



Trichogramma pretiosum parasitism of *Pseudoplusia includens* and *Anticarsia gemmatalis* eggs at different temperatures

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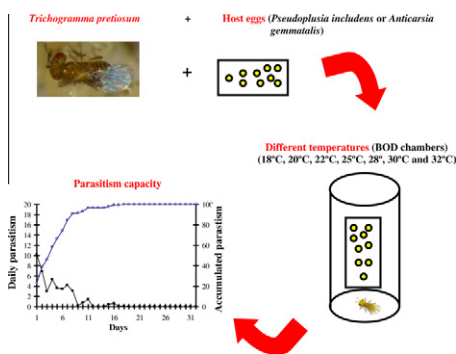
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HIGHLIGHTS

- ▶ *Trichogramma pretiosum* is suitable to control *Pseudoplusia includens*.
- ▶ *T. pretiosum* is suitable to control *Anticarsia gemmatalis*.
- ▶ *T. pretiosum* showed good parasitism on temperatures varying from 18 to 32 °C.
- ▶ *T. pretiosum* had higher parasitism on the first 24 h of parasitism.

GRAPHICAL ABSTRACT



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ABSTRACT

Egg parasitism of *Trichogramma pretiosum* strain RV when presented with eggs of *Anticarsia gemmatalis* and *Pseudoplusia includens* was investigated at 18, 20, 22, 25, 28, 30 and 32 °C. The number of eggs parasitized per day decreased for both hosts as a function of the age of parasitoids, reaching 80% of lifetime parasitism more rapidly as temperature increased; on the 4th day at 32 °C and on the 12th day at 18 °C. The lifetime number of parasitized *P. includens* eggs achieved by the parasitoid maintained at 20 °C (44.95 ± 3.94) differed from the results recorded at 32 °C (28.5 ± 1.33). Differently, the lifetime number of *A. gemmatalis* parasitized eggs did not differ among the temperatures. When *T. pretiosum* reached 100% of lifetime parasitism, each adult female had parasitized from 28.5 ± 1.33 to 44.95 ± 3.94 and from 29.58 ± 2.80 to 45.36 ± 4.50 *P. includens* and *A. gemmatalis* eggs, respectively. Also, the longevity of these adult *T. pretiosum* females, for which *P. includens* or *A. gemmatalis* eggs were offered, was inversely correlated with temperature. Not only were the survival curves of those adult *T. pretiosum* females of type I when they were presented with eggs of *A. gemmatalis* but also with eggs of *P. includens*, i.e., there was an increase in the mortality rate with time as the temperature increased. In conclusion, *T. pretiosum* strain RV parasitism was impacted by temperature when on both host eggs; however, the parasitoid still exhibited high survival and, more importantly, high number of parasitized *A. gemmatalis* and *P. includens* eggs even at the extremes tested temperatures of 18 and 32 °C. Those results indicate that *T. pretiosum* strain RV might be well adapted to this studied temperature range and, thus, be potentially suitable for use in biological control programs of *P. includens* and *A. gemmatalis* in different geographical areas that fits in this range. It is important to emphasize the results here presented are from laboratory studies and,

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therefore, field trials still need to be carried out in the future with this strain in order to support the full development of the technology intend to use this egg parasitoid in soybean fields worldwide.

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1. Introduction

Soybean, *Glycine max* [(Linnaeus, 1735) Merrill, 1917], has a worldwide production estimated at 256 million metric tons and is of economic importance worldwide. Soybean productivity could be increased if insect infestations could be mitigated (Oerke, 2006). Several species of caterpillars have adversely affected soybean yields from Argentina to the southeastern United States (Hoffmann-Campo et al., 2003). Among these pests, the velvet-bean caterpillar, *Anticarsia gemmatilis* (Hübner) (Lepidoptera: Noctuidae), is one of the most important species (Panizzi and Correa-Ferreira, 1997). However, recent outbreaks of other species, such as, the soybean looper, *Pseudoplusia includens* (Walker) (Lepidoptera: Noctuidae), have become more frequent due to changes in the use patterns of pesticides. Not only is this increase of *P. includens* a consequence of the overuse of insecticides but also fungicides for the control of Asian Soybean Rust (Bueno et al., 2007). Insecticides have been the most common control measure employed in agriculture which is often overused by some soybean growers. It triggers some negative effects (Song and Swinton, 2009) such as pesticides rapid selection of pest strains that are resistant to a given active ingredient (Diez-Rodriguez and Omoto, 2001) or the reduction of natural biological control agents, especially when non-selective insecticides are used (Carmo et al., 2010; van Lenteren and Bueno, 2003). In addition, the use of fungicide has largely contributed to the elimination of entomopathogenic fungi that used to maintain the *P. includens* populations under control (Bueno et al., 2007).

To address these problems regarding pest management and maximize soybean production, pest-control management must integrate complementary tactics into this system. Biological control programs have shown good results in managing insect pests, particularly the caterpillars (Parra et al., 1987). The egg parasitoids of the genus *Trichogramma* (Hymenoptera: Trichogrammatidae) have been widely utilized in biological control programs, because they are easily reared on alternative hosts (Parra, 1997; Haji et al., 1998) and are aggressive in their parasitization of pest-insect eggs (Botelho et al., 1999).

