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## Development of the Parasitoid *Diaeretiella rapae* (M'intosh) Reared on Certain Aphid Species in Relation to Heat Unit Requirement

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### ABSTRACT

The effect of temperature on the development of the aphid parasitoid *Diaeretiella rapae* (M'Intosh) stages was evaluated on certain aphid species (*Brevicoryne brassicae* L., *Aphis nerii* Boyer, *Aphis craccivora* (Koch) and *Hyalopterus pruni* (Geoffroy). Laboratory studies were conducted to study the effect of different temperature degrees; (10, 15 and 25°C) on the developmental stages of the parasitoid *Diaeretiella rapae*, reared on certain aphid species (*B. brassicae*, *A. nerii*, *A. craccivora* and *H. pruni*). The results indicated that the duration of the parasitoid was longer at 10°C. As temperature increased from 10-25°C the longevity decreased, the lower thermal threshold for the development of *D. rapae* 1.99, 0.46, 1.49 and 5.56°C for eggs, 3.67, 9.1, 17.95 and 3.98°C for larvae, 7.36, 7.0, 3.2 and 3.09°C for pupa while it were 2.93, 5.14, 6.09 and 3.5°C for the total duration from (egg to adult). The heat units requirement for the development of eggs were 84.55, 102.57, 73.3 and 69.14 DD's, for larvae were 86.41, 48.31, 36.74 and 104.19, for the pupal 56.93, 69.82, 74.92 and 116.69 DD's and 241.08, 207.59, 149.07 and 286.53 DD's on for the development period *B. brassicae*, *A. nerii*, *A. craccivora* and *H. pruni*, respectively. The lower thermal threshold for longevity (female and male) of *D. rapae* were 4.18 and 1.93, 3.13 and 1.31, 3.39 and 1.14 and 2.84 and 1.49°C and the heat units requirement for longevity of (female and male) were 81.76 and 70.26, 68.04 and 54.04, 71.83 and 64.03 and 62.71 and 51.23 on the same aphid species, respectively. Obtained results provide essential information for predicting the field population of the parasitoid *D. rapae*, releasing time on certain aphid species for controlling these pests and it is recommended to be an item of Integrated Pest Management Programs in Egyptians fields designed to control certain aphid species.

**Key words:** *Diaeretiella rapae*, *Brevicoryne brassicae*, *Aphis nerii*, *Aphis craccivora*, *Hyalopterus pruni*, heat unit

### INTRODUCTION

*Diaeretiella rapae* (M'Intosh) (Hymenoptera: Aphidiidae) is the most common natural enemy of the cabbage aphid (Saleh, 2008; Maghraby, 2012) and can also be used for controlling other aphids like *Myzus persicae* (Sulzer), *Diuraphis noxia* (Mordvilko), *Aphis craccivora* (Koch), *Hyalopterus pruni* (geoffroy) and *Aphis nerii* (Boyer) (Elliott *et al.*, 1994; Pike *et al.*, 1999; Maghraby, 2012). *Diaeretiella rapae* is solitary species i.e., it lays one or more eggs in a host but only one develops into an adult (Godfray, 1994) and females emerge with fully developed eggs (Flanders, 1950; Kant *et al.*, 2008; Ralec *et al.*, 2011).

*Diaeretiella rapae* allows its hosts to feed and develop after becoming parasitized. Foraging behavior, including searching, handling and oviposition, varies among and within species (Lewis *et al.*, 1990; El-Naggar *et al.*, 2008).

Parasitoids may use chemical cues (semiochemicals) and/or physical features like host size to select hosts for oviposition (Van Driesche and Bellows, 1996).

Under laboratory conditions, egg to adult development rages from 9-15 day on *Brevicoryne brassicae* (L.). Adult females live for 10-15 days while males live for 7-10 days (Hafez, 1961; Reed *et al.*, 1992) females live significantly longer than males at constant temperatures, 10.0, 21.1 and 26.7°C on *D. noxia* (Bernal and Gonzalez, 1995). A lot of works on its reproductive behavior, parasitism rate, seasonal abundance and biology have been done worldwide (Akhtar *et al.*, 2010; Bodlah *et al.*, 2012; Maghraby, 2012; Saleh, 2012). The aim of this study is to determine the effect of different temperatures and certain aphid species on the development and heat unit requirement of the parasitoid *D. rapae*.

