Thermal Constants for Development of the Aphid Parasitoid species, *Aphelinus albipodus* Hayat & Fatima (Hymenoptera: Aphelinidae)

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ABSTRACT

Relationship between thermal unit requirements and developmental rates was studied for the parasitoid, *Aphelinus albipodus* Hayat & Fatima. Four constant temperatures of 15, 20, 25, 30 ±1°C were selected to estimate the aphid thermal developmental requirements and thresholds of developmental stages of the parasitoid (*i.e.* egg, larval instars, pre-pupa, pupa, and time to adult). The thermal unit requirements and the developmental thresholds for the time to adult were estimated as 161.2 degree- days and 10.9°C for *A. albipodus*, respectively. Temperature requirement (k) of the parasitoid was higher than those of its host, *Rhopalosiphum padi* (96.15 degree-days).

Key Words: Thermal requirements, *Rhopalosiphum padi*, *Aphelinus albipodus*, wheat.

INTRODUCTION

Knowledge for the temperature requirements of insects can be useful in at least two ways. First, the temperature requirements of insects can be used for predicting their seasonal occurrence and fluctuations on a physiological time-scale (Ali-Niazee, 1976; Sevacherian *et al.*, 1977 a, b; and Harcourt, 1981). Second, knowledge of the temperature requirements together with knowledge of the diapause capabilities of insects is useful in forecasting the potential distribution and abundance of insect species (Messenger, 1970, 1971, and Flint, 1980). Thus, temperature related studies could be useful when attempting to make predictions concerning the dynamics and distribution of insect populations.

In case of biological control, the thermal requirement, *i.e.* (t) and (k) of natural enemies is one among many attributes (*e.g.* fecundity, searching capacity, host preferences ...etc.) that acting in concert with environmental factors will influence the outcome of attempts at biological control of a host. The thermal requirements of a natural enemy may determine its success, or failure, in the biological control of a given host population. In case of aphid pests, an early appearance of parasitoids in the field will facilitate the build-up of high parasitoid: aphid ratios early in the season, which may contribute to decelerating the initial growth rates of aphid populations (Wratten and Powell, 1991).

Aphelinus albipodus Hayat & Fatima (Hymenoptera: Aphelinidae) was collected from Russian wheat aphid, *Diuraphis noxia* (Mordwilko) hosts in the vicinity of Tahcheng, People's Republic of China and imported to the USA in 1992 for biological control of the latter pest species then exported to Egypt in 2001 for the biological control of cereal aphids particularly, *Rhopalosiphum padi*

A. albipodus is proved to be widely distributed, being recorded from India, the Chad Republic and Paraguay. This species was recorded to be a parasitoid mainly on *Aphis gossypii,* though several other aphid species are also parasitized, and may eventually prove to be of use in the control of these aphids (Hayat & Fatima 1992).

Present study was concerned with determining thermal requirements for different developmental stages of the parasitoid, *A. albipodus* under laboratory conditions.

MATERIALS AND METHODS

A. albipodus is a unisex (adults are all females). It was reared on *R padi* maintained on wheat (*Triticum aestivum*) seedlings. Colonies of both *A. albipodus* and *R. padi* were kept in the laboratory under controlled conditions (23±1°C, 60-70%R.H. and photoperiod L:D 16:8), as described by Adly (2002).

Developmental time (durations) was measured by using one hundred nymphs, almost 2nd and 3rd nymphal instars, placed on wheat seedlings, cultivated in small pots and kept in small cages (20 replicates / treatment). In each cage, aphids were exposed to 10 parasitoids for one hour. Afterwards, parasitoid females were removed, and then the cages were placed inside the incubators on the selected temperatures.

Photoperiod and R.H. were L:D 16:8, and 60-70%, respectively. The parasitoid was exposed to *R. padi* at four constant temperatures (15, 20, 25, 30 ±1°C). Parasitized aphids were dissected daily by a very fine needle, in a drop of Ringer's solution using a stereomicroscope to determine the durations of different parasitoid stages (egg, larval instars, pre-pupa and pupa).

The lower developmental thresholds (t) of the aphid parasitoid *A. albipodus*, the thermal constant (k) and their respective standard errors were estimated by linear regression analysis of the developmental rates on temperature (Campbell *et al.,* 1974).