The success of *Trichogramma* releases, however, depends on the knowledge of the bioecological characteristics of the parasitoid and on its interaction with the targeted host (Bourchier and Smith, 1996). Therefore, to validate the use of *Trichogramma* species in controlling insect pests in commercial releases, laboratory studies investigating parasitoid biology and its parasitism (Hassan, 1997; Scholler and Hassan, 2001) are needed. However, efficiency has proven to be different among different species or strains of *Trichogramma* (Butler and Lopez, 1980; Scholler and Hassan, 2001), and very little research on this subject has been performed so far in soybean, despite its importance (Bueno et al., 2009a).

All parasitoid biological parameters may be highly influenced by abiotic factors, such as humidity, light and temperature (Noldus, 1989). The study of the parasitism of egg parasitoids in different temperatures may provide important information for the establishment of biological control programs for *Anticarsia gemmatilis* and *Pseudoplusia includens* intended for areas that fits in those tested temperatures. Each species/strain of *Trichogramma pretiosum* may have a distinct behavior according to its adaptation to these abiotic factors, making it more or less suitable for a specific environment and host (Bleicher and Parra, 1989). Thus, for the widespread application of the technology needed for augmentative

releases of *Trichogramma* requires knowledge of strains differences in regard to development rate (Butler and Lopez, 1980). A way of addressing this question would be to study the development rate of the organism at different constant temperatures. This approach has been especially common in studies with insects (e.g. Butler and Lopez 1980; Honek, 1996), as temperature plays a major role in the course of their life (Bergant and Trdan, 2006). However, to avoid uncertainties regarded to laboratory experiments in this matter, this kind of study must include observation of insect development at several (at least five) temperatures within the range of linear response of the developmental rate to the temperature and, additionally, a sufficient temperature range should be covered in the experiment to approach the borders of the linear response as closely as possible (Bergant and Trdan, 2006). Therefore, in the present study, the egg parasitism of *T. pretiosum* RV against *A. gemmatilis* and *P. includens* was investigated at 18, 20, 22, 25, 28, 30 and 32 °C in an attempt to acquire information required for further development of biological control programs in soybean using this parasitoid.

2. Material and methods

The experiments were independently carried out for both host eggs (*Anticarsia gemmatilis* and *Pseudoplusia includens*) with a completely randomized experimental design and 20 replications composed by an individualized *T. pretiosum* female (up to 24 h old). *T. pretiosum* strain RV was chosen as the most appropriated biological control agent to be used in this research because previous laboratory work had shown this strain, which was collected in Rio Verde county, in the state of Goiás, Central Brazil, and later designated as *T. pretiosum* RV, to be much more efficient in controlling *P. includens* than the other tested strains of *T. pretiosum* or species of *Trichogramma* in a species/strain selection trial performed under controlled conditions [25 ± 2 °C, 70 ± 10% RH, and 14:10 (light:dark)] (Bueno et al., 2009a). This strain (voucher specimen number TP-17) was deposited at the “Núcleo de Desenvolvimento Científico e Tecnológico em Manejo Fitossanitário de Pragas e Doenças, NUNEMAFI”, Federal University of the State of Espírito Santo, Brazil).

2.1. Cultures of the parasitoid and hosts

Cultures of both the parasitoid and host were maintained as described by Bueno et al. (2009b). Cultures of *Pseudoplusia includens* and *Anticarsia gemmatilis* were maintained in the laboratory [25 ± 2 °C, 70 ± 10% RH, and a photoperiod of 14 h light/10 h dark]. The caterpillars were reared on the artificial diet (Greene et al., 1976; Parra, 2001). After eclosion, the adults were fed a 10% honey/water solution inside 10 cm Ø × 21.5 cm tall cages with walls covered with A4 paper, on which they laid eggs. These eggs were then removed on a daily basis and either used for the trials or for maintaining the insect colonies.

2.2. *T. pretiosum*

RV colony was maintained according to Parra (1997). Eggs of the alternative host *Anagasta kuehniella* (Zeller, 1879) (Lepidoptera: Pyralidae) was used because it is considered the most appropriated factious host for massive rearing since it is easily reared

and does not impact parasitoid quality, including its foraging behavior (Smith, 1996; Wajnberg and Hassan, 1994). These eggs were glued onto cardboard and killed by exposure to ultraviolet

light (Stein and Parra, 1987) and then offered for parasitism for 5 h. Newly emerged parasitoids were either used for trials or for maintaining cultures.