## MATERIALS AND METHODS

The present study was carried out in Plant Protection Research Institute, Sharkia Branch to evaluate the effect of temperature on the development of the aphid parasitoid *D. rapae* stages when reared on certain aphid species. The experiment was performed at three constant temperatures, 10, 15 and 25±1°C.

**Life cycle of *D. rapae* on certain aphid species:** A laboratory culture of the aphid species (*B. brassicae*, *A. craccivora*, *A. nerii* and *H. pruni*) were maintained under laboratory conditions. Fifty nymphs, almost 3rd nymphal instars from the last aphid species were placed on the last host plants under small cages (10 replicates/treatment). In each cage or on either cut flowering shoots or on detached young leaves set flat on the bottom of clear plastic jar. Aphids were exposed to five mated females for 4 h. Afterwards, parasitoid females were removed and then the cages or jars were placed in the laboratory to determine the durations of different parasitoid stages at three temperature (10, 15 and 25°C) parasitized aphids were dissected daily by a very fine needle, in a drop of Ringer's solution, to observe the development of different immature stages of the parasitoid *D. rapae*.

**Statistical analysis:** The effect of temperatures (10, 15 and 25°C) on developmental time of the aphid parasitoid *D. rapae* was determined by analysis of variance (ANOVA). The relationship between temperature and mean developmental rate of each stage and generation under tested temperature was determined using liner regression. For each temperature, Development Rate (DR) was calculated as reciprocals of Development Time (DT) of individual *D. rapae* stages (DR = 1/DT). The relations between Developmental Rate (DR) and Temperature (T) was determined using linear regression equation:

$$DR = a+bT$$

where, a, b are parameters of the linear regression.

The Lower Developmental Threshold (LDT), i.e., the temperatures when development ceases, was determined:

$$LDT = -a/b$$

On the other hand, Degree Days (DD's) for completion development of each stage was calculated according to Arnold (1959):

$$\text{DD's} = \text{DT} * (\text{T} - \text{t}_0)$$

where, DT is development time of a given stage, T is temperature in degree centigrade and t<sub>0</sub> is the lower developmental threshold.

## RESULTS AND DISCUSSION

**On *B. brassica*:** Temperature dependence of the aphid parasitoid *D. rapae* development reared on *B. brassicae* is summarized in Table 1.

**Egg stage:** The incubation period of *D. rapae* was 10.6 days at 10°C, with increasing temperature, the developmental time of the egg stage decreased to 4.14 days, at 15°C and to 2.9 days at 25°C. The study revealed that the incubation period of *D. rapae* did not differ significantly between the values at 15 and 25°C, respectively. These results are in agreement with those obtained by Ragab *et al.* (2002) who reported those 3.4 days of egg development, depending on temperature 19.5°C. Table 1 shows the rate of development of the different life history stages in relation to temperature is expressed by the linear regression equation. According to the regression line equation the lower developmental threshold of *D. rapae* eggs was 1.99°C and the thermal constant for their development was 84.55 DD's.

**Larvae stage:** At 10°C, the development of larvae took 13.1 days and decreased to 5.66 days at 15°C and to 4.99 days at 25°C. The average duration of larval stage did not differ significantly between the values at 15 and 25°C, respectively. The previously mentioned results are similar to those obtained by Ragab *et al.* (2002) who reported that the duration of larval stage of *D. rapae* was 8.44 days at 19.5°C when reared on *B. brassicae*.

In the present study, the lower developmental threshold of *D. rapae* larvae was 3.67°C and the thermal constant for their development was 86.41 DD's (Table 1).

**Pupal stage:** At 10°C, the development of pupa lasted 10.74 days, 6.5 days at 15°C and 5.26 days at 25°C, respectively. The average durations of pupal stage of *D. rapae* was significantly shortest (5.26 days) at 25°C and significantly longest (10.74 days) at 10°C, when reared on *B. brassicae*. Ragab *et al.* (2002) reported that pupa stage took 4.23 days at 19.5°C on *B. brassicae*. The lower developmental threshold of the parasitoid *D. rapae* pupa when reared on *B. brassicae* was 7.36°C and the thermal constant for their development was 56.93 DD's (Table 1).