The rate of development at each temperature was plotted against the temperature. Over a range of average temperatures, this relationship approaches a straight line (Andrewartha and Birch, 1954), which can be described by a linear regression equation of the formula: $y = a + bx$, where y is the rate of development or 1/D, D being the time in days required for the compilation of a particular developmental stage at the temperature x, in degrees centigrade; and a and b are constants, which are computed by using the least-sum-of-squares method for the fitting of the regression line.

The lower threshold for development, (t), is equal to -a/b. It can be estimated from the regression equation by solving for x when $y = 0$. The time to adult, (k), which is required for the computation of a physiological time – scale (Hughes, 1963), is given by the reciprocal of the slope b of the regression line.

Developmental times of *R. padi* on wheat and the parasitoid *A. albipodus* on *R. padi* at four constant temperatures (15, 20, 25, 30 ±1°C) were

measured in this study. Afterwards, the thermal requirement for the parasitoid was estimated.

Obtained data were recorded and statistically analyzed using ANOVA statistical method.

RESULTS AND DISCUSSION

Developmental period of the total time to adult for the parasitoid *A. albipodus*, at the four constant temperatures (15, 20, 25, 30 ±1°C) on *R. padi* are presented in table (1). As shown in the table the temperature had influenced the developmental times, and data exhibited that the time needed for development increased with the decrease of temperature. The longest duration was estimated at 15 ^{0}C, followed by 20 ^{0}C, while the shortest was at 30 ^{0}C.

Statistical analysis of data showed that there was no significant difference in the incubation periods, first larval instar and second larval instar between 25 and 30 °C but a significant difference was found between 15 and 20 °C. There were significant differences in the third larval instar, pre-pupal, pupal stage and developmental times at the four temperatures.

The present results agreed with those of Campbell *et al.* (1974) and Cloutier *et al.* (1981), who reported that under average conditions, the developmental rate of a parasitoid species (Aphidiids) was influenced by temperature in a linear way within certain limits.

Harley *et al.* (1971) reported that the parasite *A. asychis* took approximately 16 days to develop from egg to adult at 23.9 °C and 10 days at 32.2 °C on *R. maidis*.

Developmental rates for different instars (*i.e.* egg, larval instars, pre-pupa, and pupa) and total times to adult of the parasitoid *A. albipodus* on *R. padi* are presented in Table (2). In general, the developmental rates of respective stages of *A. albipodus* were influenced by the temperature to which they were exposed. Developmental times were shorter (Table1), and developmental rates were faster, as temperature increased (Table (2) and Figure (1).

Regression equations indicated that there was a correlation between temperature and developmental rates for the parasitoid *A. albipodus* for different stages and total time to adult on *R. padi*. Out of these equations, lower developmental threshold (t), and thermal units requirement (k) were presented in Table (3). The lower developmental threshold (t) of the parasitoid *A. albipodus* for egg, first, second, and third larval instars, pre-pupa, pupa, and the time to adult were 11, 13, 12.3, 10.9, 12.6, 9.4 and 10.9 °C, respectively, (Table 3). The thermal units' requirements for correspondent stages were 17.24, 1.89, 18.98, 17.39, 17, 91.74 and 161.2 degree-days, respectively, (Table 3).

Temperature requirement (k) of the parasitoid was higher than those of its host, *R. padi*. The thermal requirement of the parasitoid, *A. albipodus* was estimated as 161.2 degree-days, while that for *R. padi* was 96.15 degree-days on wheat. The temperature threshold (t) for the time to

adult of the parasitoid was 10.9 °C, while the threshold for the time to adult of the aphid was 4.4 °C on wheat (El-Heneidy *et al.* 2003).

The present results agreed with those of Campbell *et al.* (1974) who suggested that temperature requirements of parasitoids were higher than of their hosts and had a two fold effect on the host-parasitoid complex: one, ensuring that, in a temperate climate, parasitoids did not appear before their hosts early in the season, and the other, that a continued minimum host supply was available throughout the season. This hypothesis can be tested. For example, one would expect that because of differences in the threshold values, the primary parasitoids appeared together with or shortly after the fundatrix generation of the aphid in the season.

