuehniella* and lived longer when fed.

Key words: *Trichogramma*, factitious host, *Eucalyptus*.

RESUMO

Características biológicas de *Trichogramma maxacalii* (Hymenoptera: Trichogrammatidae) em ovos de *Anagasta kuehniella* (Lepidoptera: Pyralidae)

Duas populações de *Trichogramma maxacalii* (Hymenoptera: Trichogrammatidae) foram coletadas de ovos de *Euselasia apisaon* (Lepidoptera: Riodinidae), um lepidóptero desfolhador de *Eucalyptus*, em plantios nos Estados de São Paulo e Minas Gerais, Brasil. Esta pesquisa avaliou a razão sexual, o número de parasitóides por ovo e a longevidade dos indivíduos dessas duas populações de *T. maxacalii*, quando esse parasitóide foi criado recebendo ovos do hospedeiro alternativo *Anagasta kuehniella* (Lepidoptera: Pyralidae) em diferentes períodos após a emergência e recebendo ou não mel como alimento. A razão sexual de *T. maxacalii* variou de 0,44 a 0,60 e foi afetada pela interação entre população, disponibilidade de alimento (mel) e tempo que o parasitóide ficou sem receber ovos do hospedeiro. A população de *T. maxacalii* coletada em São Paulo produziu maior número de indivíduos por ovo de *A. kuehniella* e teve maior longevidade quando alimentada.

Palavras-chave: *Trichogramma*, hospedeiro alternativo, *Eucalyptus*.

INTRODUCTION

Trichogramma species are the most studied group worldwide of egg parasitoids for biological control due to their efficiency and easy maintenance under laboratory conditions (Parra & Zucchi, 1997). These natural enemies are used in more than 30 countries in biological control programs against insect pests in over 30 cultures (Wajnberg & Hassan, 1994). Because these species can be found in the majority of ecosystems where they can suppress many pests, these natural enemies are favored in many commercial biological control programs (Morrison, 1985; Parra *et al*., 1989).

In Brazil, studies with *Trichogramma* species started with the importation and mass rearing of *Trichogramma minutum* (Riley) for control of the sugarcane borer *Diatraea saccharalis* (Fabricius) (Lepidoptera: Pyralidae) (Pratissoli, 1986). Parasitoids of this group are promising control agents against pests in many agricultural and forest crops (Parra & Zucchi, 1997).

Moraes *et al*. (1983) found *Trichogramma demoraesi* (Nagaraja) and *Trichogramma soaresi* (Nagaraja); Brun *et al*. (1984) described *Trichogramma manicobai*, *Trichogramma caiaposi*, and *Trichogramma acacioi*; and Voegelé & Pointel (1980) and Oliveira *et al*. (2000) found *Trichogramma maxacalii* (Hymenoptera: Trichogrammatidae), all of them as parasitoids of lepidopteran pest species in *Eucalyptus* plantations.

It is necessary to study biological characteristics of *Trichogramma* species before using them in biological control programs (Ashley *et al*., 1974). Many parameters such as sex ratio and development cycle can be used to select species and/or strains of *Trichogramma* (Ashley *et al*., 1974; Gou, 1988).

The objective of this study was to investigate some biological characteristics of two populations of the parasitoid *T. maxacalii* in eggs of *A. kuehniella* to determine if this factitious host is appropriate for their mass rearing, and to identify the best way to rear them in the laboratory.

MATERIALS AND METHODS

This research was conducted at the Laboratory of Entomology of the Agrarian Sciences Center of the Universidade Federal de Espírito Santo (CCAUFES), in Alegre, Espírito Santo State, Brazil. We collected individuals of two populations of *T. maxacalii* from eggs of the defoliator *E. apisaon* in *Eucalyptus* plantations in the regions of Ribeirão Preto, São Paulo State (population 1), with a mean annual temperature of 20ºC and relative humidity of 70.6%, as well as in Nova Era, Minas Gerais State, Brazil (population 2), with a mean annual temperature of 23.1ºC and 79.6% relative humidity. The sex ratio, longevity of the offspring, and number of individuals per egg of these two populations were studied in eggs of the host *A. kuehniella* when given no food and when provided with a diet of honey. We wanted to know if the biological characteristics of *T. maxacalii* were affected by the presence of food and the length of time before the parasitoid received eggs of the host which were supplied at 0, 6, 12, 24, 36, 48, or 60 hours after the emergence of the parasitoid. The sex ratio of the offspring was determined as the number of females/number of females + males. With an increasing sex ratio there are more females and, consequently, a higher number of individuals produced to parasitize the host. The parasitoids were reared on eggs of *Anagasta kuehniella* as a standard laboratory host for *T. maxacalii*.