**Total development periods:** The data revealed that the total developmental period of *D. rapae* was significantly shortest (13.15 days) at 25°C and significantly longest (33.42 days) at 10°C, when reared on *B. brassicae*. Other authors recorded similar values for development period Bueno and Souza (1992) who reported that the development from egg to adult varied from 8-18 days an average 10 days at 26±1°C on *B. brassicae*. Ragab *et al.* (2002) reported that the total development period of this parasitoid averaged 16.07 days at 19.5°C when reared on *B. brassicae*. Silva *et al.* (2010) mentioned that the total development period of *D. rapae* was 11.5 days on *B. brassicae* at 25±1°C. Meanwhile, Basheer *et al.* (2014) studied that temperature dependent development, longevity and mortality of the aphid parasitoid *D. rapae* at four constant temperatures, ranged

Table 1: Effect of different temperature on *Diaeretiella rapae* development when reared on *Brevicoryne brassicae* and *Aphis nerii*

Temperature (°C)	Egg			Larvae stage			Pupal stage			Development period			Longevity ♀			Longevity ♂		
	DT	DR	DD	DT	DR	DD	DT	DR	DD	DT	DR	DD	DT	DR	DD	DT	DR	DD
<b><i>Brevicoryne brassicae</i></b>																		
10	10.61 <sup>a</sup>	9.83	84.98	13.10 <sup>a</sup>	7.80	82.92	10.74 <sup>a</sup>	9.24	28.35	33.42 <sup>a</sup>	2.96	236.28	17.29 <sup>a</sup>	5.78	100.63	11.09 <sup>a</sup>	9.02	89.49
15	4.14 <sup>b</sup>	24.15	53.86	5.66 <sup>b</sup>	17.67	64.13	6.50 <sup>b</sup>	15.38	49.66	16.30 <sup>b</sup>	6.13	196.74	6.00 <sup>b</sup>	16.67	64.92	4.02 <sup>b</sup>	24.88	52.54
25	2.90 <sup>b</sup>	34.48	114.82	4.99 <sup>b</sup>	20.04	112.19	5.26 <sup>c</sup>	19.01	92.79	13.15 <sup>c</sup>	7.60	290.22	3.83 <sup>b</sup>	26.11	79.74	2.98 <sup>b</sup>	33.56	68.75
Mean			84.55			86.41			56.93		241.08			81.76				70.26
LSD <sub>0.05</sub>	1.573			1.157			0.868			1.495			2.449			2.592		
<b>Regression equation</b>																		
a		3.09			2.73			4.47		0.83				5.42				2.96
b		1.55			0.74			0.61		0.28				1.29				1.53
LDT		1.99			3.67			7.36		2.93				4.18				1.93
<b><i>Aphis nerii</i></b>																		
10	10.69 <sup>a</sup>	9.69	101.98	11.31 <sup>a</sup>	9.16	10.18	12.91 <sup>a</sup>	7.92	38.73	34.57 <sup>a</sup>	2.95	167.86	11.92 <sup>a</sup>	8.39	81.89	7.78 <sup>a</sup>	12.85	67.61
15	4.80 <sup>b</sup>	20.83	69.79	6.24 <sup>b</sup>	16.03	36.82	7.48 <sup>b</sup>	13.37	59.84	18.52 <sup>b</sup>	5.40	153.03	4.64 <sup>b</sup>	21.55	55.08	3.01 <sup>b</sup>	33.22	41.21
25	3.50 <sup>c</sup>	28.57	135.95	5.54 <sup>b</sup>	18.18	97.94	6.16 <sup>c</sup>	16.23	110.88	15.20 <sup>b</sup>	6.58	301.87	3.07 <sup>c</sup>	32.57	67.14	2.25 <sup>b</sup>	39.68	53.30
Mean			102.57			48.31			69.82		207.59			68.04				54.04
LSD <sub>0.05</sub>	1.268			1.272			1.301			3.947			1.372			1.385		
<b>Regression equation</b>																		
a		0.56			5.05			3.68		1.17				4.82				2.59
b		1.21			0.56			0.53		0.23				1.54				1.97
LDT		0.46			9.10			7.00		5.14				3.13				1.31