Obtained results indicated that the developmental threshold "t" estimated for *A. albipodus* was slightly higher than that reported by other authors. Bernal and Gonzalez (1996), and Lee and Elliott (1998) obtained't' values of 8.56, and 9.7 °C, respectively. The thermal requirement 'k' values obtained by those authors were higher than the present; they obtained 'k' value of 208.24 and 205 degree-days, respectively, on *D. noxia*. The difference among the present results and other references for the estimated "t" and "k" values may be due to differences among the parasitoid populations from different geographical areas (local climatic) as suggested by Gonzalez *et al.* (1979).

Table (1): Mean durations (days ± S.E. + range), of different immature stages of the aphid parasitoid, *Aphelinus albipodus* on *Rhopalosiphum padi* at the four constant temperatures 15, 20, 25 and 30 °C, 60-70% R.H. and L:D 16:8.

Host insect	***R. padi***			
Temp.	**15 °C**	**20 °C**	**25 °C**	**30 °C**
Egg	4.5 ± 0.11 (4-5)	2.3 ± 0.08 (2-3)	1 ± 0 (1)	1 ± 0 (1)
Larva				
L_1	1.25 ± 0.09 (1-2)	0.31 ± 0.005 (0.29-0.33)	0.125 ±0 (0.125)	0.125 ±0 (0.125)
L_2	5.6 ± 0.21 (5-6)	2.5 ± 0.41 (2-3)	1.75± 0.09 (1-2)	1 ±0 (1)
L_3	4.3 ± 0.15 (4-5)	2.35 ± 0.22 (2-3)	1 ± 0 (1)	1 ±0 (1)
Pre-pupa	7.3 ± 0.33 (7-8)	2.4 ± 0.51 (2-3)	1.3 ± 0.1 (1-2)	1 ± 0 (1)
Pupa	16.65 ±0.1 (16-17)	8.7 ± 0.11 (8-9)	5.7 ± 0.11 (5-6)	4.5 ± 0.11 (4-5)
Time to adult	39.6 ±0.11 (39-40)	18.56 ± 0.09 (18-19)	10.89 ± 0.12 (10-11)	8.63± 0.23 (8-9)

Temp.=Temperature, L_1 = 1st larval instar, L_2 = 2nd larval instar, L_3 = 3rd larval instar

Table (2): Developmental rates (1/D) of different stages of the parasitoid, *Aphelinus albipodus* on *Rhopalosiphum padi* on wheat at 15, 20, 25, 30 ^{0}C, 60-70% R.H., and L: D 16:8.

Developmental rates	Temperatures			
	15 °C	20 °C	25° C	30 °C
Egg	0.2222	0.4348	1	1
Larva				
L_1	0.8	3.2258	8	8
L_2	0.1786	0.4	0.5714	1
L_3	0.2325	.4255	1	1
Pre-pupa	0.1369	.4167	0.7692	1
Pupa	0.0601	.1149	0.1754	0.2222
Time to adult	0.0253	.0539	0.0918	0.1159

Table (3): Thermal constants (k), developmental thresholds (t), and regression equations of the parasitoid, *Aphelinus albipodus* on *Rhopalosiphum padi*.

Stages	Thermal constant (k) (degree-days)	Developmental threshold (t) (°C)	Regression equation (y = a + bx)	Coefficient of determination (r2)
Egg	17.24	11	y = - 0.6401 a + 0.0580 x	0.887
Larva				
L_1	1.89	13	y = - 6.8619 a + 0.5275 x	0.897
L_2	18.98	12.3	y = - 0.6485 a + 0.0527 x	0.957
L_3	17.39	10.9	y = - 0.6302 a + 0.0575 x	0.883
Pre-pupa	17	12.6	y = - 0.7431 a + 0.0588 x	0.994
Pupa	91.74	9.4	y = - 0.1029 a + 0.0109 x	0.998
Time to adult	161.2	10.9	y = - 0.0677 a + 0.0062 x	0.993