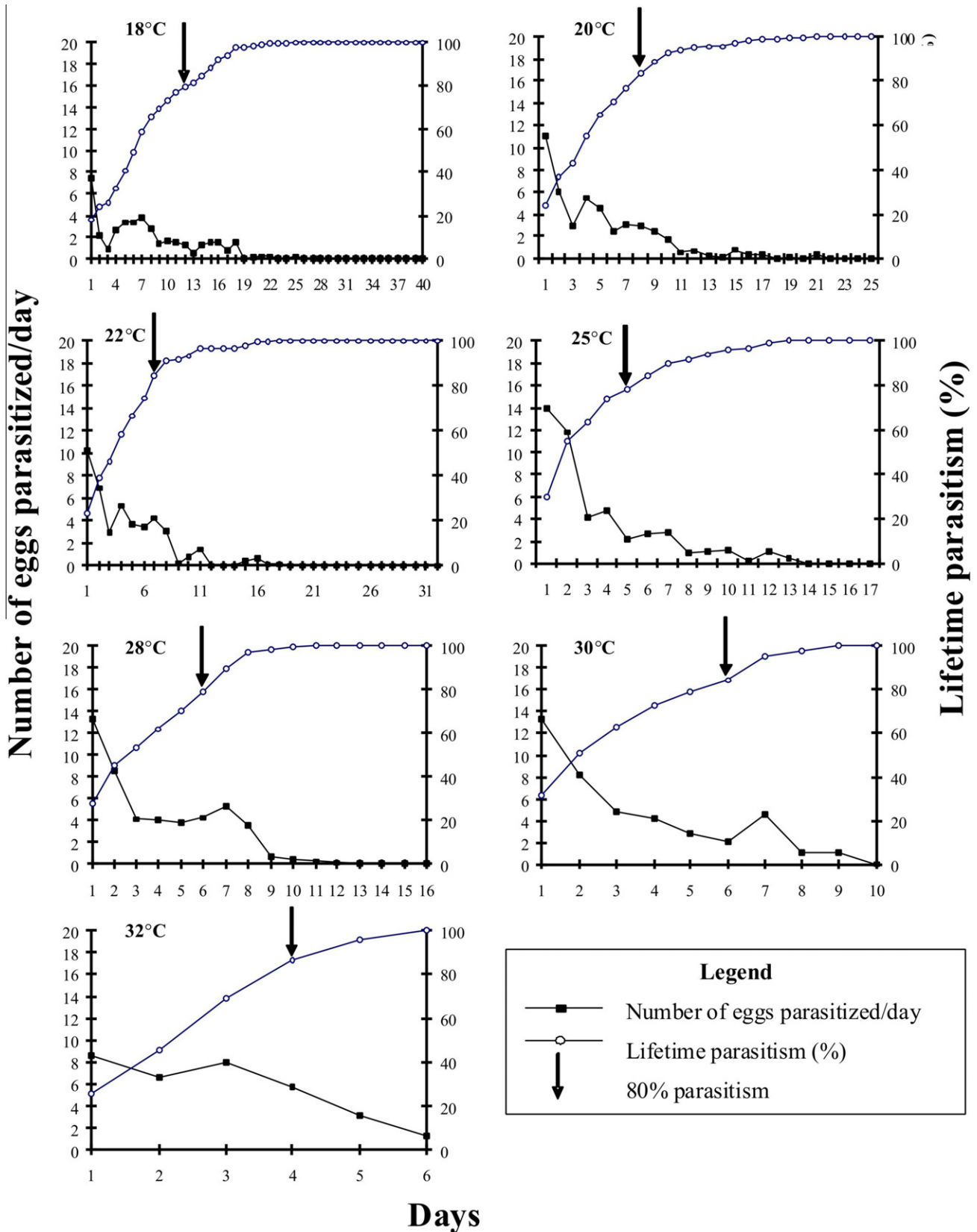


Fig. 1. Number of eggs parasitized per day and lifetime parasitism (%) of *Pseudoplesia includesens* eggs by *Trichogramma pretiosum* strain RV under different controlled conditions [70 ± 10% RH and 14 h photophase (14/10 h L/D)].

2.3. *T. pretiosum* strain RV parasitism on eggs of *Pseudopiusia includens* and *Anticarsia gemmatalis*

Individual mated *T. pretiosum* RV females (newly emerged: ≤ 24 h old) were placed into separate glass tubes (12 mm

$\varnothing \times 75$ mm tall) covered with PVC film. Droplets of pure honey on the walls of the glass tubes were offered to the females. Twenty glass tubes (replications) were prepared for each temperature. The tubes were then kept inside environmental chambers at the temperatures of 18, 20, 22, 25, 28, 30 and 32 °C ± 1 °C, 70 \pm 10% RH,