DT: Development time in days, DR: Development rate, DD: Degree days, LDT: Lower developmental threshold, a: Intercept and b: Slope

between 15°C and 30°C and aphid *B. brassicae*. The shortest developmental period for egg-adult (10.6±0.13 days) was recorded at 30°C, while the longest (24.3±0.14 days) was at 15°C. According to the regression line equation the lower developmental threshold of *D. rapae* was 2.93°C and the thermal constant for their development was 241.08 DD's. Also Basheer *et al.* (2014) showed that the temperature threshold for egg-mummy, mummy-adult and egg-adult developmental periods was 2.33, 4.81 and 3.36°C, respectively. The sum of effective temperatures was 192.3, 90.1 and 277.8 DD's for egg-mummy, mummy-adult and egg-adult of *D. rapae* on aphid *B. brassicae*.

**Longevity:** The average life span of adult female and male of *D. rapae* decreased as the temperature increased from 17.29 and 11.09 days at 10°C to 3.83 and 2.98 days at 25°C, respectively. The average longevity of adult female and male of *D. rapae* did not differ significantly between the values at 15 and 25°C, respectively. The obtained results are generally in agreement those obtained by Ragab *et al.* (2002) they mentioned that the average longevity of the parasitoid *D. rapae* decreased linearly with increasing temperature. Silva *et al.* (2010) reported that longevity (female and male) of *D. rapae* were 7.4 and 5.9 days when reared on *B. brassicae* at 25±1°C. According to the regression line equation, the lower developmental threshold of *D. rapae* life span (female and male) 4.18 and 1.93°C and the thermal constant for their development were 81.76 and 70.26 DD's, respectively.

**On *A. nerii*:** Temperature dependence of *D. rapae* development of different stages when reared on *A. nerii* is summarized in Table 1.

**Egg stage:** The incubation period of *D. rapae* was 10.69 days at 10°C, with increasing temperature, the developmental time of the egg stage decreased to 4.8 days at 15°C and 3.5 days at 25°C. There are significant differences among the average of incubation period at the different temperatures. Other authors recorded similar values for egg stage as Saleh *et al.* (2009) reported that the development of the egg stage was 4.25 days on *A. nerii* at 18±1°C.

Table 1 show the rate of development of the different life history stages in relation to temperature is expressed by the linear regression equation. The lower developmental threshold of *D. rapae* eggs was 0.46°C and the thermal constant was 102-57 DD's.

**Larval stage:** At 10°C, the development of larvae took 11.31 days. With increasing temperature, the developmental times of the larval stage decreased to 4.8 days at 15°C and 3.50 days at 25°C. These results are in agree with those obtain by Saleh (2008) who reported the development of larvae of *D. rapae* took 4.92-11.34 days at 28-10°C when reared on *A. nerii*. The durations of larvae stage of *D. rapae* was significantly shortest (3.50 days) at 25°C and significantly longest (11.31 days) at 10°C. The lower developmental threshold of *D. rapae* larvae was 9.1°C and the thermal constant for their development was 48.31 DD's (Table 1).

**Pupal stage:** At 10°C, the development of pupa was 12.91 days. As temperature increases, the developmental times of the pupa stage decreased to 7.48 days 15°C and 6.16 days at 25°C. The data revealed that average durations of pupal stage of *D. rapae* was significantly shortest (6.16 days) at 25°C and significantly longest (12.91 days) at 10°C, when reared on *A. nerii*. The previously mentioned results are similar to those obtained by Saleh *et al.* (2009) who reported that duration

of pupal stage of *D. rapae* was 7.01 days at 18±1°C when reared on *A. nerii*. The lower developmental threshold of *D. rapae* pupa when reared on *A. nerii* was 7.0°C and the thermal constant for their development was 69.82 DD's (Table 1).

**Total development periods:** The mean duration of *D. rapae* (from egg to adult) were 34.54 days at 10°C, 18.52 days at 15°C and 15.2 at 25°C. The study revealed that the mean duration of *D. rapae* did not differ significantly between the values at 15 and 25°C, respectively when reared on *A. nerii*.

