BIOLOGICAL CONTROL

Effect of Temperature on the Development and Progeny Production of *Glyptapanteles muesebecki* (Blanchard) (Hymenoptera: Braconidae) Parasitizing Larvae of *Pseudaletia sequax* Franclemont (Lepidoptera: Noctuidae)

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An. Soc. Entomol. Brasil 28(2): 243-249 (1999)

Efeito da Temperatura no Desenvolvimento e Reprodução de *Glyptapanteles muesebecki* (Blanchard) (Hymenoptera: Braconidae) Parasitando Lagartas de *Pseudaletia sequax* Franclemont (Lepidoptera: Noctuidae)

RESUMO - O tempo de desenvolvimento de *Glyptapanteles muesebecki* (Blanchard) e o número de pupas produzido por hospedeiro foram avaliados em seis temperaturas constantes entre 14° e 30°C, utilizando como hospedeiro lagartas de segundo ínstar de *Pseudaletia sequax* Franclemont. A duração dos estágios internos do parasitóide (ovo e larva) variou entre 17,8 dias (26° e 29°C), e 56,4 dias (14°C), enquanto que o estágio de pupa variou de 6,4 a 34,5 dias a 29° e 14°C, respectivamente. Os estágios internos requereram um total de 291,9 graus-dia (GD) acima da temperatura base (Tb) de 8,9°C, e o estágio de pupa necessitou de 107,0 GD acima da Tb de 11,1°C. O desenvolvimento de ovo a adulto foi completado em 397,4 GD acima da Tb de 9,6°C. Entre 18° e 26°C, o número de pupas de *G. muesebecki* por hospedeiro foi estatisticamente semelhante e variou de 86,9 (22°C) a 92,1 (18°C). Nas duas temperaturas extremas, este valor foi significativamente menor, resultando em 27,6 e 19,8 pupas por lagarta a 14° e 29°C, respectivamente. Nestas duas temperaturas, a proporção de lagartas parasitadas foi significativamente menor do que entre 18° e 26°C, e a 14°C não houve sincronismo na emergência dos adultos de uma mesma lagarta. A 30°C, as lagartas hospedeiras morreram antes da emergência dos parasitóides. O desenvolvimento e a produção de descendentes do parasitóide não foram alterados após a sua criação por cinco gerações consecutivas entre 18° e 26°C em laboratório.

PALAVRAS-CHAVE: Insecta, endoparasitóide, lagarta do trigo, exigências térmicas.

ABSTRACT - The developmental time of *Glyptapanteles muesebecki* (Blanchard) parasitizing the armyworm *Pseudaletia sequax* Franclemont, and the number of pupae/host were determined at six constant temperatures ranging from 14° to 30°C. The egg + larval stages lasted from 17.8 days at 26° and 29°C to 56.4 days at 14°C, while the pupal stage ranged from 6.4 days at 29°C to 34.5 days at 14°C. *G. muesebecki* required 291.9 degree-days (DD) above the lower

threshold of 8.9°C to complete the egg + larval development, while the pupae required 107.0 DD above 11.1°C. Development from egg to adult was completed after 397.4 DD above the lower threshold of 9.6°C. The number of pupae/host was not significantly different between 18°° and 26°C, and ranged from 86.9 at 22°C to 92.1 at 18°C. At the lower (14°°C) and upper (29°C) threshold temperatures, this number was significantly lower, averaging 27.6 and 19.8 pupae/host, respectively. Moreover, at 14° and 29°C the proportion of parasitized caterpillars was significantly lower than in the range between 18° and 26°C and at the lower temperature there was no synchronism in the pupation of parasitoids from the same host. At 30°C, the host larvae died before the emergence of the parasitoids. At 18, 22 or 26°C, the development and progeny production of *G. muesebecki* was not affected in the laboratory after five consecutive generations.

KEY WORDS: Insecta, endoparasitoid, biological control, parasitism, thermal requirements.

