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Thermal Requirements of *Trichogramma pretiosum* and *T. acacioi* (Hym.: Trichogrammatidae), Parasitoids of the Avocado Defoliator *Nipteria panacea* (Lep.: Geometridae), in Eggs of two Alternative Hosts

Dirceu Pratissoli[1], José Cola Zanuncio[2*], Ulysses Rodrigues Vianna[2], Josimar Souza Andrade[3], Tobias Baruc Moreira Pinon[2] and Gilberto Santos Andrade[1]

[1]Departamento de Fitotecnia; Centro de Ciências Agrárias; Universidade Federal do Espírito Santo; Alegre; 29500-000; ES - Brasil. [2]Departamento de Biologia Animal/BIOAGRO; [3]Departamento de Fitotecnia; Universidade Federal de Viçosa; zanuncio@ufv.br; 36571-000; Viçosa - MG - Brasil

ABSTRACT

This research studied the thermal requirements of Trichogramma pretiosum *and* T. acacioi *(Hymenoptera: Trichogrammatidae), parasitoids of* Nipteria panacea *(Lepidoptera: Geometridae), with eggs of the alternative hosts* Anagasta kuehniella *(Lepidoptera: Pyralidae) and* Sitotroga cerealella *(Lepidoptera: Gelechiidae) aiming to use these natural enemies in biological control programs of this pest in avocado orchards.* T. pretiosum *needed 151.83 and 160.04 degree-days, above threshold of 10.70 and 10.75°C, while these values were 158.50 and 155.46 degree-days, above threshold of 10.67 and 10.46°C for* T. acacioi *when exposed to eggs of* A. kuehniella *and* S. cerealella, *respectively.*

Key words: Avocado, alternative host, biological control, temperature

INTRODUCTION

The world production of avocado (*Persea americana* Mill.) is around 1.2 million tons per year. Brazil is the fourth largest producer and its production could increase due to adequate soils and climate conditions (Donadio, 1995). The Highland Region of the State of Espírito Santo presents one of the best areas to produce this fruit in Brazil, which could represent an alternative for Brazilian agriculture diversification. Avocado plantations in this area increased from 100 hectares in 1985 to more than 2,000 hectares in 1995 (Teixeira et al., 1996). Avocado trees present many pest insect species (Donadio, 1995). The expansion of this crop in the State of Espírito Santo and the use of chemical control against pests have contributed to the appearance of the defoliator *Nipteria panacea* Tierry-Mieg (Lepidoptera: Geometridae), which can reduce leaf area and productivity of avocado trees (Pratissoli et al., 1999). Control of habitual pests and, mainly, this new one, should consider ecological criteria based on association of different control methods (Pratissoli and Parra, 2000), especially the biological control.

This control method has been using egg parasitoids in South Africa and Israel against avocado pests (Donadio, 1995), especially in this last country, with *Trichogramma platineri*

[*] Author for correspondence

Nagarkatti (Hymenoptera: Trichogrammatidae) from California against two Lepidoptera defoliators of this plant. This group of parasitoid is important because many *Trichogramma* species are used to control more than 69 key pests of 34 cultures in 32 million hectares of 30 countries (Wajnberg and Hassan, 1994; Parra and Zucchi, 1997; Oliveira et al., 2000). However, the success of biological control with *Trichogramma* species depends on preliminary surveys because these organisms can be affected by many factors such as host, temperature, architecture and phenology of the plants, searching area, wind and chemical products like insecticides (Goodenough and Witz, 1985).

Temperature is the most important climatic factor affecting insects and also egg parasitoids of the genus *Trichogramma*, because within certain limits the development rate of these parasitoids increases with temperature (Buttler Junior and Lopez, 1980; Russo and Voegelé, 1982; Calvin et al., 1984; Bleicher and Parra, 1989; Pratissoli, 1995). Besides, thermal requirements of *Trichogramma* vary with species (Russo and Voegelé, 1982) and hosts used to rear them (Buttler Junior and Lopez, 1980; Goodenough et al., 1983).