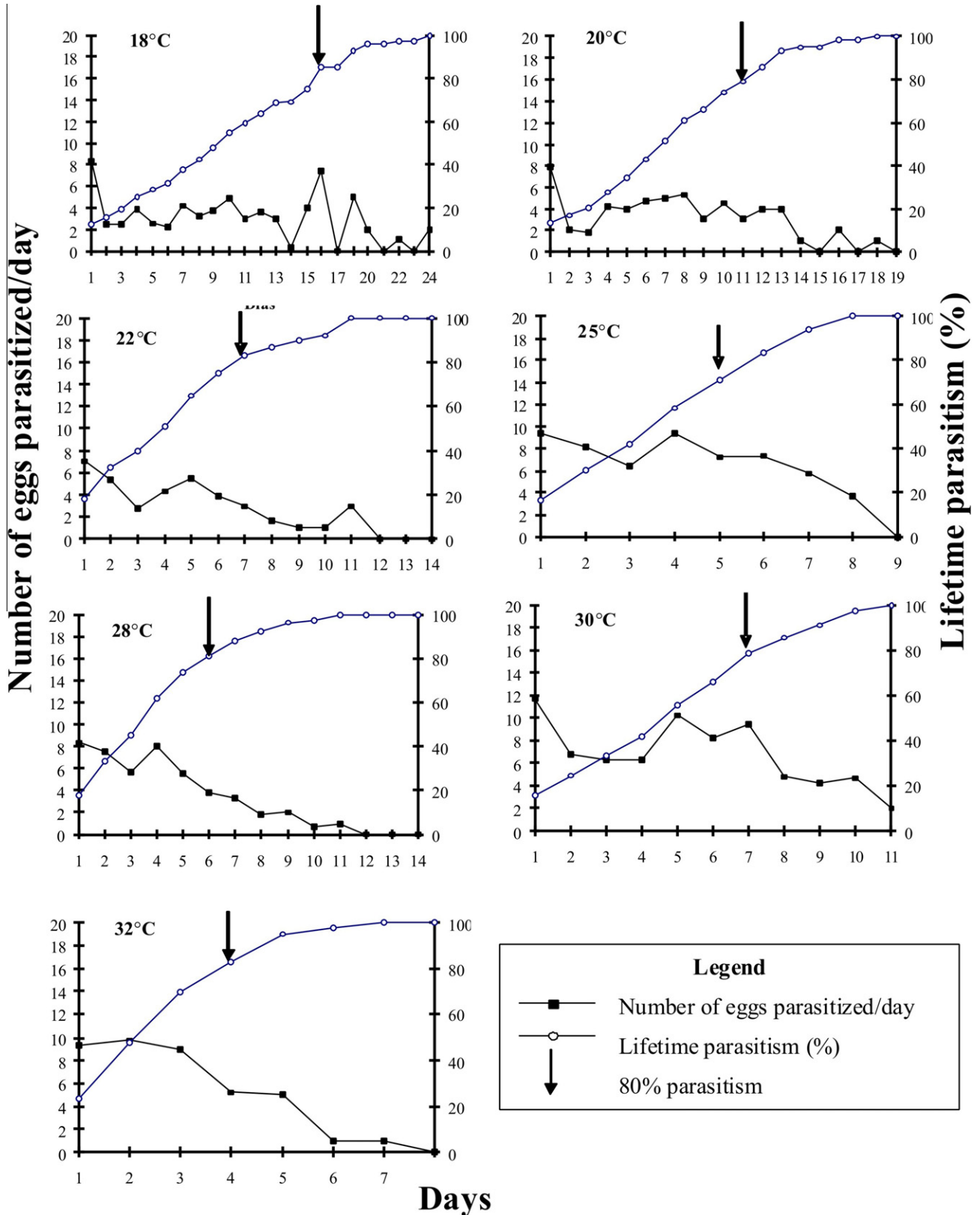


Fig. 2. Number of eggs parasitized per day and lifetime parasitism (%) of *Anticarsia gemmatalis* eggs by *Trichogramma pretiosum* strain RV under different controlled conditions [70 \pm 10% RH and 14 h photophase (14/10 h L/D)].

and 12 h photophase. The host eggs (≤ 24 h old), from the host colony, were offered for parasitism for 24 h. These eggs, which had been laid on the A4 paper as previous described, were glued on a cardboard (50 eggs each), where the date and information of the treatment and replication were recorded. These cards (with the eggs) were replaced daily until the death of the parasitoids. The

eggs daily removed from the glasses were maintained inside the same controlled environmental chambers under the controlled conditions until the emergence of the parasitoids.

The parameters recorded were: (1) the number of eggs parasitized per day; (2) the lifetime percent parasitism; (3) the lifetime number of eggs parasitized per female; and (4) the longevity of

Table 1
Lifetime number of parasitized eggs and female longevity of *Trichogramma pretiosum* strain RV when presented with *Pseudoplusia includens* and *Anticarsia gemmatilis* eggs at different temperatures, $70 \pm 10\%$ RH, and 14/10 h L/D.

Temperature (°C)	Number of females	Lifetime number of parasitized eggs/female (\pm SE) ¹		Parental adult female longevity (days \pm SE) ¹	
		<i>P. includens</i>	<i>A. gemmatilis</i>	<i>P. includens</i>	<i>A. gemmatilis</i>
18	20	31.85 \pm 4.27 ab	38.90 \pm 7.27 ^{ns}	17.75 \pm 2.56 a	11.10 \pm 1.82 a
20	20	44.95 \pm 3.94 a	29.85 \pm 3.53	19.25 \pm 1.18 a	7.00 \pm 1.52 ab
22	20	38.75 \pm 4.3 ab	29.58 \pm 2.80	13.75 \pm 1.90 ab	7.00 \pm 0.89 ab
25	20	40.90 \pm 3.53 ab	33.04 \pm 3.69	10.15 \pm 0.85 bc	5.00 \pm 0.79 b
28	20	43.85 \pm 4.2 ab	40.44 \pm 3.31	7.9 \pm 0.97 bcd	8.30 \pm 1.7 ab
30	20	33.80 \pm 1.84 ab	45.36 \pm 4.5	5.5 \pm 0.1 cd	6.0 \pm 1.1 ab
32	20	28.5 \pm 1.33 b	38.0 \pm 2.1	4.0 \pm 0.30 d	4.0 \pm 0.9 b
CV (%)		23.70	26.19	23.87	23.01

