Effect of Temperature on the Developmental Rate, Longevity and Parasitism of *Aphidius ervi* Haliday (Hymenoptera: Aphidiidae)

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Abstract

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Temperature-dependent development, longevity and parasitism of the parasitoid *Aphidius ervi* Haliday was measured at four constant temperatures between 15°C and 30°C using *Aphis pomi* de Geer as host. The thresholds for egg-mummy and mummy-adult development were 6.8°C and 3.9°C, respectively. Development into mummies required an average of 146.3 degree-days (DD), while development into adults took an average of 85.3 DD. Longevity was increasing linearly in the range from 15°C to 25°C (8–15 days), but was lower at 30°C (11 days). The relationship between parasitism, recorded as percent aphids mummified, and temperature was increasing at the temperatures 15–25°C, but decreasing at higher temperatures; 10.8% of the aphids were parasitised at 15°C, 15.9% at 25°C and 14.6% at 30°C. These results are compared with previously reported data on temperature-dependent development of *A. ervi* on a different host.

Keywords: *Aphidius ervi*; development time; parasitism; longevity; thermal constants

Hymenopterous parasitoids of aphids have provided spectacular success in biological control (Starý *et al*. 1988). The impact of a parasitoid on its host population greatly depends upon its ability to find and parasitise hosts and to increase offspring numbers in response to increasing host density (Waage & Hassell 1982; Mackauer 1983). Therefore, the effective parasitoid should develop very quickly. Species in the subfamily Aphidiidae have rapid larval development and short preoviposition intervals, giving minimum life cycles of 10 to 15 days (Danks 2000). Like with other insects, the rate of development of aphidiids is also temperature dependent.

Aphidius ervi Haliday is a cosmopolitan, solitary, endophagous parasitoid (Marsh 1977) and a major biological control agent of several aphid species on economically important crops such as legumes and cereals (Powell 1982; Starý *et al*. 1988). Sigsgaard (2000) has studied the temperature-dependent duration of development of *Aphidius ervi* and two other parasitoids reared on *Sitobion avenae* (Fabricius) (Sternorrhyncha: Aphidoidea). Several authors (Miller & Gerth 1994; Tripathi & Padney 1994; Bueno & van Cleave 1997; Deng & Tsai 1998) have studied the effect of temperature on the development and parasitism of some other aphid parasitoid species.

Ohta & Ohtaishi (2003) have reported also the temperature-dependent longevity of *Aphidius gifuensis* Ashmead.

The apple aphid, *Aphis pomi* de Geer, is a common inhabitant of apple orchards. Dense populations may cause abnormal growth of terminal shoots, reduce the levels of non-structural carbohydrates in shoots, roots and leaves and lower the yield of fruit (Kaakeh *et al*. 1993).

The knowledge of thermal constants and lower development thresholds provides essential information to determine the development rate of a particular species of arthropod (Jarošík *et al*. 2002). Thermal constants are frequently used to create predictive models of pest development in various environments, including stored products (Subramanyam *et al*. 1990), greenhouses and orchards (Graf *et al*. 1996).

We studied the effect of temperature on the development, percentage of parasitism and longevity of *Aphidius ervi* at four constant temperatures to evaluate its potential as a biological agent to control *Aphis pomi*.

MATERIAL AND METHODS

Host aphid source. *Aphis pomi* colonies used in this study originated from a single collection of wild aphids from apple trees in the town Banská Bystrica (48°44'N, 19°08'E) in April 2006. The colonies were maintained on fresh apple tree shoots (replaced every 2 days after all aphids had migrated from dry to fresh shots) in a thermostat at 25 ± 1°C, 60 ± 5% RH and a photoperiod of 16:8 (L:D) hours. After a 1-month rearing period, the colonies were used for parasitoid experiments.

Parasitoid source. *Aphidius ervi* were obtained from a single collection of aphid mummies from apple trees in the town Banská Bystrica in May 2006. Mummies were kept individually in small glass vials (5 × 1.5 cm) under the same temperature and humidity conditions as aphids. Mummies were checked daily and parasitoid adults retrieved as they hatched.