Glyptapanteles muesebecki (Blanchard) is a gregarious endoparasitoid of the armyworm *Pseudaletia sequax* Franclemont, a pest of winter cereals and pastures in Southern Brazil. The life cycle of the parasitoid was studied under laboratory conditions by Oliveira & Foerster (1986); parasitism took place between the second and fourth instars of the host and parasitoids emerged from the host to pupate during the last instar of *P. sequax*, independently of the age of the host at the time of parasitism. Estimates of thermal requirements indicate the degree of synchrony in development between parasitoids and their hosts and provide accurate predictions of phenological events within the range of temperatures encountered in the field (Lysyk & Nealis, 1988). Foerster (1996) estimated the thermal requirements of *P. sequax*, establishing a lower threshold of 8.4ºC for the larval stage and 396.4 degree-days (DD) above such temperature for the completion of this stage. Threshold temperatures and thermal constants have been determined for a number of braconids parasitizing lepidopterous larvae (Butler Jr. *et al.*1983; Madar & Miller 1983; Al-Maliky *et al*. 1988). The present study reports the development and progeny production of *G. muesebecki* at six constant temperatures ranging from 14º to 30ºC and discusses the possibility of mass-rearing the parasitoid for field-release purposes.

Material and Methods

The experiment was conducted in temperature-controlled chambers adjusted to 14°, 18°°, 22°, 26°, 29° and 30°C (± 0,5°C) and photoperiod of 12 hours, in a completely randomized design, using 20 replicates/treatment. Mated females of *G. muesebecki* obtained in the laboratory from field-collected armyworm larvae were transferred to the different chambers and allowed to parasitize second-instar *P. sequax* for 24 hours. Hosts were parasitized individually and reared on kikuyu grass (*Pennisetum clandestinum* Hochstetter) in 80 ml polythene tubes. Humidity was measured with a digital thermo-hygrometer inserted through the lid of a rearing tube, and was kept at 70 ± 10% by a moistened filter paper disk placed at the bottom of the tubes; fresh food was provided and faecal pellets were removed daily. The number of parasitoids emerging from each host and the duration of the internal (egg + larval) and pupal stages were recorded. At 18°, 22° and 26°C, the experiment was conducted for five consecutive generations, in order to investi-

gate the effects of long-term rearing on the rate of development of the parasitoids and to evaluate the viability of large-scale production of *G. muesebecki* in the laboratory. The data for developmental time and number of pupae/host among generations were submitted to analysis of variance, and means were compared by Tukey's test ($P<0.05$). The lower temperature thresholds (T_0) and the thermal constants (K) were estimated for the immature stages and for the complete developmental cycle by means of the least square linear regression equation (Haddad & Parra 1984) within 95% confidence limits (software Statistica, Version 5), using the reciprocal of the developmental time.

Results and Discussion

Females of *G. muesebecki* were able to parasitize larvae of *P. sequax* at all temperatures, but the proportion of hosts that survived until the parasitoids completed the larval stage was severely reduced at 14°C and 29º and 30°C (Table 1). At 14ºC although ca. 60% of the hosts had been parasitized, only 17.4% of the parasitized caterpillars produced adult parasitoids (Table 1); moreover, the emergence of the parasitoids from the hosts was not synchronized as at the other temperatures. At 29º and 30ºC, although parasitism took place, adult emergence was low at 29°C, and at 30ºC all hosts died before the emergence of the parasitoids. Death of the hosts was due to parasitism, because unparasitized larvae of *P. sequax* are able to pupate at 30ºC although the adults fail to emerge (Foerster 1996). At 29ºC only 22.8% of the caterpillars exposed to parasitism produced adults of *G. muesebecki* (Table 1). The development of two hymenopterous parasitoids of the jack pine budworm *Choristoneura pinus pinus* Freeman (Lepidoptera: Tortricidae), *Apanteles fumiferanae* Viereck (Braconidae) and *Glypta fumiferanae* Viereck (Ichneumonidae) was also inhibited above 27ºC (Lysyk & Nealis 1988).

The rate of parasitism and progeny production did not differ statistically in the range between 18º and 26ºC; the percentage of parasitism was higher than 80% at these temperatures, and the mean number of pupae/host ranged from 86.9 at 22ºC to 92.1 at 18ºC (Table 1). At 14º and 29ºC, besides the reduced proportion of parasitoids reaching the adult stage, the number of progeny/host was significantly lower than at the other temperatures (Table 1). A similar reduction in progeny production was reported by Al-Maliky & Al-Izzi (1990) in *Apanteles* sp. group *ultor*, in which

Table 1. Effect of temperature on the number of adults of *G. muesebecki* emerged from second instar *P. sequax* and average number of pupae/host.