¹ Means (mean \pm standard error) followed by the same letter in the column are not significantly different from each other by the Tukey test at 5% probability; ¹Original results followed by statistics performed on transformed data by $\sqrt{X+1}$; ^{ns}ANOVA non-significant.

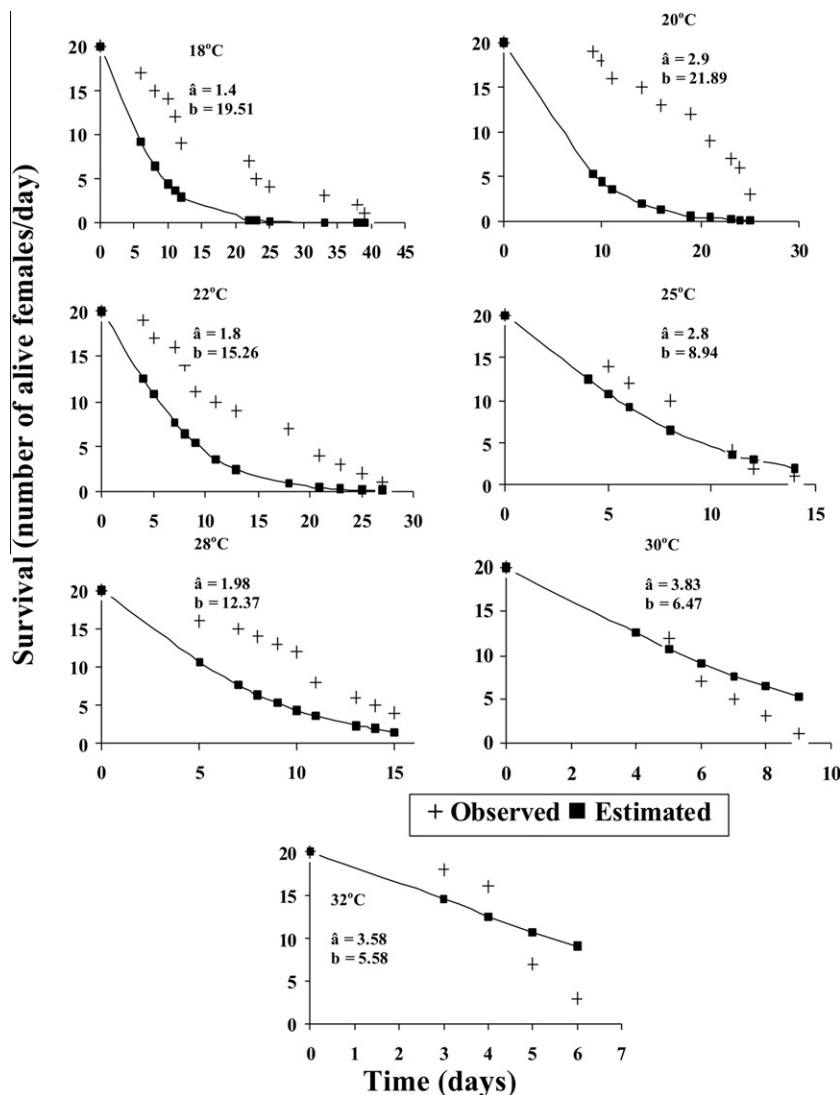


Fig. 3. Survival of *Trichogramma pretiosum* strain RV adult females presented with *Pseudoplusia includens* eggs under controlled environmental conditions [$70 \pm 10\%$ RH and 14 h photophase (14/10 h L/D)]. Values observed and estimated by the Weibull equation.

the adult parasitoids (and therefore the mortality that used in the Weibull distribution) when presented with both hosts. The data for lifetime number of parasitized eggs and the longevity of females were submitted to exploratory analysis to verify the assumptions of normality of residues, homogeneity of treatment variance, and additivity of the model to allow for ANOVA. If data had normal distribution, means were compared by Tukey test ($P \leq 0.05$). Data were also transformed when necessary according to Bartlett's Homogeneity Variance Test for Statistical Analysis (SAS Institute, 2001). Weibull distribution model was used to estimate the mean longevity of *T. pretiosum* RV using survival data, as described by Sgrillo (1982). The estimations of the coefficients of shape (\hat{a}) and scale (b) parameters were obtained by the least-squares method, after linearization of the Weibull model (Sgrillo, 1982). Such a model provides the following types of curves: (1) $\hat{a} > 1$ = type I, in which the mortality rate increases with time; (2) $\hat{a} \cong 1$ = type II, in which the mortality rate is constant over time; and (3) $\hat{a} < 1$ = type III, in which the mortality rate decreases with time. The mean longevity was estimated with the \hat{a} and b , and

the data were analyzed using the MOBAE program (Haddad et al., 1995).