The objective of this work was to study thermal requirements of *T. pretiosum* Riley and *T. acacioi* Brun, Moraes and Soares, egg parasitoids of *N. panacea*, in eggs of the alternative hosts *Anagasta kuehniella* (Zeller) (Lepidoptera: Pyralidae) and *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae) aiming to use these natural enemies in biological control programs of this pest in avocado orchards.

MATERIAL AND METHODS

Experiments were carried out in acclimatized chamber with relative humidity of 70 $\pm$ 10%, photophase of 14 hours and constant temperatures of 15, 20, 25, 30 and 35 ± 1°C. Egg parasitoids of the genus *Trichogramma* were collected in the Municipality of Venda Nova do Imigrante, State of Espírito Santo, Brazil, in eggs of the avocado defoliator *N. panacea* at altitudes of 800 and 1,000 meters. Some individuals of these populations were sent to Dr. R.A. Zucchi, (Department of Entomology and Zoology of the "Escola Superior de Agricultura Luiz de Queiroz") who identified them as *T. pretiosum* and *T. acacioi*. These species were reared in laboratory conditions with eggs of the alternative hosts *A. kuehniella* and *S. cerealella.*

Rearing techniques and multiplication of *A. kuehniella* were based on methodology of Parra (1997) with artificial diet composed by integral wheat and corn flour (97%) besides beer yeast (3%) with adjustments to laboratory conditions. The alternative host *S. cerealella* was multiplied with a diet based on wheat grain without peel and humidity from 11 to 14%. Two kilograms of wheat grains were infested with one gram of newly laid eggs of these insects free of mites (Hassan, 1997). Adults of parasitoid species were put during one week in cages where they laid eggs and removed after this period.

The experiment started with newly emerged *T. acacioi* and *T. pretiosum* females reared with both alternative hosts and individualised in Duran tubes (3.5 x 0.5 cm) sealed with plastic PVC film. Females of two parasitoids were fed with droplets of pure honey deposited in the internal wall of each tube. Each parasitoid female received a 3.5 x 0.5 cm blue colour cardboard with 40 eggs of *A. kuehniella* collected on the same day when they were offered and agglutinated with 5% Arabic gum diluted in distilled water. All these eggs were previously turned unviable by exposing them to a germicidal lamp during 45 minutes (Parra, 1997). Similar procedure was used with eggs of the alternative host *S. cerealella*, but without exposition to germicidal light.

Parasitoid females were removed under stereoscopic microscope after 24 h of contact with host eggs into the tubes. These tubes (containing a cardboard with parasitized eggs) were maintained in acclimatized chambers to evaluate parasitism rate. Daily observations were made to register the development time of *T. pretiosum* and *T. acacioi*. Inferior thermal threshold (Tb) (expressed in degree Celsius) and thermal constant (K) (expressed in degree-days) were calculated with the hyperbole method (Haddad and Parra, 1984) based on development time of these parasitoids at temperatures of 15, 20, 25, 30 and 35ºC. The period from egg to adult emergence was obtained as function of development rate at constant temperatures (15, 20, 25, 30 and 35ºC) which allowed to determine the inferior thermal development limit (Tb) and the thermal constant (K) for *T. pretiosum* and *T. acacioi* in eggs of the hosts *A. kuehniella* and *S. cerealella*.

RESULTS AND DISCUSSION

T. pretiosum needed 151.83 degree-days, above threshold of 10.70°C, when exposed to eggs of the alternative host *A. kuehniella*. This temperature (Tb) increased by 0.05°C and reached 10.75°C when the thermal constant reached 160.04 degree-days for this parasitoid with eggs of *S. cerealella*. *T. acacioi* needs 155.46 and 158.50 degree-days, above thresholds of 10.46 and 10.67°C with eggs of *A. kuehniella* and *S. cerealella*, respectively (Figs 1, 2). The temperature (Tb) and the different thermal constants for the hosts were reported for other parasitoid species (Russo and Voegelé, 1982; Bleicher and Parra, 1989; Pratissoli and Parra, 2000). This variation could be affected by the thermal requirement of the analyzed host (Parra et al., 1991; Pratissoli and Parra, 2000). The results of thermal requirements of these parasitoids were not compared with those of *N. panacea* because no report for this host reared under different temperatures was available.