Saleh *et al.* (2009) reported that the total development period of *D. rapae* was 19.38 days at 18±1°C when reared on *A. nerii*. The lower developmental threshold of *D. rapae* duration was 5.14°C and the mean thermal constant is 207.59 DD's Table 2.

**Longevity:** On the other hand, the average life span of adult female and male of *D. rapae* decreased as the temperature increased from 11.92 and 7.78 days at 10°C to 3.07 and 2.25 days at 25°C, respectively.

Saleh *et al.* (2009) showed that longevity of *D. rapae* (female and male) were 5.32 and 2.77 days at 18±1°C when reared on *A. nerii*.

The lower developmental threshold of *D. rapae* longevity (female and male) 3.13 and 1.31°C and the thermal constant for their development were 68.04 and 54.04 DD's, respectively (Table 1).

**On *A. craccivora*:** Temperature dependence of *D. rapae* development reared on *A. craccivora* is summarized in Table 2.

**Egg stage:** The incubation period of *D. rapae* was 7.12 days at 10°C, with increasing temperature, the developmental time of the egg stage decreased to 3.3 days at 15°C and 2.59 days at 25°C. The study revealed that the incubation period of *D. rapae* did not differ significantly between the values at 15 and 25°C, respectively However, Ragab *et al.* (2002) studied the biology of *D. rapae* on *A. craccivora* and reported that 2.4 days of egg development; depending on temperature 19°C. Table 2 show the rate of development of the different life history stages in relation to temperature is expressed by the linear regression equation. According to the regression line, equation the lower developmental threshold of *D. rapae* eggs was 1.49°C and the thermal constant for their development was 73.3 DD's (Table 2).

**Larval stage:** At 10°C, the development of larvae took 8.20 days with increasing temperature, the developmental times of the larval stage decreased to 5.35 days at 15°C and 4.88 days at 25°C. The study revealed that the larvae period of *D. rapae* did not differ significantly between the values at 15 and 25°C, respectively On the other hand, Ragab *et al.* (2002) in Egypt showed that the development of larvae took 6.61 days on *A. craccivora* at 19.5°C.

According to the regression line equation, the lower developmental threshold of *D. rapae* larvae was 17.95°C and the thermal constant for their development was 36.74 DD's (Table 2).

**Pupal stage:** At 10°C the development of pupa was 9.13 days. Also, with increasing temperature, the developmental times of the pupa stage decreased to 6.12 days at 15°C and 4.15 days at 25°C. The data indicated that average the durations of pupal stage of *D. rapae* was significantly shortest (4.15 days) at 25°C and significantly longest (9.13 days) at 10°C, when reared on *A. craccivora*. Meanwhile, Saleh (2008) reported that development of pupa was 5.89 days on *A. craccivora* at 16°C.

Table 2: Effect of different temperature on *Diaeretiella rapae* development when reared on *Aphis craccivora* and *Hyalopterus pruni*