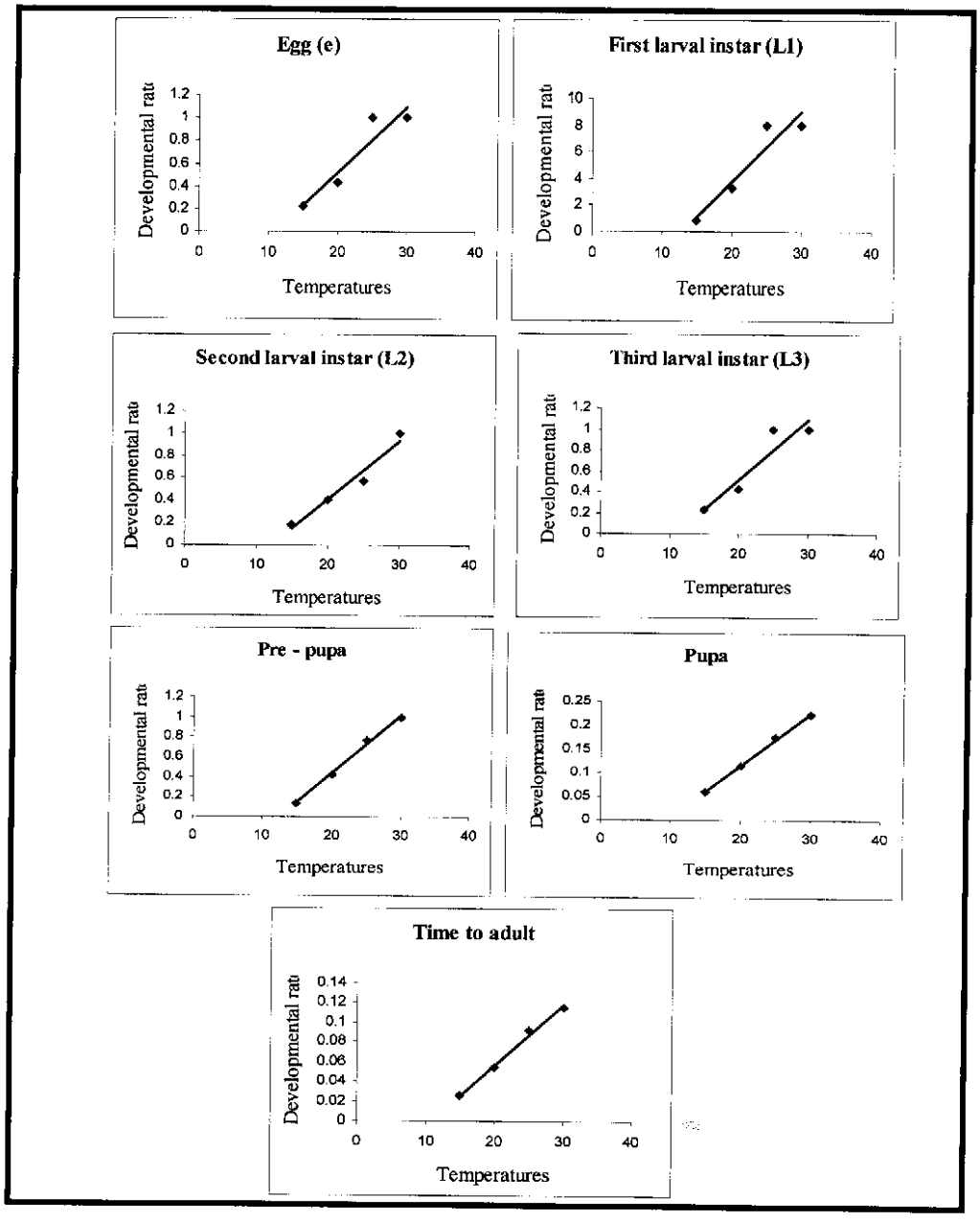

Fig. (1): Regression lines of developmental rates of *Aphelinus albipodus* on *Rhopalosiphum padi* for six developmental periods e, L1, L2, L3, PP, P and total time to adult.

REFERENCES

Adly, Dalia. 2002. Biological and ecological studies on the parasitoid *Aphidius matricariae* Hal. (Hymenoptera: Aphidiidae) parasitizing the cereal aphids. M. Sc. Thesis, Fac. Agric., Cairo Univ., Egypt. 134pp.

Ali-Niazee, M. T. 1976. Thermal unit requirements for determining adult emergence of the westrn cherry fruit fly (Diptera: Tephritidae) in the Willamette Valley of Oregon. Environ. Entomol. 5: 397-402.