3. Results

The number of parasitized eggs per day varied with temperature and host species but, it was higher on the first days of the experiment on both studied hosts. For *Pseudopius includens*, the average numbers of eggs parasitized during the first 24 h were 7.4, 11.1, 10.1, 14.0, 13.3, 13.3 and 8.7 at 18, 20, 22, 25, 28, 30 and 32 °C, respectively (Fig. 1). For *Anticarsia gemmatalis*, the parasitism in the first 24 h was lower than for *P. includens* eggs; the average numbers of *A. gemmatalis* eggs parasitized were 4.0, 4.5, 7.1, 9.3, 8.4, 8.4 and 8.3 at 18, 20, 22, 25, 28, 30 and 32 °C, respectively (Fig. 2). It can be observed that the parasitoids decreased the number of daily ovipositions on both lepidopteran species as a function of the time of parasitism and of the temperature at which they were subjected (Figs. 1 and 2). Higher numbers of parasitized

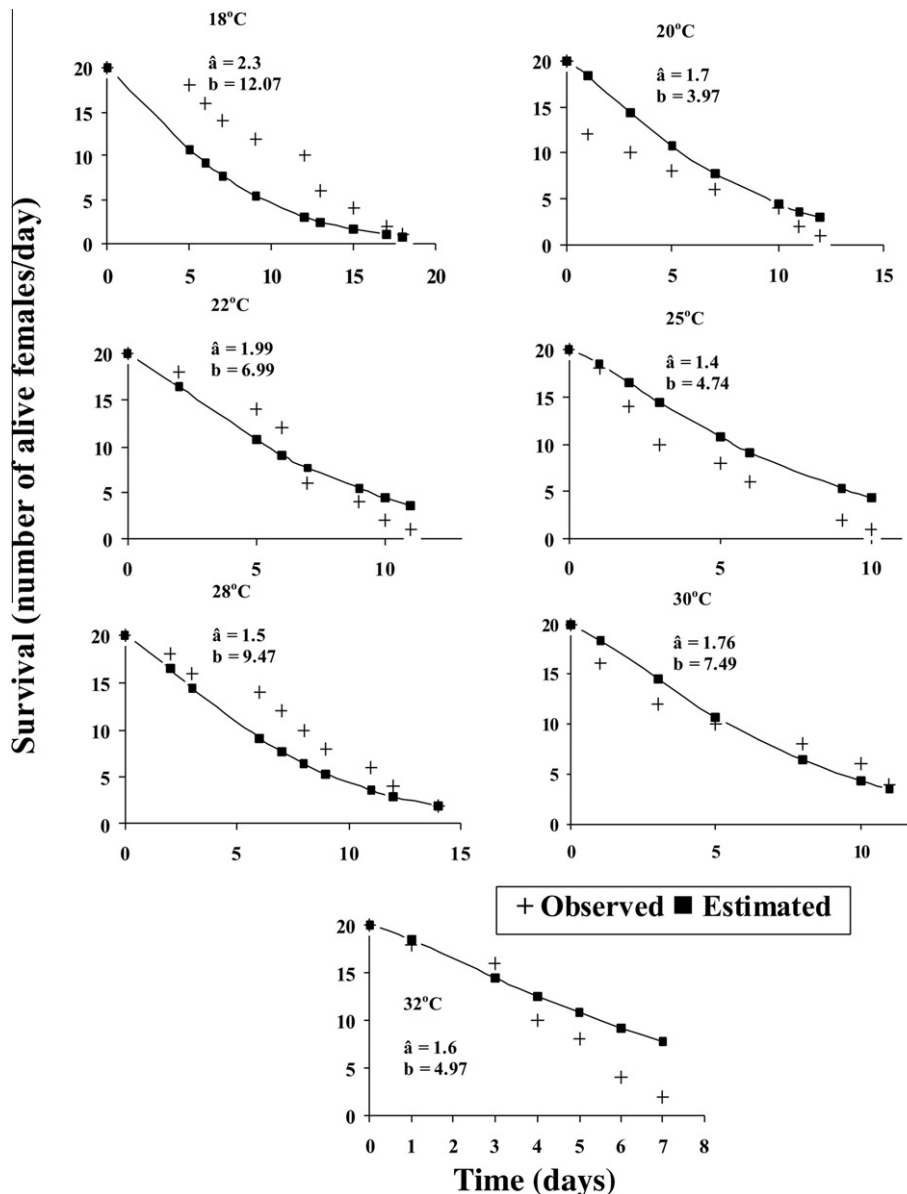


Fig. 4. Survival of *Trichogramma pretiosum* strain RV adult females presented with *Anticarsia gemmatalis* eggs under controlled environmental conditions [70 ± 10% RH and 14 h photophase (14/10 h L/D)]. Values observed and estimated by the Weibull equation.