Temperature (°C)	Egg			Larvae stage			Pupal stage			Development period			Longevity ♀			Longevity ♂		
	DT	DR	DD	DT	DR	DD	DT	DR	DD	DT	DR	DD	DT	DR	DD	DT	DR	DD
<b><i>Aphis craccivora</i></b>																		
10	7.12 <sup>a</sup>	12.90	60.59	8.20 <sup>a</sup>	12.02	65.19	9.13 <sup>a</sup>	11.19	62.08	24.52 <sup>a</sup>	4.00	95.87	12.99 <sup>a</sup>	7.70	85.86	9.02 <sup>a</sup>	11.09	79.92
15	3.30 <sup>b</sup>	30.30	44.58	5.35 <sup>b</sup>	18.69	15.78	6.12 <sup>b</sup>	16.34	72.22	14.77 <sup>b</sup>	6.77	131.60	5.06 <sup>b</sup>	19.76	58.75	3.53 <sup>b</sup>	28.33	48.93
25	2.59 <sup>b</sup>	38.61	114.73	4.88 <sup>b</sup>	20.49	29.26	4.15 <sup>c</sup>	24.10	90.47	11.62 <sup>c</sup>	8.61	219.73	3.28 <sup>c</sup>	30.49	70.88	2.65 <sup>b</sup>	37.74	63.23
Mean			73.3			36.74			74.92			149.07			71.83			64.03
LSD <sub>0.05</sub>	0.861			0.606			0.691			1.396			1.451			1.680		
<b>Regression equation</b>																		
a	2.28			8.79			2.77			1.74			4.94			1.90		
b	1.52			0.49			0.86			0.29			1.46			1.66		
LDT	1.49			17.95			3.20			6.09			3.39			1.14		
<b><i>Hyalopterus pruni</i></b>																		
10	8.54 <sup>a</sup>	11.47	37.91	13.70 <sup>a</sup>	7.25	82.47	15.32 <sup>a</sup>	6.42	105.86	37.37 <sup>a</sup>	2.62	244.27	10.81 <sup>a</sup>	9.25	77.39	6.96 <sup>a</sup>	14.37	59.23
15	5.17 <sup>b</sup>	19.34	48.80	8.56 <sup>b</sup>	11.68	94.83	8.62 <sup>b</sup>	11.60	102.66	22.34 <sup>b</sup>	4.48	256.91	4.04 <sup>b</sup>	24.75	49.13	2.85 <sup>b</sup>	35.09	38.50
25	4.00 <sup>c</sup>	25.00	120.72	6.21 <sup>c</sup>	16.10	135.79	6.46 <sup>c</sup>	15.48	141.54	16.67 <sup>c</sup>	6.00	358.41	2.78 <sup>c</sup>	35.97	61.60	2.38 <sup>b</sup>	42.02	55.95
Mean			69.14			104.19			116.69			286.53			62.71			51.23
LSD <sub>0.05</sub>	0.650			0.618			1.060			2.061			1.550			1.248		
<b>Regression equation</b>																		
a	4.68			2.26			1.75			1.39			4.79			2.51		
b	0.84			0.57			0.57			0.39			1.69			1.68		
LDT	5.56			3.98			3.09			3.50			2.84			1.49		

DT: Development time in days, DR: Development rate, DD: Degree days, LDT: Lower developmental threshold, a: Intercept and b: Slope



In the present study, the lower developmental threshold of *D. rapae* pupa when reared on *A. craccivora* was 3.2°C and the thermal constant for pupal development was 74.92 DD's (Table 2).

**Total developmental periods:** The mean duration of *D. rapae* (from egg to adult) were 24.52 days at 10°C, 14.77 days at 15°C and 11.62 days at 25°C. These results are in agreement with those obtained by Saleh (2008) who reported the duration of *D. rapae* (egg to adult) lasted 16.34 days on *A. craccivora* at 16°C.

The lower developmental thresholds of *D. rapae* duration was 6.09°C and the mean thermal constant is 149.07 DD's (Table 2).

**Longevity:** The mean longevity of adult female and male of *D. rapae* decreased as the temperature increased from 12.99 and 9.02 days at 10°C to 3.28 and 2.65 days at 25°C, respectively. The obtained results are generally in agreement those obtained by Ragab *et al.* (2002) reported that the average longevity of the parasitoid *D. rapae* (female and male) were 5-8 and 3-5 days at 19.3°C. In this present study, the lower development threshold of *D. rapae* longevity (female and male) 3.39 and 1.14°C and the thermal constant for their development were 71.83 and 64.03 DD's, respectively (Table 2).

**On *H. pruni*:** Temperature dependence of *D. rapae* development when reared on *H. pruni* is summarized in Table 2.

**Egg stage:** The data revealed that average durations of pupal stage of *D. rapae* was significantly shortest (4.0 days) at 25°C and significantly longest (8.54 days) at 10°C, when reared when reared on *H. pruni*. There are significant differences among the average durations of incubation period at different temperature. These results are in agree with those obtained by Saleh *et al.* (2013) who reported those 2.33-8.08 days of *Aphidius colemani* (Vierecke) egg development, depending on temperature (9-30°C) when reared on *H. pruni*. The lower developmental threshold of *D. rapae* eggs was 5.56°C and the thermal constant for their development was 69.14 DD's (Table 2).