Temperature studies. Colonies of about 100 aphids (mixed adult with nymphs) were reared on fresh apple tree shoots. Into a plastic box (30 cm long, 25 cm high, 10 cm wide) containing an aphid colony at 25 ± 1°C, ten adult parasitoids were introduced for a 24 h stinging period. At the end of the oviposition period, the plants with exposed nymphs were then placed in a thermostat at either 15, 20, 25 or 30°C, 60 ± 5% RH, and a photoperiod of 16:8 (L:D) hours. At least 10 aphid colonies, each containing 100 aphids, were used for each temperature. Aphids at each temperature treatment were checked four times a day for presence of sedentary and bloated mummies. The mummies were collected in glass vials and returned to the same temperature treatment. All mummies were checked daily until all parasitoids had emerged. Adults were transferred to plastic vials (25 × 10 cm diameter) and kept under the same temperature treatment. Each adult was fed with a 15% honey solution. Individual development time was recorded for the period from egg oviposition to mummy formation, and from mummy formation to adult emergence. Longevity was recorded from adult emergence to its death. Percentage of parasitism was calculated as follows: parasitism % = number of mummies × 100/number of aphids.

Data analysis. Normality of distribution was checked with the Shapiro-Wilk test before comparative analyses were performed. Parametric tests were used when possible; nonparametric tests were used when normality was not established. Effect of temperature on time periods from parasitoid oviposition to mummy formation and from mummy formation to adult emergence, was analysed by one-way analysis of variance (ANOVA) and means were separated using Tukey multiple comparison test. Temperature dependent longevity and percentage of parasitism were analysed by nonparametric Kruskal-Wallis test. Linear regression was applied to compute the lower developmental thresholds of aphid mummies and parasitoids, using developmental rate data (1/days) as dependent variables (y-axis) and constant temperature treatments of 15–30°C as independent variables (x-axis). The lower developmental threshold was determined as x-intercept of the linear equation. The degree-day (DD) required was determined as the value of the inverse of equation slope (Campbell *et al*. 1974). JMP software (Ver. 6.0.0, SAS Institute) was used for all statistical analyses.

RESULTS

Development of aphid mummies

The developmental times for the formation of mummies at four constant temperatures are presented in Table 1. This developmental time decreased linearly as temperature increased in the

Table 1. Mean ± SD developmental time of *Aphis pomi* mummies and percentage of parasitism by *Aphidius ervi* at four constant temperatures

Temperature (°C)	Development (days)	Parasitism (%)
15	17.54 ± 0.87a	10.8 ± 1.03a
20	11.15 ± 0.93b	13.1 ± 0.55b
25	8.11 ± 0.96c	16.9 ± 0.74c
30	6.26 ± 0.77d	14.6 ± 0.87d

Within the columns means followed by the same letters are not significantly different $P < 0.05$ (Tukey multiple comparison test). Percentage of parasitism data were transformed to decimal numbers before Tukey multiple comparison test; untransformed data are presented. ANOVA statistics were: development day $F = 3702.389$, df = 3, 531, $P < 0.001$; percentage of parasitism Kruskal-Wallis test, $P < 0.001$

range of 15–30°C (Table 1). A linear regression analysis comparing temperature with mummy developmental rate (15–30°C) resulted in the equation $R = 0.0068376 \times t - 0.046405$ ($r^2 = 0.99937$, $P = 0.0003$). Therefore, the mummy development of *Aphis pomi* required 146.25 DD above a lower developmental threshold of 6.79°C.

The percentage of parasitism was significantly affected by temperature ($P < 0.001$, Table 1). The lowest level of parasitism (10.8%) occurred at 15°C and the highest (16.9%) at 25°C, above which temperature the level declined (14.6% at 30°C).