We used a total of 140 females for each population of *T. maxacalli*, and for each period (0, 6, 12, 24, 36, 48, or 60 hours), 20 recently emerged females of this parasitoid were used, half of them containing food and half without. They were placed individually in closed glass tubes (4.0 x 0.7 cm) and maintained in the laboratory at 25 ± 1ºC, relative humidity of 70 ± 10% and a 14-hour photoperiod. In each glass tube, a female of the parasitoid received one piece of light blue cardboard (3.5 x 0.5 cm) with 40 *A. kuehniella* eggs collected on the same day. These eggs were glued to the cardboard and made inviable by a 50-minute exposure to germicidal light. This was done to prevent the eggs from hatching, because the caterpillars that could emerge from nonparasitized eggs might eat the rest of the eggs (Parra & Zucchi, 1997). After 24 hours the cardboard containing the eggs was removed and female parasitoids were left devoid of a host in each tube so as to measure their longevity. The cardboards were placed in closed plastic bags (23.0 x 4.0 cm) and maintained under the same conditions as the females of the parasitoid.

The experiment was set up in a completely randomized split plot design in a 2 x 2 factorial (two populations either without food or provided with a diet of honey) and subparcels of seven periods of time (0, 6, 12, 24, 36, 48, and 60 hours) with 10 replications per treatment. An analysis of variance was conducted for all parameters tested, and when the F value was found to be significant, we submitted it to ANOVA at 5% probability level and regression analysis.

RESULTS

Sex ratio

The sex ratio of *T. maxacalii* was affected by the interaction between the population and presence of food and by the time in which adults of *T. maxacalii* were left without eggs of the host (Table 1). The sex ratio varied from 0.44 to 0.60 and showed that the honey supplement had a significantly increasing effect on population 2, and did not change for population 1, when supplemented with honey (Table 2). Both populations had a decreasing sex ratio with age increase of *T. maxacalii* (Fig. 1).

Number of individuals per eggs

The number of individuals per egg of *T. maxacalii* was affected by the interaction between parasitoid population, presence of food, and the length of the initial host-deprivation period (Table 1). The mean number of individuals per egg of the parasitoid in each host egg was always very close to one.

Longevity

Population, feeding, time in which adults of *T. maxacalii* were left without eggs of the host, and interaction between the population and presence of food, affected the longevity of *T. maxacalii* adults (Table 1). The longevity of both populations was longer when they were provided with honey than when they were not given food (Table 3). When comparing adults that were fed, population 2 had higher longevity than population 1. Both populations showed an increase of adult longevity as period of initial host deprivation increased (Fig. 2).