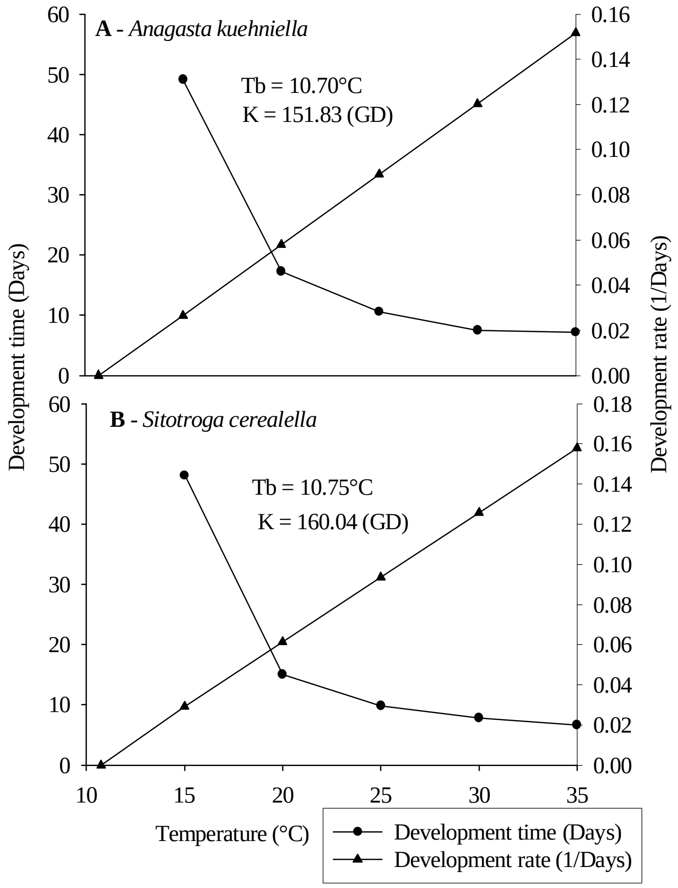

Figure 1 - Development time (days) and development rate (1/days) of *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae) reared with eggs of the alternative hosts *Anagasta kuehniella* (Lepidoptera: Pyralidae) (A) (R^2 = 98.12) and *Sitotroga cerealella* (Lepidoptera: Gelechiidae) (B) (R^2 = 96.03) under different temperatures.