Development and longevity of parasitoids

The time from mummy formation to emergence of adults of *A. ervi* was inversely correlated with temperature in the range of 15–30°C (Table 2). An average of 7.5 days and 3.06 days were required for adult development from mummy formation to adult exclusion at 15°C and 30°C, respectively. A linear regression analysis was applied to the developmental data within the 15–30°C range. The developmental rate increased linearly with temperature, resulting in the equation $R = 0.0117237 \times t - 0.045601$ ($r^2 = 0.9958$, $P = 0.0021$). The theoretical developmental threshold (i.e. the point where developmental rate presumably equals 0) was estimated at 3.9°C. Thus, it required 85.30 DD for the parasitoid to emerge from the mummy.

The developmental times from oviposition to emergence of adult parasitoids are also presented in Table 2. A linear regression analysis comparing temperature treatment (15–30°C) with parasitoid developmental rate resulted in the equation $R = 0.004353 \times t - 0.026017$ ($r^2 = 0.99926$, $P = 0.0004$). Therefore, the adult parasitoid required 229.73 DD above a lower developmental threshold of 5.98°C.

Table 2. Average number of days ± SD from mummy formation to adult emergence (M–A), from oviposition to adult emergence (E–A) and longevity of *Aphidius ervi* adults at four constant temperatures

Temperature (°C)	Development (days)		Longevity (days)
	M–A	E–A	
15	7.46 ± 0.93a	25.00 ± 1.27a	8.29 ± 0.92a
20	5.50 ± 0.90b	16.65 ± 1.24b	12.29 ± 0.43b
25	4.00 ± 0.36c	12.10 ± 1.12c	15.19 ± 1.09c
30	3.06 ± 0.75d	9.53 ± 1.15d	11.22 ± 0.43d

Within the columns means followed by the same letters are not significantly different $P < 0.05$ (Tukey multiple comparison test). ANOVA statistics were: development day (M–A) $F = 678.5791$, df = 3, 531, $P < 0.001$; development day (E–A) $F = 3852.051$, df = 3, 531, $P < 0.001$; longevity Kruskal-Wallis test, $P < 0.001$

The lower developmental thresholds are different for egg-mummy (6.79°C) and mummy-adult (3.9°C) development. Statistical analyses have shown significant differences in developmental rate of these stages (one-way ANOVA, $F = 769.22$, df = 1, 1068, $P < 0.001$).

The longevity increased significantly with temperature ($P < 0.001$, Table 2) in the range of 15–25°C, but was significantly lower at 30°C. The mean longevity of adults was 8.29 days at 15°C, 15.19 days at 25°C and 11.22 days at 30°C.

DISCUSSION

The species *Aphidius ervi* is morphologically similar to other species from the genus *Aphidius* Nees. Overall, the developmental times, the lower temperature threshold and total effective temperatures (DD) from oviposition to adult emergence are different from other *Aphidius* species. The developmental times of *Aphidius colemani* Viereck have been described by some authors as follows: on *Aphis gossypii* Glover 13.9 days at 20°C (Harizanova & Ekbom 1997), 12.7 days (♀), 12.6 days (♂) at 20°C and 10.0 days (♀), 9.6 days (♂) at 25°C (van Steenis 1993). These durations are shorter then those of our *A. ervi* at 20°C and 25°C (Table 2).

Aphidius ervi required 229.73 DD, while *A. matricariae* Haliday required 273.1 DD (Miller & Gerth 1994). The lower developmental thresholds are 5.98°C and 4.5°C for *A. ervi* and *A. matricariae*, respectively. Work by Ohta *et al.* (2001) has shown that the female of the parasitoid *A. gifuensis* Ashmead reared on green peach aphid *Myzus persicae* (Sulzer) at 15, 20, 25 and 30°C required 188.6 DD above a lower developmental threshold of 5.5 °C. *Aphidius rhopalosiphi* De Stefani-Perez required 124 DD for mummy formation and 70 DD for adult emergence (Sigsgaard 2000) which is less than in *A. ervi*. Sigsgaard (2000) reared parasitoids at 8, 12, 16, 20 and 25°C and reported that *A. ervi* on *Sitobion avenae* required 159 DD above a lower developmental threshold of 2.2°C and 73 DD (lower threshold 6.60°C) for egg-mummy development and mummy-adult development, respectively. These differences could be attributed to differences in species of host aphid and/or temperature treatment. Temperature is known to differentially affect the development of host aphids and parasitoids (Campbell *et al.* 1974). These authors also showed that the temperature requirement for the development of *Diaeretiella rapae* McIntosh collected from Berkeley in the USA was higher than that of the same species from Vancouver in Canada. Accordingly, some discrepancy in developmental times of *A. ervi* may reflect the genetic diversity among different populations.