Andrewartha, H. G. and L. C. Birch. 1954. The abundance and distribution of animals. The University of Chicago Press. U.S.A. 782 pp.

Bernal, J. and Gonzalez, D. 1996. Thermal requirements of *Aphelinus albipodus* (Hayat and Fatima) on *Diuraphis noxia* (Mordwiko) (Hom., Aphididae) hosts. J. Appl. Ent., 120: 631-638.

Campbell, A. B., D. Frazer, N. Gilbert, P. Gutierrez and M. Mackauer. 1974. Temperature requirements of some aphids and their parasites. J. Appl. Ecol. 11: 431-438.

Cloutier, C., McNeil, J. N. and Regniere, Y. 1981. Fecundity, longevity, and sex ratio of *Aphidius nigripes* (Hymenoptera: Aphidiidae) parasitizing different stages of its host, *Macrosiphium euphorbias* (Homoptera: Aphididae). Canadian Entomologist, 113: 193-198.

El-Heneidy, A. H, M. M. El-Hussieni, E. A. Agamy and Dalia Adly 2003. Thermal Constants for Development of the Cereal Aphid, *Rhopalosiphum padi* (Homoptera: Aphididae) and its Parasitoid, *Aphidius matricariae* (Hymenoptera: Aphidiidae). Egypt J. Biol. Pest Control, 13(1-2): 13-18.

Flint, M. L. 1980. Climatic ecotypes in *Trioxys complanatus,* a parasite of the spotted alfalfa aphid. Environ. Entomol. 9:501-507.

Gonzalez, D., Gordh, G., Thompson, S. N. and Adler, J. 1979. Biotype discrimination and its importance to biological control, pp. 129-136. In Genetics in relation to insect management, M. Hoy and J. Mckelvey (eds.). The Rockefeller Foundation, NY., 179 pp.

Harcourt, D. G. 1981. A thermal summation model for predicting seasonal occurrence of the alfalfa weevil, *Hypera postica* (Coleoptera: Curculionidae), in Southern Ontario. Can. Entomal. 113: 601-605.

Harley, G. Raney, Leon, W., Coles, R. D. Eikenbary, Robert, D. Morrison and Kennth, J. Starks 1971. Host preference, longevity, developmental period and sex ratio of *Aphelinus asychis* with three sorghum fed species of aphids held at controlled temperatures. Annals of the Entomological Society of America, 64(1): 169-176.

Hayat, M. and Fatima, K. 1992. Taxonomic studies on *Aphelinus* (Hymenoptera: Aphelinidae). 5. Description of a new species and further records of *A. gossypii,* with a new synonymy. Entomo., 17(1-2): 103-107.

Hughes, R. D. 1963. Population dynamics of the cabbage aphid *Brevicoryne brassicae* (L.). J. Anim. Ecol. 32: 393-424.

Lee, J. H. and Elliott, N. C. 1998. Temperature effects on development in *Aphelinus albipodus* (Hymenoptera: Aphelinidae) from two geographic regions. The Great lakes Entomologist, 31(3-4): 173- 179.

Messenger, P. S. 1970. Bioclimatic inputs to biological and pest management programs. In: R. L. Rabb and F. E. Guthrie (eds.).pp. 84-99. Concepts of pest Management. North Carolina State Univ., Raleigh, N. C.

Messenger, P. S. 1971. Climatic limitations to biological control. Tall Timbers Conference on Ecological Animal Control by Habital Management, Tallahasee, Florida. 3: 97-114.

Sevacherian, V., V. M. Stern and A. J. Mueller. 1977 a. Heat accumulation for timing *Lygus* control measures in a safflower – cotton complex. J. Econ. Entomol. 70: 399-402.

Sevacherian, V., N. C. T. Toscano, R. A. van Steenwyk, R.K. Sharma and R. R. Sanders. 1977 b. Forecasting pink boll-worm emergence by thermal summation. Environ. Entomol. 6: 545-546.

Wratten, S. D., and W. Powell 1991. Cereal aphids and their natural enemies. In: The ecology of temperature cereal fields. Ed by l. G. Fair Bank, N. Carter, J. F. Darbyshire and G. R. Potts. Oxford, UK: Blackwell Scientific Publications, 233-257.