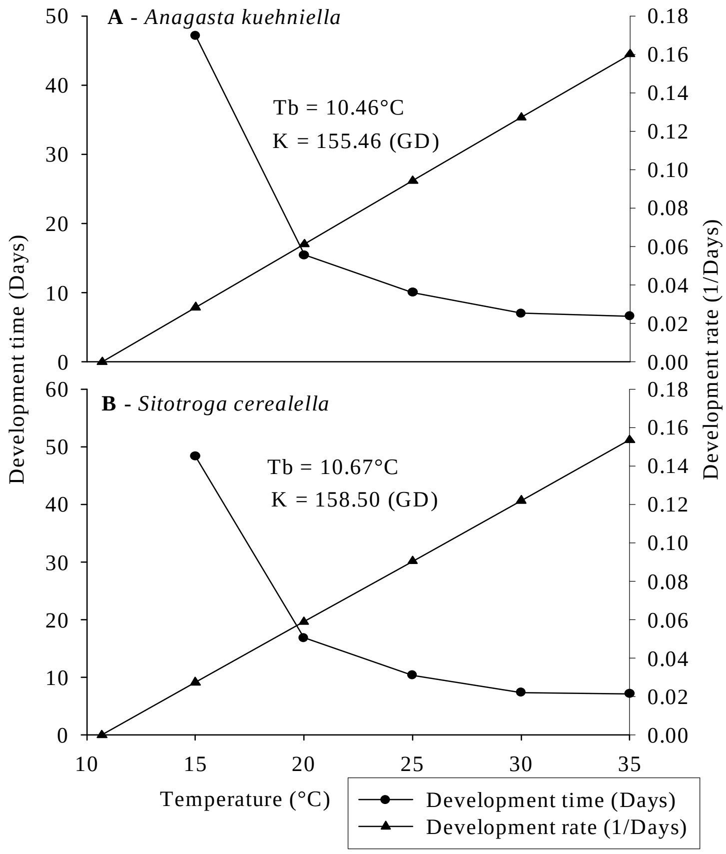

Figure 2 - Development time (days) and development rate (1/days) of *Trichogramma acacioi* (Hymenoptera: Trichogrammatidae) reared with eggs of the alternative hosts *Anagasta kuehniella* (Lepidoptera: Pyralidae) (A) (R^2 = 97.95) and *Sitotroga cerealella* (Lepidoptera: Gelechiidae) (B) (R^2 = 95.69) under different temperatures.

The determination coefficient (R^2) for the threshold (Tb) and thermal constant (K) of *T. pretiosum* with eggs of the alternative hosts *A. kuehniella* and *S. cerealella* were 98.12 and 96.03%, respectively. *T. acacioi* presented determination coefficient (R^2) of 97.95 and 95.69%, respectively, in eggs of *A. kuehniella* and *S. cerealella* (Figs 1, 2). Determination coefficient for thresholds and thermal constants of *T. pretiosum* and *T. acacioi* with eggs of *A. kuehniella* and *S. cerealella* were higher than 95% what was considered satisfactory to assure a good reliability of the results ($P<0.05$).

These two parasitoids presented lower threshold with *A. kuehniella* than with *S. cerealella* but an inverse relation for the thermal constant was found with both hosts. This could be associated to the process of host acceptance, which could be affected by factors such as size, format, texture, presence of chemical substances and nutritional quality of host eggs (Pratissoli, 1995; Gomes, 1997; Vinson, 1997; Pratissoli et al., 2003). This could also vary with lineages of these parasitoids because *T. pretiosum* presented fecundity and longevity 14.94 and 4.4 times higher in eggs of the alternative host *A. kuehniella* than with those of *S. cerealella* (Parra, 1997). The size of host egg is also important for its acceptance because eggs of different hosts such as those of *Corcyra cephalonica* Staiton (Lepidoptera: Pyralidae) and *A. kuehniella* present similar biological characteristics but different sizes (Vinson, 1997). However, eggs of extremely reduced size such as those of *S. cerealella* were inadequate for mass rearing some parasitoids species including *T. galloi* Zucchi and *T. pretiosum* (Gomes, 1997).

The threshold (Tb) and thermal constant (K) of *T. pretiosum* and *T. acacioi* found in our study were similar to those reported for different species and/or lineage of *Trichogramma* (Table 1). The thermal constant, which was based in the duration of the development period of these parasitoids under different temperatures from an inferior thermal threshold (Tb) presented higher values than that of most species of this group reported in the literature (Table 1).

Table 1 - Threshold (Tb), thermal constant (K) and determination coefficient (R^2) of species or lineages of *Trichogramma* (Hymenoptera: Trichogrammatidae) by different authors.