We observed different lower developmental thresholds for egg-mummy and mummy-adult development. Sigsgaard (2000) and Deng and Tsai (1998) reported similar differences of lower thresholds for egg-mummy, mummy-adult and egg-adult development. The thresholds for *Aphidius ervi* were 2.2°C for egg-mummy development and 6.6°C for mummy-adult development, those for *A. rhopalosiphi* were 4.5°C and 7.2°C, and those for *Praon volucre* were 3.8°C and 5.5°C (Sigsgaard 2000). The lower developmental thresholds for *Lysiphlebia japonica* were 1.13°C for egg-mummy development and 2.9°C for egg-adult development (Deng & Tsai 1998). These differences are not surprising if we consider the facts about differences of development and metabolic pathways of both stages. The larval stage (egg-mummy) is one of quantitative growth, while the pupal stage (mummy-adult) is a qualitative metamorphosis.

High temperature (> 25°C) had a marked negative effect on longevity of *A. ervi* (Table 2). Miller and Gerth (1994) presented a similar effect in their study of *A. matricariae* wherein no adult wasps emerged from parasitised aphids at 31°C. Tang and Yokomi (1995) reported that pupal mortality of *Lysiphlebus testaceipes* (Cresson) increased greatly at 27°C and above. The survival rate of *A. colemani* decreased as temperature increased above 20°C (van Tol & van Steenis 1994). Ohta *et al.* (2001) observed the same effect on *A. gifuensis*.

High temperature had a similar negative effect on the level of parasitism. Percentage of parasitism by *A. ervi* increased in the interval from 15°C to 25°C but was lower at 30°C (Table 1). This is in agreement with the report by Sigsgaard (2000) that parasitisation was very low up to 12°C and thereafter increased with increasing temperature. The relationship between parasitisation and temperature was linear at the temperatures tested and *A. ervi* parasitised 11.1% aphids at 20°C and 16.6% aphids at 25°C (Sigsgaard 2000). Increased mortality of and decreased parasitisation by *A. ervi* at elevated temperatures could suggest that this parasitoid cannot tolerate the extreme temperatures during the summer months.

Thermal constants can be used to predict the time of appearance of *A. ervi* in aphid colonies. For example, from the data gained in this study, it can be expected that *A. ervi* will appear 4 days after mummy formation at locations with an average temperature of 25°C. This information may be useful for the timing of a treatment with parasitoids or a chemical treatment.

In order to establish an efficient method for using parasitoids as biological control agents against *A. pomi*, the properties of *A. ervi* adults and other parasitoids on fruit tree aphids should also be studied.

References

Bueno R., van Cleave H.W. (1997): The effect of temperature and host density on the reproduction of *Aphelinus perpallidus* (Hymenoptera: Aphelinidae). Southwestern Entomologist, **22**: 29–37.

Campbell A., Frazer B.D., Gilbert N., Gutierrez A.P., Mackauer M. (1974): Temperature requirements of some aphids and their parasites. Journal of Applied Ecology, **11**: 431–438.

Danks H.V. (2000): Insect adaptations to cool and changing environments, I Short life cycles in insect and mites. Canadian Entomologist, **138**: 407–463.

Deng Y.X., Tsai J.H. (1998): Development of *Lysiphlebia japonica* (Hymenoptera: Aphidiidae), a parasitoid of *Toxoptera citricida* (Homoptera: Aphididae) at five temperatures. Florida Entomologist, **81**: 415–423.

Graf B., Höhn B.G., Höpli H.U. (1996): The apple sawfly, *Hoplocampa testudinea*: a temperature driven model for spring emergence of adults. Entomologia Experimentalis et Applicata, **78**: 301–307.