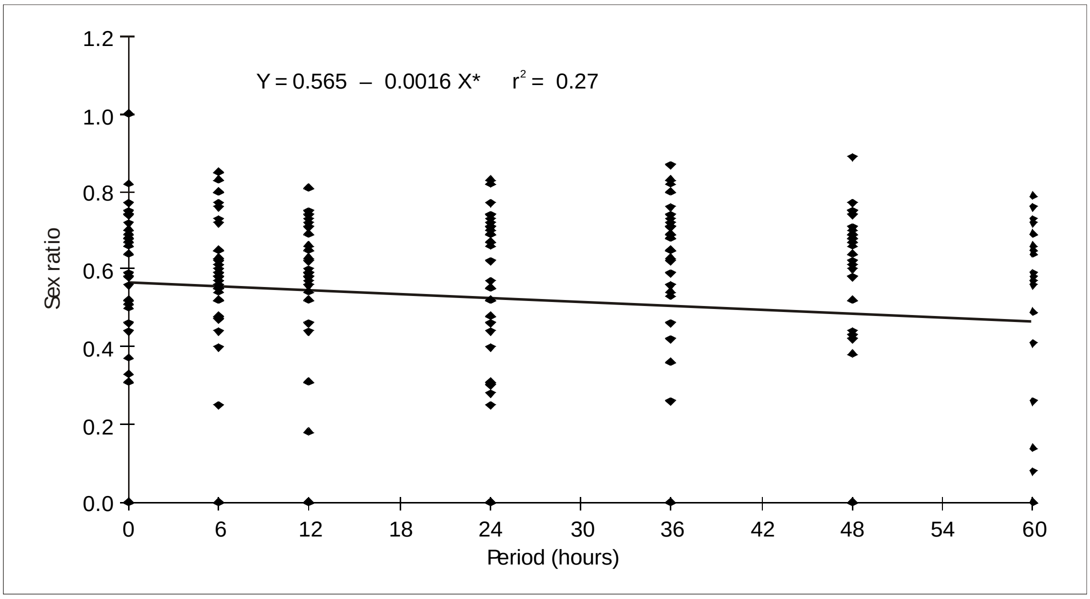

Fig. 1 — The sex ratio for individuals of *Trichogramma maxacalii* (Hymenoptera: Trichogrammatidae) of two populations parasitizing eggs of *Anagasta kuehniella* (Lepidoptera: Pyralidae) as a function of time (hours after emergence of the parasitoid). 25 ± 1ºC, 70 ± 10% relative humidity and a photoperiod of 14 hours.
* indicates significance at $p < 0.05$.

TABLE 1

Analysis of variance of sex ratio, number of individual per egg, and longevity of *Trichogramma maxacalii* (Hymenoptera: Trichogrammatidae), on eggs of *Anagasta kuehniella* (Lepidoptera: Pyralidae) at 25 ± 1ºC, 70 ± 10% relative humidity, and a photophase of 14 hours.

Source of variation	Degrees of freedom	Medium square		
		Sex ratio	Number of individual per egg	Longevity
Population	1	0.001	0.0005	33.84*
Feeding	1	0.212	0.0004	1450.03*
Population x feeding	1	0.458*	0.0007	27.74*
Error a	36	0.058	0.0007	2.19
Time	6	0.172*	0.0004	26.77*
Population x time	6	0.111	0.0016	5.09
Feeding x time	6	0.105	0.0006	2.98
Population x feeding x time	6	0.098	0.0025*	2.63
Error b	181	0.061	0.0008	3.19

* Significant by F test at 5% probability level.