P. includens eggs per day were evident at all temperatures during the first 2 days of parasitism, significantly decreasing after that (Fig. 1). Among all temperatures, the number of parasitized egg per day at those first days was higher mainly at 25 and 28 °C (Fig. 1). Similar trends occurred with *A. gemmatalis* eggs (Fig. 2). As a result of that parasitism rhythm, *T. pretiosum* RV reached more than 80% lifetime parasitism on eggs of *P. includens* on the 12th, 8th, 7th, 5th, 6th, 6th and 4th days at 18, 20, 22, 25, 28, 30 and 32 °C, respectively (Fig. 1) and on eggs of *A. gemmatalis* on the 12th, 11th, 7th, 5th, 6th, 8th, and 4th days at 18, 20, 22, 25, 28, 30 and 32 °C, respectively (Fig. 2).

The longevity of parental adult *T. pretiosum* RV females when presented with eggs of *P. includens* was inversely correlated to temperature (Table 1). The highest longevity was recorded at 18, 20 and 22 °C. At 25 °C and higher temperatures, adult parasitoids had shorter lifespan varying from 4.0 to 10.15 days (Table 1). Differently, the longevity of parental adult *T. pretiosum* RV females when presented with *A. gemmatalis* eggs were similar among 18, 20, 22, 28 and 30 °C with the lowest longevity recorded at 25 and 32 °C that had no statistical difference with 20, 22, 28 and 30 °C (Table 1). As a combination of adult longevity associated with parasitoid egg load and host quality, the lifetime number of parasitized eggs varied among the temperatures and hosts (Table 1). The lifetime number of parasitized *P. includens* eggs achieved by females maintained at 20 °C (44.95 ± 3.94) differed from the results recorded at 32 °C (28.5 ± 1.33) with fewer eggs parasitized on average at this higher temperature (Table 1). Differently, this parameter on eggs of *A. gemmatalis* was statistically similar among the studied temperatures (Table 1).

Using the parameters shape (\hat{a}) and scale (b), it was possible to estimate the mean longevity of the population at the different temperatures and to verify that the data fit the Weibull distribution. The estimated survival values demonstrated that all curves fit the type I curve. At all studied temperatures, there was an increase in the mortality rate with time as the temperature was increased, and the parameter shape (\hat{a}) was always higher than 1, varying from 1.4 to 3.83 and from 1.35 to 2.3 for *P. includens* and *A. gemmatalis* eggs, respectively (Figs. 3 and 4).

4. Discussion

The parasitization period (which is the time for how long the females are active) might vary due to differences in temperature (Reznik and Vaghina, 2006), hosts (Reznik et al., 2001), or parasitoid species/strain (Pratissoli and Parra, 2000; Pizzol et al., 2010) and can influence the success of biological control programs using egg parasitoids of the genus *Trichogramma* spp. (Smith, 1996; Wajnberg and Hassan, 1994). Thus, whether parasitism is more active in the first days of life or evenly distributed throughout adulthood is an important characteristic to be considered in choosing the best parasitoid release strategy (Bueno et al., 2010). Also, this parasitoid characteristics should be consider when choosing the most suitable parasitoid species or strain to be used in the field, since the sooner the parasitoid reaches 80% of its lifetime parasitism, the better, because while the parasitoid are exposed in the field, they might be susceptible to biotic and abiotic factors that can impair its action. In practice, these factors might be, for example, a fungicide or herbicide spraying that can come to be necessary to the crop management or an abrupt change in temperature that can more easily kill the egg parasitoids (Carmo et al., 2010; Denis et al., 2011) but hardly ever will kill the pests. Eggs parasitoids are usually tiny little wasps, more susceptible to chemicals used in agriculture as herbicides and fungicides, for example, than their hosts (Carmo et al., 2010). Furthermore, parasitoids differ from herbivorous insects by their usual inability to synthesize lipids as

adults what makes them more vulnerable to an increase in temperature than most of the pests (Denis et al., 2011).

Even though the number of parasitized egg per day varied among the different temperatures and between both host species, the oviposition peak of *T. pretiosum* strain RV was always at the first 24 h of parasitism. Oviposition peak of egg parasitoids from the genus *Trichogramma* usually have been reported in the literature on the first day after adult emergence for several different species (Pak and Oatman, 1982; Bai et al., 1992; Volkoff and Daumal, 1994). This is usually a consequence of most of these *Trichogramma* species to have the capacity to store a full complement of mature eggs in the ovaries or oviducts and complete oogenesis either before or shortly after adult emergence (pro-ovigenic parasitoids) (Mills and Kuhlmann, 2000) and, thus, adults emerge ready to lay eggs. In contrast, other studies indicate that some *Trichogramma* species emerge with an egg load that accounts for only a fraction of their potential parasitism, which exceeds their capacity to store mature eggs in their ovaries or oviducts (synovigenic parasitoids) (Houseweart et al., 1983; Smith and Hubbes, 1986; Kuhlmann and Mills, 1999).