Jarošík V., Honěk A., Dixon A.F.G. (2002): Developmental rate isomorphy in insects and mites. The American Naturalist, **160**: 497–510.

Harizanova V., Ekbom B. (1997): An evaluation of the parasitoid, *Aphidius colemani* Viereck (Hymenoptera: Braconidae) and the predator *Aphidoletes aphidimyza* Rondani (Diptera: Cecidomyiidae) for biological control of *Aphis gossypii* Glover (Homoptera: Aphididae) on cucumber. Journal of Entomological Science, **32**: 17–24.

Kaakeh W., Pfeiffer D.G., Marini R.P. (1993): Effect of *Aphis spiraecola* and *A. pomi* (Homoptera: Aphididae) on the growth of young apple trees. Crop Protection, **12**: 141–147.

Mackauer M. (1983): Quantitative assessment of *Aphidius smithi* (Hymenoptera: Aphidiidae): fecundity, intrinsic rate of increase, and functional response. Canadian Entomologist, **115**: 399–415.

Miller J.C., Gerth W.J. (1994): Temperature-dependent development of *Aphidius matricariae* (Hymenoptera: Aphidiidae) as a parasitoid of Russian wheat aphid. Environmental Entomology, **23**: 1304–1307.

Marsh P.M. (1977): Notes on the taxonomy and nomenclature of *Aphidius* species (Hym.: Aphidiidae) parasitic on the pea aphid in North America. Entomophaga, **22**: 365–372.

Ohta I., Miura K., Kobayashi M. (2001): Life history parameters during immature stage of *Aphidius gifuensis* Ashmead (Hymenoptera: Braconidae) on green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae). Applied Entomology and Zoology, **36**: 103–109

Ohta I., Ohtaishi M. (2003): Fertility, longevity and intrinsic rate of increase of *Aphidius gifuensis* Ashmead (Hymenoptera: Braconidae) on the green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae). Applied Entomology and Zoology, **39**: 113–117.

Powell W. (1982): The identification of hymenopterous parasitoids attacking cereal aphids in Britain. Systematic Entomology, **7**: 465–473.

Sigsgaard L. (2000): The temperature-dependent duration of development and parasitism of three cereal aphid parasitoids, *Aphidius ervi*, *A. rhopalosiphi*, and *Praon volucre*. Entomologia Experimentalis et Applicata, **95**: 173–184.

Starý P., Lyon J.P., Leclant F. (1988): Biocontrol of aphids by the introduced *Lysiphlebus testaceipes* (Cress.) (Hym., Aphidiidae) in Mediterranean France. Journal of Applied Entomology, **105**: 74– 87.

Subramanyam B., Hagstrum D.W., Harein P.K. (1990): Upper and lower temperature for development of six stored-product beetles. In: Proceedings 3rd International Working Conference Stored-Product Protection. Bordeaux, France. Vol. III: 2029–2036.

Tang Y.Q., Yokomi R.K. (1995): Temperature-dependent development of three hymenopterous parasitoids of aphids (Homoptera: Aphididae). Environmental Entomology, **24**: 1736–1740.

Tripathi S.P., Padney M.K. (1994): Effect of temperature on the length of development period and percent emergence of parasitoid *Diaeretiella rapae* (McIntosh) (Hymenoptera: Aphidiidae). Journal of Advanced Zoology, **15**: 76–78.

van Steenis M.J. (1993): Intrinsic rate of increase of *Aphidius colemani* Vier. (Hym., Braconidae), a parasitoid of *Aphis gossypii* Glov. (Hom., Aphididae), at different temperatures. Journal of Applied Entomology, **116**: 192–198.

van Tol S., van Steenis M.J. (1994): Host preference and host suitability for *Aphidius matricariae* Hal. and

A. colemani Vier. (Hym.: Braconidae), parasitizing *Aphis gossypii* Glov. and *Myzus persicae* Sulz. (Hom.: Aphididae). Medical Faculty Landbouww, University Gent, 59/2a: 273–279.

Waage J.K., Hassell M.P. (1982): Parasitoids as biological control agents: a fundamental approach. Parasitology, **84**: 241–268.

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