Parasitoids	Host	Tb (ºC)	K (GD)	R2 (%)	Authors
T. pretiosum	*Heliothis virescens*	10.22	164.60	95.62	Goodenough et al. (1983)
T. pretiosum	*Sitotroga cerealella*	10.70	174.40	95.95	Goodenough et al. (1983)
T. pretiosum	*Anagasta kuehniella*	10.05	169.45	95.09	Goodenough et al. (1983)
T. pretiosum	*Galleria mellonella*	11.46	183.29	99.41	Goodenough et al. (1983)
T. pretiosum	*Diatraea grandiosella*	9.91	158.71	91.23	Calvin et al. (1984)
T. pretiosum	*Sitotroga cerealella*	11.53	125.56	96.05	Orphanides and Gonzales (1971)
T. pretiosum	*Sitotroga cerealella*	12.20	128.70	99.60	Butler Jr. and Lopez (1980)
T. pretiosum	*Tricloplusia ni*	11.30	131.50	99.30	Butler Jr. and Lopez (1980)
T. pretiosum (Iguatu)	*Anagasta kuehniella*	12.81	133.25	96.31	Bleicher and Parra (1989)
T. pretiosum (Goiânia)	*Anagasta kuehniella*	11.98	131.95	97.87	Bleicher and Parra (1989)
T. pretiosum	*Anagasta kuehniella*	9.56	154.82	99.47	Tironi (1992)
T. pretiosum	*Tuta absoluta*	12.98	131.33	98.62	Pratissoli (1995)
T. pretiosum	*Phithorimaea operculella*	13.53	120.90	99.03	Pratissoli (1995)
T. galloi	*Diatraea saccharalis*	12.60	148.00	99.02	Sales Jr. (1992)
T. minutum	*Cydia pomonella*	9.98	130.74	98.16	Yu et al. (1984)
T. minutum	*Anagasta kuehniella*	10.25	128.53	97.78	Yu et al. (1984)
T. pretiosum	*Anticarsia gemmatalis*	12.10	133.10	97.05	Salamina (1997)
T. ostrinieae (female)	*Ostrinia nubilalis*	9.83	174.63	98.43	Volden and Chiang (1982)
T. ostrinieae (male)	*Ostrinia nubilalis*	9.78	174.16	98.18	Volden and Chiang (1982)
T. semifumatum	*Colias eurytheme*	10.78	141.31	98.01	Stern and Bowen (1963)
T. semifumatum	*Sitotroga cerealella*	10.25	152.15	96.12	Bowen and Stern (1966)
T. retorridum	*Helicoverpa zea*	11.48	145.51	97.72	Stern and Atallah (1965)
T. maidis	*Anagasta kuehniella*	11.90	131.00	-	Russo and Voegelé (1982)
T. rhenana	*Anagasta kuehniella*	10.45	145.50	-	Russo and Voegelé (1982)
T. schuberti	*Anagasta kuehniella*	10.45	145.50	-	Russo and Voegelé (1982)
T. nubilale	*Anagasta kuehniella*	11.30	137.00	-	Russo and Voegelé (1982)

- data were not calculated for these species.

Different values for thresholds and thermal constants of *Trichogramma* species (Figs 1, 2 and Table 1) with the alternative hosts *A. kuehniella* and *S. cerealella* could be related to factors such as variation on their searching behaviour, host preference and impact of environmental conditions on species and/or lineage of *Trichogramma* (Hassan, 1997). Thus, the determination of thermal requirements was important for quality control in rearing egg parasitoids for biological control programs. These requirements could be obtained with studies on biological characteristics of these parasitoids at different temperatures, which could help to plan their mass production (Hassan, 1997; Parra, 1997; Vinson, 1997; Pratissoli et al., 1998; Pratissoli and Parra, 2000).

Species and/or lineage and rearing methodologies of the host affect thermal requirements of *Trichogramma* species. For this reason, it is important to develop researches aiming to obtain alternative hosts with similar characteristics as those of the pest to be controlled. This is necessary to allow the parasitoid to express its full potential for biological control in field conditions.

RESUMO

O objetivo desta pesquisa foi estudar as exigências térmicas de *Trichogramma pretiosum* e *T. acacioi* (Hymenoptera: Trichogrammatidae), parasitóides de *Nipteria panacea* (Lepidoptera: Geometridae), em ovos dos hospedeiros alternativos *Anagasta kuehniella* (Lepidoptera: Pyralidae) e *Sitotroga cerealella* (Lepidoptera: Gelechiidae) visando utilizar estes inimigos naturais em programas de controle biológico desta praga em pomares de abacate. *T. pretiosum* apresentou temperaturas base (Tb) de 10.70 e 10.75°C e constantes térmicas (K) de 151.83 e 160.04 graus-dia, sendo estes valores de 10.67 e 10.46°C e 158.50 e 155.46 graus-dia para *T. acacioi* em ovos de *A. kuehniella* e *S. cerealella*, respectivamente.

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