**Larval stage:** At 10°C, the development of larvae last 13.7 days but it was 8.56 days at 15°C and 6.21 days at 25°C. Saleh (2008) showed that the development of larvae ranged 3.38-13.79 days of *D. rapae* on *H. pruni* at 10-28°C, respectively. There are significant differences among the average durations of larval stage at the different temperature. It was significantly shortest (6.21 days) at 25°C and significantly longest (13.7 days) at 10°C, when reared on *H. pruni*.

The lower developmental threshold of *D. rapae* larvae was 3.98°C and the thermal constant for their development was 104.19 DD's (Table 2).

**Pupal stage:** At 10°C, the development of pupa was 15.32 days. With increasing temperature, the developmental times of the pupa stage decreased to 8.62 days at 15°C and 6.46 days at 25°C. There are significant differences among the average durations of pupal stage at the different temperature. It was significantly shortest (6.46 days) at 25°C and significantly longest (15.32 days) at 10°C, when reared on *H. pruni*. These results are in agreement with those obtained by Saleh (2008) who reported those 4.96-15.3 days of pupa development, depending on temperature (10-28°C). According to the regression line equation the lower developmental threshold of *D. rapae* pupa when reared on *H. pruni* was 3.09°C and the thermal constant for their development was 116.69 DD's (Table 2).

**Total developmental period:** The average duration of *D. rapae* (from egg to adult) were 37.58 days at 10°C, 22.34 days at 15°C and 16.67 days at 25°C. The data revealed that the total developmental period of *D. rapae* was significantly longer (37.58 days) at 10°C and significantly shorter (16.67 days) at 25°C, when reared on *H. pruni*. The results are in agreement with those of Saleh (2008) in Egypt who mentioned that the parasitoid *D. rapae* completed its life cycle on various aphid species (*B. brassicae*, *A. nerii*, *A. gossypii*, *A. craccivora*, *M. persica* and *H. pruni*). It were an average 19.87, 24.39, 17.28, 16.34, 18.2 and 18.55 days, respectively at 16°C.

According to the regression line equation the lower developmental thresholds of *D. rapae* duration was 3.5°C and the mean thermal constant is 286.53 DD's (Table 2).

**Longevity:** The mean longevity of adult female and male of *D. rapae* decreased as the temperature increased from 10.81 and 6.96 days at 10°C to 2.78 and 2.38 days on 25°C, respectively. The average longevity of adult female and male of *D. rapae* did not differ significantly between the values at 15 and 25°C, respectively.

According to the regression line equation, the lower development threshold of *D. rapae* longevity (female and male) 2.84 and 1.49°C and the thermal constant for their development were 62.71 and 51.23 DD's, respectively (Table 2).

Generally, *D. rapae* has more ability to finding and parasitizing host (*D. noxia*) between temperature of 15 and 25°C. The activity of *D. rapae* adults reduced at lower (10°C) and higher temperatures 30 and 32.5°C (Zamani *et al.*, 2006). However Elliott *et al.* (1995) estimated that thermal requirements for development from egg to adult (*D. rapae*) were 297, 278 and 301 DD's at 12, 18 and 24°C. On the other hand, Bernal and Gonzalez (1995) investigated thermal requirement of *D. rapae* on *Diuraphis noxia* at five constant temperatures 10, 15.5, 21.1, 26.7 and 29.4°C. The temperature on development and thermal requirements values were 2.47°C and 198.99 DD's, for the egg-pupa period; 3.89°C and 106.45 DD's, for the pupa-adult period and 3.56°C and 292.26 DD's, for the egg-adult period. Liu (1989) reported that the development threshold and thermal constant for the period from egg to adult of the parasitoid *D. rapae* on *M. persicae* were 8.76°C and 139.51 DD's, respectively.

## CONCLUSION

The results in this study indicated that the effect of different temperatures (10, 15 and 25°C) and certain aphid species (*B. brassicae*, *A. nerii*, *A. craccivora* and *H. pruni*) on the development and heat unit requirement of the parasitoid *D. rapae*. Life cycle of the parasitoid at three temperatures on various aphid species was studied. The results indicated that the duration of the parasitoid was longer at 10°C. The lower thermal threshold for the development period of *D. rapae* was 2.93, 5.14, 6.09 and 3.5°C for the total duration from (egg to adult). The heat units requirement of the development period were 241.08, 207.59, 149.07 and 286.53 DD's on the same aphid species, respectively.

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