Temperature (ºC)	Exposed N	Adult emergence (%)	N	Pupae/host X ± S.E
14	35	(17.4)	6	27.6 ± 18.8
18[1]	105	(85.7)	90	92.1 ± 26.9
22[1]	100	(90.0)	90	86.9 ± 11.4
26[1]	80	(85.0)	68	90.2 ± 21.5
29	35	(22.8)	8	19.8 ± 16.5
30	37	(0.0)	0	-

[1]Pooled data from five generations at 18°, 22° and 26°C.

significantly more progeny was produced at 26ºC than at either 15ºC or 30ºC.

Developmental time of the immature stages of *G. muesebecki* was inversely related to temperature; the egg+larval stages ranged from 17.8 days at 26º and 29ºC to 56.4 days at 14ºC, and the pupal stage lasted between 6.4 and 34.5 days at 29ºC and 14ºC, respectively (Table 2).

Developmental rate, i.e. the reciprocal of developmental time, was linearly correlated with temperature between 18º and 26ºC (Fig. 1); the pupal stage was relatively less responsive to low temperatures, with no development at 11.1ºC (Figure 1b). This value for the egg+larval stages was 8.9ºC, indicating that the stages within the host are more tolerant to the cold (Figure 1a), and close to the lower limit of the larval stage of its host, *P. sequax* (8.4ºC) (Foerster 1996). The parasitoid required a total of 291.9 DD above the lower threshold temperature to complete the egg+larval stages and 107 DD for the pupal stage. The entire development of *G. muesebecki* was completed in 397.4 DD (Figure 1c). This value is close to the amount of heat required by *P. sequax* to complete its larval stage (396 DD) (Foerster 1996), showing that the generation time of *G. muesebecki* is shorter than that of *P. sequax*. The development cycle of *P. sequax* is completed in 573.9 DD (Foerster 1996).

There was no difference in the development time of males and females; all adults from a single host emerged within one hour, in the range between 18° and 26°C, indicating that males and females of *G. muesebecki* emerge simultaneously. Nealis & Fraser (1988), on the other hand, found that males of the solitary braconid *A. fumiferanae* required approximately 15% less time to complete larval development than did females.

We conclude that the optimal temperature range for both the parasitoid and its host lies between 18º and 26ºC; outside these limits the proportion of parasitoids reaching the pupal stage and the progeny production of *G. muesebecki* were severely affected; at 30ºC parasitism led to the death of the hosts and the parasitoid was unable to complete its larval stage.

Continuous rearing of *G. muesebecki*. The parasitoid was reared continuously in the labo-

Table 2. Mean developmental time (days) of the immature stages of *G. muesebecki* at different temperatures.

Temperature ºC	Mean developmental time (days)		
	Egg+larva	Pupa	Total
14	56.4 a	34.5 a	90.9 a
18	33.0 b	15.3 b	48.4 b
20	26.2 bc	12.2 b	38.1 b
22	21.7 c	10.1 bc	31.8 bc
26	17.8 d	7.2 c	25.1 cd
29	17.8 d	6.4 c	24.3 d

[1]Means followed by the same letter within columns are not significantly different by Tukey's test ($P<0.05$).