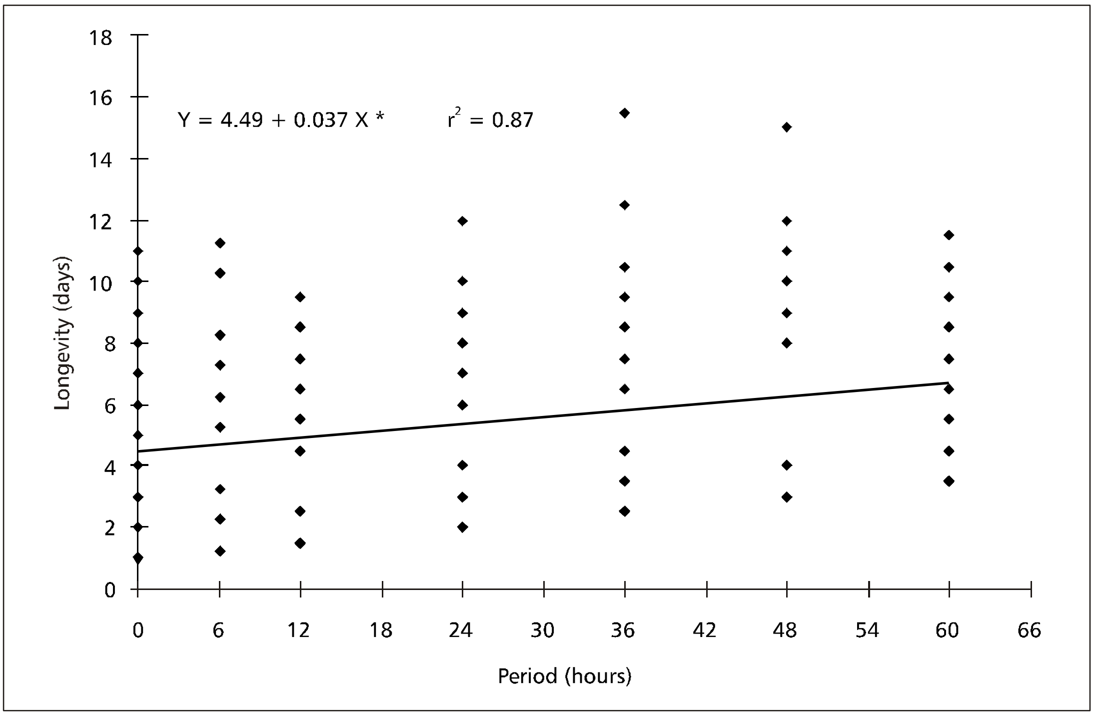

Fig. 2 — Longevity as a function of time (hours after the emergence of the parasitoid) for adults of two populations of *Trichogramma maxacalii* (Hymenoptera: Trichogrammatidae) without exposure to eggs of *Anagasta kuehniella* (Lepidoptera: Pyralidae). 25 ± 1ºC, 70 ± 10% relative humidity, and a photoperiod of 14 hours.
* indicates significance at $p < 0.05$.

TABLE 2

Mean sex ratio and standard deviation in two populations of *Trichogramma maxacalii* (Hymenoptera: Trichogrammatidae), provided with honey or without food, when reared at 25 ± 1ºC, 70 ± 10% relative humidity, and a photoperiod of 14 hours.

Population	Fed with honey	
	Yes	No
1	0.51 ± 0.04 aA	0.53 ± 0.03 aA
2	0.60 ± 0.03 aA	0.44 ± 0.03 bA

Means followed by the same lower case letter in the line or capital letter in the column are not different between themselves (Anova, $p < 0.05$).

TABLE 3

Mean longevity (days) and standard deviation of individuals of two populations of Trichogramma maxacalii (Hymenoptera: Trichogrammatidae) provided with honey or without food, when reared at 25 ± 1ºC, 70 ± 10% relative humidity, and a photoperiod of 14 hours.

Population	Fed with honey	
	Yes	No
1	7.18 ± 0.34 aB	2.37 ± 0.12 bA
2	8.67 ± 0.26 aA	2.55 ± 0.11 bA

Means followed by the same lower case letter in the line or capital letter in the column are not different between themselves (Anova, $p < 0.05$).

DISCUSSION

Sex ratio

The sex ratio (0.44 to 0.60) of *T. maxacalii* in eggs of *A. kuehniella* was similar to that reported by Sá & Parra (1994) for two strains of *Trichogramma pretiosum* Riley which were 0.44 and 0,57, and lower than those found by Lopes & Parra (1991) for *Trichogramma distinctum* (Zucchi), Corrigan & Laing (1994) for *T. minutum*, and Abbas (1989) for *Trichogramma buesi* Dugast & Voegelé, which were 0.78, 0.75, and 0.77, respectively, in eggs of *A. kuehniella*. Pratissoli (1995) reported that the sex ratio of different strains of *T. pretiosum* ranged from 0.37 to 0.87 in eggs of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) and 0.54 to 0.92 in eggs of *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae). This demonstrates that the sex ratio of *Trichogramma* can vary between species, strains, and populations when this parasitoid is reared on the same host.

The type of host also influences the sex ratio of egg parasitoids. Corrigan & Laing (1994) found a sex ratio of 0.81, 0.76, and 0.76 for *T. minutum* in eggs of *Lambdina fiscellaria* (Guenée) (Lepidoptera: Geometridae), *Manduca sexta* (L.) (Lepidoptera: Sphingidae), and *Choristoneura fumiferana* (Clem.) (Lepidoptera: Tortricidae). Bai *et al*. (1995) showed that *Trichogramma brassicae* (Bezdenko) presented a sex ratio of 0.75 and 0.82 in eggs of *L. fiscellaria* and *C. fumiferana*, respectively, while *T. minutum* showed a sex ratio of 0.85 and 0.86 in eggs of *L. fiscellaria* and *C. fumiferana*, respectively.