Moreover, not only can oviposition peak vary as consequence of pro-ovigenic or synovigenic relationship between oogenesis and oviposition, but also due to parasitoid's behavior changes (Denis et al., 2011). Adults of most *Trichogramma* species are incapable of lipogenesis (Denis et al., 2011) but, as an ectotherm insects, temperature is inversely related to their metabolic-rate and lipid consumption (Huey and Berrigan, 2001). Thus, in those species, allocation of lipids accumulated during the larval stage determines adult lifespan and fecundity (Visser and Ellers, 2008) and, therefore, its lifetime reproductive success (Huey and Berrigan, 2001). Because foraging decisions are affected by the state of external and internal variables, such as the lipid reserves and the number of mature eggs (Godfray, 1994), in their females, lipids carried over from the larval stage can be allocated to either egg production or to adult lipid reserves, leading to a trade-off between reproduction and lifespan (Pexton and Mayhew, 2002). It ratifies the crucial importance of this knowledge of strain differences in regard to developmental rate for widespread application of augmentative releases of *Trichogramma* spp. (Butler and Lopez, 1980). In this context, the higher number of parasitized eggs/day observed in this study in the first 24 h is a positive characteristic of the *T. pretiosum* strain RV.

The impact of increased temperature reducing the parental adult longevity was already reported in the literature for different *Trichogramma* species/strains. Longevity of *T. pretiosum* and *T. annulata* was decreased as a consequence of the temperature increase (Maceda et al. 2003). Similar results were also found for *Trichogramma turkestanica* at four different temperatures, in which study, adult parasitoid longevity (mean \pm SD) of 31.8 ± 6.3 , 12.6 ± 7.5 , 8.9 ± 4.4 , and 2.3 ± 2.6 days was recorded at 15, 20, 25, and 30 °C, respectively (Hansen and Jensen, 2002). Similarly, the influence of temperature on *Trichogramma* spp. had also been reported in studies with other different *Trichogramma* species and strains (Bourchier and Smith, 1996; Scholler and Hassan, 2001; Pratissoli and Parra, 2000; Pereira et al., 2004).

Regarding to the survival curve, these results (Figs. 3 and 4) demonstrate that, in warm regions, the mean longevity of the natural enemies may be reduced in field releases, thus suggesting that biological control programs using *T. pretiosum* RV in those regions might demand a higher frequency of releases than is the case in regions with cooler temperatures.

Some differences, observed between the two studied hosts, might be associated with the different size (quality) of these host eggs (Smith, 1996). Differences in host eggs had been previously pointed out as an important feature for *Trichogramma* spp. survival and development by Cónsoli et al. (1999). These differences might

also be due to the characteristics of each particular host species. The host eggs have different surfaces, sizes, and chorion structures, as well as differences in some other egg characteristics, such as changes in color during embryonic development and volume. All these peculiarities of each host species, as well as their relative differences, can affect not only the *Trichogramma* handling time and exploitation but also the host suitability for parasitoid development, which also influences developmental time (Cônsoi et al., 1999). Furthermore, parasitoid adaptation to the host under study is very important because different species, or even different strains, of *Trichogramma* might have had different time spans for co-evolving with each host pest species, thus possessing better or worse adaptation to each specific host egg (Bueno et al. 2009b). Notwithstanding the differences between hosts, in general *T. pretiosum* RV performed well on eggs of both *A. gemmatilis* and *P. includens* hosts under different temperatures.

It is worth emphasizing that, although temperature is considered extremely important, it is not the only factor responsible for changes in the development and survival of the insects. Other abiotic factors, such as photoperiod and relative humidity, and biotic factors, such as interspecific and intraspecific competition, may interfere with these biological characteristics (Parra, 1997; Pratisoli and Parra, 2001). Another point to be considered is the specific ability of *T. pretiosum* RV to introduce the ovipositor into the corium of the host eggs once these eggs might gradually lose its turgidity following an increase in temperature (Bueno et al. 2009b). The possible effects of temperature on this ability can be responsible for the differences in the quantity and uniformity of parasitism, and that might be further studied in future researches regarding to this issue. This event has already been reported by Pereira (2004), who observed the effect of the turgor of the eggs of *Plutella xylostella* (Linneus, 1758) (Lepidoptera: Plutellidae) on parasitism by *T. exiguum*.

In conclusion, *T. pretiosum* strain RV parasitism was impacted by temperature when on both studied host eggs; however, the parasitoid still exhibits high survival besides high number of parasitized *A. gemmatilis* and *P. includens* eggs even at the extremes tested temperatures of 18 and 32 °C. Those results indicate that *T. pretiosum* strain RV might be well adapted to this studied temperature range and, thus, be potentially suitable for use in biological control programs of *P. includens* and *A. gemmatilis* in different geographical areas that fits in this range. In the literature, it has not been reported large differences in the biology of *Trichogramma* spp. when the parasitoid was laboratory-reared under constant or fluctuating temperatures (Cônsoi and Parra, 1995a,b, Butler and Lopez, 1980), what might indicate that this biological control agent may succeed on *A. gemmatilis* and *P. includens* egg control in the field. However, it is important to emphasize the results here presented are from laboratory studies and, therefore, additional studies in field conditions are still needed to fully develop a biological control program using this egg parasitoid and confirm or not the hypotheses here presented.

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