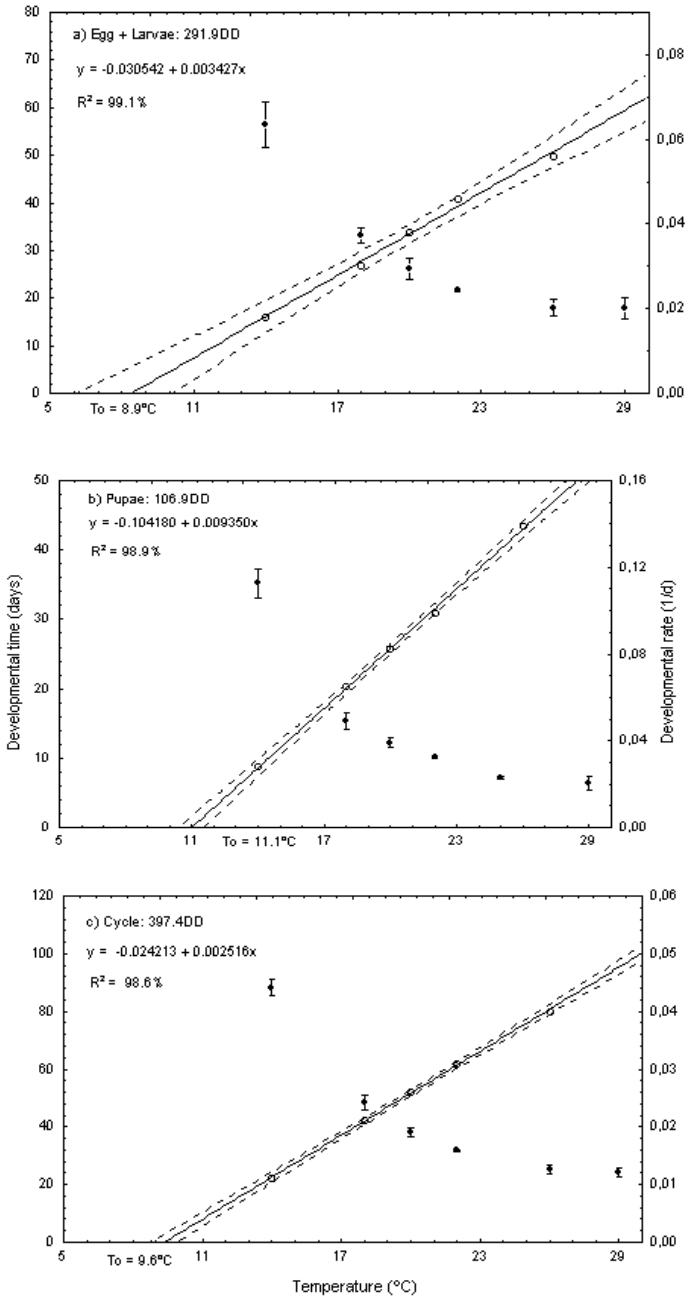

Figure 1. Relationship between developmental time (days ± S.E.), development rate (1/d) and temperature for the immature stages and for the developmental cycle of *G. muesebecki* parasitizing second instar *P. sequax*. (T_o = lower threshold temperature).

ratory for five generations at 18°, 22° and 26°C using larvae of *P. sequax* as hosts. Although the developmental time from oviposition to adult emergence and the mean number of pupae/host were not significantly affected (Table 3), a progressive decline in the production of female progeny led to the termination of the colony, which was then resumed reducing the time spent in feeding parasitized larvae with natural food.

Table 3. Developmental time (days) from oviposition to adult emergence and mean number of pupae/host of *G. muesebecki* during five consecutive generations at three temperatures.

	Temperature					
	18°C[1]		22°C[1]		26°C[1]	
Generation	D.T.[2]	Pupae/host	D.T.	Pupae/host	D.T.	Pupae/host
First	49.6	102.4	31.5	82.3	24.1	74.7
Second	45.5	77.3	29.0	74.2	25.6	89.5
Third	48.2	80.4	34.6	101.4	23.9	105.3
Fourth	51.1	104.5	33.2	85.8	28.0	86.1
Fifth	47.5	96.1	30.8	90.6	24.1	95.5

[1]Means among generations for any temperature were not significantly different by Tukey's test ($P < 0.05$).
[2]D.T. Development time from oviposition to adult emergence.

with the collection of field parasitized larvae of *P. sequax*. The probable reason for the male-biased progeny of *G. muesebecki* was the small size of the hosts at the time of parasitism (one day-old second instars), since smaller hosts tend to produce a male-biased sex-ratio (Fisher 1971, Vinson & Iwantsch 1980, Singh 1982). After the re-establishment of the colony, larger hosts were used (two to three day-old second instars) and the sex-ratio of *G. muesebecki* has remained constant. Nealis & Fraser (1988) reported quantitative and qualitative changes in the development and progeny production of another braconid, *A. fumiferanae*, in the laboratory after five generations. Neither the developmental time, nor the quality and number of emerging adults were affected by the continuous rearing of *G. muesebecki* in the laboratory. The use of an artificial diet to rear *P. sequax* may contribute to the mass-rearing of *G. muesebecki* by

Acknowledgements

The authors are grateful to Dr. P. M. Marsh, retired research entomologist from the Systematic Entomology Laboratory, USDA for the identification of *G. muesebecki*, and to Dr. A.C. Pont from the Dept. of Entomology, Oxford University for the revision of the manuscript. Voucher specimens of *G. muesebecki* are deposited in the entomological collection of the Department of Zoology, UFPR. This research was supported by CNPq.

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Received 27/V/98. Accepted 15/III/99.