The sex ratio of *Trichogramma* species can be influenced by the presence and quality of food

(Leatemia *et al.*, 1995a) as demonstrated in this research, through which we found a higher sex ratio for population 2 when provided with honey (Table 2).

The sex ratio of *T. maxacalii* decreased with the length of time in which the two populations of this parasitoid were initially kept without host eggs. However, this decrease was not exclusively due to the period of host deprivation as indicated by the low correlation coefficient ($r^2 = 0.27$). This suggests that other factors can also affect the sex ratio of *T. maxacalii* (Fig. 1). The highest sex ratio was found when the parasitoids were supplied with host eggs immediately after their emergence. This result conflicts with findings of Leatemia *et al*. (1995b) who showed that sex ratio increased with the initial period of host deprivation from 0.45 to 0.59 for *T. minutum* in eggs of *C. fumiferana*.

Number of individuals per eggs

The number of individuals of *T. maxacalii* per host egg (*A. kuehniella*) found was very close to one, which is similar to that reported by Stein & Parra (1987) for *Trichogramma* spp. in eggs of *Sitotroga cereallela* (Oliv.) and *Plodia interpunctella* (Hueb.) (Lepidoptera: Pyralidae). However, it is lower than that found by Lopes & Parra (1991) for *Trichogramma galloi* Zucchi in eggs of *Diatraea saccharalis* (Fabr.) (Lepidoptera: Pyralidae); by Tironi & Ciociola (1994) for *Trichogramma* spp. in eggs of *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae); and by Pratissoli & Oliveira (1999) for *T. pretiosum* in eggs of *H. zea*. These differences can be explained by Schmidt & Smith (1987) who reported that the number of individuals per egg is a function of egg size, with a higher number of parasitoids per egg in bigger eggs.

Longevity

The longevity of *T. maxacalii* increased with an increasing initial period of host deprivation (Fig. 2). This can be explained by the fact that receiving eggs of the host, *T. maxacalii* means energy spent to parasitize them. Similar results for *T. minutum* showed that longevity decreased without a defined sequence from 29.2 to 20.8 days for parasitoids receiving host eggs one to 16 days after emergence (Leatemia *et al*., 1995a). Santa-Cecília *et al.* (1987) reported that *T. demoraesi* had similar longevity patterns up to the 10th day without a host, after which a sharp decline occurred regardless of the feeding regime. An important finding in these studies is the existence of a threshold point after which a significant parasitoid longevity decrease occurs. *T. maxacalii* showed total adult mortality after 60 hours without food.

Females of *T. maxacalii* lived longer without receiving host eggs (*A. kuehniella*). On the other hand, longevity should be shorter in the field than under laboratory conditions. This parasitoid should, therefore, be released in places adequate for host finding because, besides expending energy on parasitizing, it also uses energy searching for hosts.

Santa-Cecília *et al*. (1987) found no differences in longevity of *T. demoraesi* adults with (11.59 days) or without (11.38 days) supplemental feeding, while Leatemia *et al*. (1995b) reported longevity of 26.4 and 3.5 days for adults of *T. minutum*, with or without honey, respectively. Cônsoli & Parra (1994) showed longevity of 3.77 days for *T. galloi* fed with honey, in eggs of *D. saccharalis.* Berti & Marcano (1993) found longevity of 5.9 days for *T. pretiosum* fed with honey in eggs of *S. cerealella*. Longevity of *Trichogramma* adults also varies with host type because longevity in *T. brassicae, T. minutum,* and *T.* nr. *sibiricum* varied from 8.6 to 9.2 days, 10.2 to 11.7 days, and 8.3 to 12.4, respectively, depending on the host type (Bai *et al*., 1995). In most cases, it is very important to provide food like honey because it could increase longevity (Amaya, 1982).

The results found in this research showed that *A. kuehniella* can be a good factitious host in rearing *T. maxacalii* in mass programs, and that this parasitoid must be fed to increases its longevity

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